Belt Filter Press Optimization with the Use of Drainage Measurement

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BELT FILTER PRESS OPTIMIZATION

WITH THE USE OF

DRAINAGE MEASUREMENT

by

Jeffrey E. Farnsworth

A Thesis submitted in partial fulfillment of the course requirements for the Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan
April 18, 1983
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Figures</td>
<td>iii</td>
</tr>
<tr>
<td>Abstract</td>
<td>iv</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>1</td>
</tr>
<tr>
<td>History</td>
<td>1</td>
</tr>
<tr>
<td>Description</td>
<td>1</td>
</tr>
<tr>
<td>Problems</td>
<td>3</td>
</tr>
<tr>
<td>Theoretical Discussion</td>
<td>4</td>
</tr>
<tr>
<td>Fundamentals of Sludge Dewatering</td>
<td>4</td>
</tr>
<tr>
<td>Sludge Moisture Meters</td>
<td>5</td>
</tr>
<tr>
<td>Paper Machine Freeness Meters</td>
<td>6</td>
</tr>
<tr>
<td>Experimental Procedure</td>
<td>11</td>
</tr>
<tr>
<td>Materials</td>
<td>11</td>
</tr>
<tr>
<td>Equipment</td>
<td>11</td>
</tr>
<tr>
<td>Procedure</td>
<td>12</td>
</tr>
<tr>
<td>Results and Standard Values</td>
<td>14</td>
</tr>
<tr>
<td>Discussion of Results</td>
<td>24</td>
</tr>
<tr>
<td>Conclusions</td>
<td>25</td>
</tr>
<tr>
<td>Recommendations</td>
<td>26</td>
</tr>
<tr>
<td>Footnotes</td>
<td>27</td>
</tr>
<tr>
<td>Bibliography</td>
<td>28</td>
</tr>
<tr>
<td>Appendix A</td>
<td>29</td>
</tr>
</tbody>
</table>
# TABLE OF FIGURES

4. The Specific Resistance Tester ..................................... 10.
ABSTRACT

The objective of this project is to determine if paper machine freeness meters can be applied to belt filter presses, so as to control the dosage rate of the polymer addition. Currently polymer dosage rates are set for the high demand loads and therefore, more polymer is used than is needed at the low demand loads. With the cost and use of chemical polymers increasing, the application of a control means to regulate polymer dose as required, should provide substantial savings in conditioning costs.

This study wants to show that a specific resistance tester is sensitive enough to pick up changes in the conditioning rate with reproducible measurements. The similarities between the specific resistance tester and a paper machine freeness meter, should show that the paper machine freeness meter could be used in an on-line application with similar results.

The results of the resistance testing shows that the specific resistance tester is sensitive at picking up changes in polymer loading. The graphs of the data shows the tester to have a useful value relationship from the unconditioned level to about 40 lbs. of polymer per ton of dry sludge. Generally, the 40 to 100 lbs of polymer per ton of dry sludge levels have a flat curve relationship which would not be useful in a control set up. A measurement in the 40 to 100 lb level could not show a significant difference between the two levels. An interpretation of these results shows that a paper machine freeness meter could be applied to a belt filter press with effective results, but only within a limited working range. The meter would not be effective at the higher polymer levels, without further testing of sludge at higher collection volumes.
INTRODUCTION

Purpose

This Thesis examines the use of moisture measurement and drainage rate for application on a belt filter press, to optimize chemical polymer conditioning of papermill sludge.

History

The paper industry has utilized biological and chemical sludge to reduce the emissions of pollutants, like dissolved organics. Biological and chemical sludge are much more difficult to dewater in comparison to primary sludge. The difficult dewatering of secondary sludge (Biological or Chemical) and combination sludge (mixture of secondary and primary) has been the primary motive for the installation of over 24 sludge dewatering presses in the last decade. Many of these presses were belt filter presses. Dewatered sludge is easier to handle and reduces the amount of leaching in landfills.

Description

A belt filter press is a device used to dewater sludge. A belt filter press is divided into three sections: a gravity drainage section; a low pressure section; and a high pressure section. Manufacturers of belt filter presses have used many designs similar to paper making machinery. Figure 1 shows the popular concepts used for each section. Combine one concept from each section and you have a belt filter press.
**FIGURE 1** ALTERNATIVE CONCEPTS FOR INDIVIDUAL SEGMENTS OF BELT FILTER PRESSES

<table>
<thead>
<tr>
<th>Gravity Drainage</th>
<th>Low Pressure Section</th>
<th>High Pressure Section</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Gravity Drainage Diagram" /></td>
<td><img src="image" alt="Low Pressure Section Diagram" /></td>
<td><img src="image" alt="High Pressure Section Diagram" /></td>
</tr>
<tr>
<td><img src="image" alt="Vacuum Assisted Diagram" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Problems

Chemical polymers have been developed to condition the sludge to increase the drainage rate and increase the output of dewatered sludge. These chemical conditioners have performed well, but their addition rates are controlled by the press operator. Unfortunately, the press operator keeps the addition rate high to make his job easier, which contributes to needless chemical costs. At present, there are no on-line sludge monitoring meters available to help improve the performance of belt filter presses by optimizing chemical conditioning rates.
THEORETICAL DISCUSSION

Fundamentals of Sludge Dewatering

"One of the primary problems with chemical conditioning is the difficulty of adjusting dosage to changes in sludge consistency or dewaterability."² Some of the more severe problems identified have been associated with (a.) pH swings resulting from chemical or liquor spills, (b.) fluctuations in sludge consistency resulting from intermittent solids losses from the mill, (c.) lack of adequate control over primary to secondary sludge ratios, (d.) occasional episodes with sludge septicity, and (e.) polymer feed systems which do not vary polymer feed rate in response to changes in sludge pumping rate. These factors contribute both to overconditioning and underconditioning of press feed.

Overconditioning and underconditioning of the sludge create varied responses depending on machine configurations for handling sludge. "In general, overconditioning creates awake doctoring difficulties and aggravates media blinding problems. Polymer type also has been shown to influence blinding. In addition, overflocculated sludge may drain so rapidly that the solids do not distribute themselves across the media."³

On the other hand, underconditioning results in inadequate dewatering in the initial drainage section(s) causing either extrusion of inadequately drained solids from the press section(s) or, in extreme instances, and uncontrolled overflow of sludge from the drainage section(s). Press operation may automatically shut off when sludge level becomes too high, due to this being a safety feature on some presses. Underconditioned biological solids can blind fine mesh media or have poor solids retention when using coarse media.
Little is known of the factors which make some primary sludges difficult to dewater. "It was found that removal of Xylan component markedly improved dewatering characteristics." This study was performed at the IPC (Appleton, WI) and statistical analysis of the data showed no significant correlation between dewaterability and sludge particle size, but size distribution must play some part in drainage.

Many factors affect sludge dewatering in the pulp and paper industry. Many of these factors are dependent on the paper production process and we have little control of them. Then there are those variables that we can adjust like pH. The sludge must be monitored for variations in its characteristics to improve handling and dewatering.

**Sludge Moisture Meters**

Instrumentation and control measurements are still being developed for use in sludge press operations. Many of the ideas are being adapted from the papermaking process because of its close similarities with the belt filter press. Moisture meters are in common use on paper machines. The measurement is made by utilizing two different infra-red wavelengths. One wavelength is selective to water and therefore absorbed by water only. The other wavelength is reflected off the water and paper sheet. The meter measures the intensity of the reflectance of the two wavelengths and by difference can calculate the percent moisture, which is compared to a set point for control adjustment.
"The many techniques, such as infra-red, microwave, and other adaptations of these moisture reflectance analyzers have shown to be sound in theory, but too sensitive to other variables."5 Another major drawback to the moisture meters was that the "data indicated that the lime slurry in sludge absorbs incident radiation strongly near the wavelength used to measure moisture, and therefore may cause strong interferences."6 These drawbacks have hindered the development of moisture meters after dewatering.

**Paper Machine Freeness Testers**

Measuring the dewatering rate of paper pulp is called a freeness test.

"An automatic freeness tester for paper stock includes a standpipe connected to a paper stock line, a screen within the standpipe dividing the standpipe into an intake chamber and a filtrate chamber, and admission means for admitting paper stock into the standpipe, so that a fibrous mat is formed on the screen and filtrate passes through the screen into the filtrate chamber. The time required to accumulate a predetermined quantity of filtrate in the filtrate chamber is used as a measure of stock freeness."7

The pulp freeness value determined is compared to the set point value. To increase freeness, the pulp is refined less on the disk or Jordan refiners and vice versa. For a better understanding of the freeness tester look at Figure 2, which is a paper machine freeness tester. Air pressure is used to discharge the test sample, before the cycle of the test begins again.

The best location of a freeness tester (dewaterability meter) on a sludge press would correspond to a location on the sludge pipeline before the press, but at a point where the sludge has been uniformly conditioned. The dewaterability meter would measure the sludge's drainage time and compare it to the set point. To decrease the drainage time, the meter
Figure 2. Paper Freeness Tester
would send a signal to decrease the polymer additions in proportion to the measured error. The opposite would be true for increasing the drainage time.

The freeness tester is said to have drawbacks. "In all common freeness testers, a relatively thick mat of fibers is formed without agitation, and the resulting entrapment of most of the debris slows the drainage so as to destroy reliable or consistent correspondence with actual wire drainage." The industry, in general, believes this error to be minimal as freeness testers are very widely used with effective results.

Variations in sludge dewaterability are generally identified on the basis of press performance and compensated for with appropriate changes in sludge conditioning. "A pressurized specific resistance apparatus is in common use in the industry and approximates the conditions in the filter press." Figure 3 is of the specific resistance apparatus. "It was brought out that filter presses are similar in concept to belt filter presses and that the specific resistance apparatus can be adapted to become a gravity drainage tester (Figure 4) which will also simulate the press." With the use of the gravity drainage tester and the many similarities between paper machines and sludge presses, this thesis should show the usefulness of applying a freeness meter on a belt filter press, so as to control the chemical conditioning of the sludge.
Sludge → Graduated Cylinder + Filter Media Which Provides Even Drainage and Complete Retention of Solids → Vent → Filtrate

FIGURE 3. SPECIFIC RESISTANCE APPARATUS
Illustration is not drawn to scale.

FIGURE #4
THE SPECIFIC RESISTANCE TESTER
EXPERIMENTAL PROCEDURE

Materials (courtesy of Plainwell Paper)

1. 55 gal. (3-6 %) unconditioned combination sludge
2. 10 lbs. Nalco 7121 Chemical Conditioning Polymer
3. 55 gal. of sludge press white water for dilution of sludge (if at consistency greater than 3%)

Equipment

1. Specific Resistance Tester (see Fig. 4)
2. Liter Graduated Cylinder
3. 5 gallon bucket
4. Buchner Funnel and Tared Filter Paper
5. Oven
6. pH Meter
7. Large Funnel
8. 250 ml. Graduated Cylinder
9. 100 ml. Graduated Cylinder
10. 2x500 ml. Beakers
11. 5 ml. Plastic Syringe
12. Thermometer
13. Magnetic Stir Bar and Stirrer
14. Weighing Balance
15. Stopwatch
Procedure

1. Chemical Polymer Preparation

   In one 500 ml. beaker, mix up 400 ml. of Nalco 7121 at 10% consistency using the magnetic stirrer.
   In the other 500 ml. beaker, mix up 400 ml. of Nalco 7121 at 1% consistency using the magnetic stirrer.
   The 1% solution will be used at low polymer doses.

2. Sludge Preparation

   A 5 gal. sample of sludge will be taken for testing.
   This unconditioned sludge will be tested for beginning consistency (using: Buchner funnel, filter paper, oven, and balance), pH (using pH meter), temperature (thermometer), and Specific Resistance (procedure in Appendix A). The ratio of primary to secondary sludge was given by Plainwell Paper.
   If sludge consistency is greater than 3%, then dilute the sludge sample to the 3% consistency using the sludge press white water. This simulates what the machine sees and does.

3. Drainage Rate Testing

   The unconditioned sludge will be conditioned in increments of polymer dosage (0-120 lbs/ton dry sludge) and tested for changes in specific resistance as specified in Appendix A. Triplicate tests to be run at every incremental polymer dosage rate used.
4. Additional Testing

Samples of machine conditioned sludge, from a belt filter press, will be taken and tested for specific resistance for comparison with the laboratory conditioned sludge data.

5. Analysis

The data generated will be plotted for comparison. The x-axis will represent the change in polymer dosage rate (0-120 lbs./ton dry sludge) and the Y-axis will represent the time required to drain a set volume. The total graph will show the change in drainage time as polymer dosage is increased.

Analysis of the graphs should show if the laboratory conditioning is representative of what the machine has conditioned and is dewatering. Further analysis of the graphs should show whether the curvature of the plot, would be useful in future control of polymer dosage rate on belt filter press.
Results and Standard Values

Calculations

Sludge flow: 160 gpm
Sludge consis.: 3-4 %
Press operations: 25 fpm x 6.4 ft. width = 160 ft²/min.
160 gpm ÷ 160 ft²/min = 1 gal./ft² = normal liquid loading
Tester area: .065 ft² → .065 gal. through tester per min.
Press speed: 25 fpm for 5 ft. length gravity drainage
5 ft = .2 min. = 12 sec.
25 fpm

.2 min. x .065 gpm = .013 gal. = 50 ml.

Target Value = 50 ml. (to best simulate press)

Other Data

Temperature of water (filtrate during runs): Range from 65-68₀°F
Viscosity range of water: 1.00-1.04 centipoise
pH range of sludge: 6.25 - 7.50
Filter Media: a portion of belt filter press (courtesy of Plainwell Paper)
Pressure drop: 170.0 mm head at start
161.5 mm head after 50 ml. has drained
8.5 mm head loss = .335 inches

The rest of the data is contained in the following graphs.
Effects of Polymer Dosage on the Time Required to Drain 50 ml.

- 95% C.I.
Trial #1

Sec. to Drain 50 mL

Ibs. Polymer / Ton Dry Sludge

95% Confidence Interval

Trial #2

Sec. to Drain 50 mL

Ibs. Polymer / Ton Dry Sludge
Trial #3

Machine set ~ 60 lbs. tested at 1 sec. (= 50 lb.)

1.5 sec.

Trial #4

Machine set ~ 90 lbs. tested at 3 sec. (= 75 lb.)

2.0 sec.
Trial #5

Sec. to Drain 50 mL.

0 20 40 60 80 100 120 140
Lbs. Polymer / Ton Dry Sludge

Trial #6

Sec. to Drain 50 mL.

0 20 40 60 80 100 120 140
Lbs. Polymer / Ton Dry Sludge
**Trial #7**

Machine set ~ 65 lbs.
tested at 5 sec. (= 50 lbs)

3.5 sec.

**Trial #8**

Machine set ~ 40 lbs.
tested at 3 sec (= 30 lbs)
Trial #9

Sec. to Drain 50 ml.

Lbs. Polymer / Ton Dry Sludge

Trial #10

Sec. to Drain 50 ml.

Lbs. Polymer / Ton Dry Sludge
Effects of Polymer Dosage on

Milliliters Drained at 12 sec.

(Trial #3 Data)
Effects of Polymer Dosage on the Time Required to Drain 50, 80, & 100 ml.
(Trial 3 Data)

---

= 95% C.I.

---

Seconds Required to Drain

Ibs Polymer/Ton Dry Sludge
Effects of Polymer Dosage on the Time Required to Drain 50, 80, 100 ml. (Trial 7)

\[ = 95\% \text{ C.I.} \]

Seconds Required to Drain

Lbs. Polymer / Ton Dry Sludge
DISCUSSION OF RESULTS

The results of the ten trials are plotted in the preceding graphs. Each polymer level increment used was run in triplicate for every trial. Analizing the data statistically gave the 95% confidence interval used in the graphs. The ten trials run were looking at the time required to drain 50 ml. Only a couple of the trials had sufficient data for the higher volumes collected, so that they could be graphed (80 ml & 100ml).

The ten trials gave very reproducible curves for the time required to drain 50 ml. The 50 ml. was the target value calculated to best simulate the gravity drainage section of a belt filter press, on the specific resistance tester. Analysis of the ten trials, shows an area from 40 to about 100 lbs. of polymer per ton of dry sludge to be of little use for control means (50 ml graphs). Testing of machine conditioned sludge, showed values within the 40 to 100 lb. range.

First analysis of the ten trials, would lead us to believe that the polymer conditioning level could be switched from the high to the low-end (90 to 40), without a significant change in sludge drainage to be noticed by the belt filter press. This would greatly increase chemical savings.

This would appear to be too evident, to not to be noticed by press supervisors. Therefore, another factor may be necessary to be found if possible.

Analysis of the data, that was available, for measuring 80 ml. and 100 ml. showed steeper curves than for the 50 ml., with a much less flat section. However, the confidence interval was greatly increased for each of these curves. More testing is required for further analysis.
CONCLUSION

With the cost and use of chemical polymers increasing, the need for a control means to regulate polymer dosage to actual sludge requirements has greatly increased. The research of this Thesis has shown great similarities between a paper machine freeness tester and a specific resistance tester. The moisture meter, though, was shown to have major drawbacks at this time.

The results of the resistance testing shows that the specific resistance tester is sensitive at picking up changes in polymer loading. The graphs of the data, shows that the specific resistance tester to have a useful value relationship (in measuring 50 ml. drained) from the unconditioned level to 40 lbs. of polymer per ton of dry sludge. Generally, the 40 to 100 lbs of polymer per ton of dry sludge levels have a flat curve relationship, which would not be useful in a control set up. A measurement in the 40 to 100 lbs level could not show a significant difference, between the two levels. An interpretation of these results, shows that a paper machine freeness tester could be applied to a belt filter press in an on-line arrangement with effective results, but only within a limited working range (0–40 lbs). The tester would not be an effective control means at the higher polymer levels (40–100 lbs).
RECOMMENDATIONS

The specific resistance tester produces very reproducible results therefore it would be a good control tool, but more testing is needed to determine a curve with a relationship that would be more effective in the 40 to 100 lbs. of polymer per ton of dry sludge region (region where Plainwell Paper generally ran).

Further testing should be carried out to determine if the tester results are greatly changed by upsets in pH, sludge ratios (secondary and primary), etc. Preliminary testing showed sludge consistency and solids drainability changes to have only minor effects. Research shows that pH and sludge ratio changes should also have minor effects.

Application of a freeness tester in an on-line set up would be the next step. Filter media should be changed to simulate the belt press and the volume measurement changed to the one with the best relationship for a belt filter press.
FOOTNOTES


2Ibid.

3Ibid.


6Ibid.


11Ibid.

12Reid Miner, Regional Manager of NCASI, in interviews on comparing filter presses with belt filter presses and on the specific resistance apparatus, Fall 1982 and Winter 1983.
BIBLIOGRAPHY


Miner, Reid. "Regional Manager of Central-Lake States NCASI. Interviews regarding comparisons of pulp and sludge dewaterability characteristics, and the similarities between the specific resistance tester and a belt filter press. Kalamazoo, MI., 1982 Fall semester, and 1983 Winter Semester.

APPENDIX A

Using The Gravity Drainage Tester

1. Set Up Tester

Place the gravity drainage tester (specific resistance tester in figure 4) in upright position and attached to a metal post. Place the desired graduated cylinder (depending on volume desired) directly beneath the tester, with a funnel in the top of the graduated cylinder.

2. Materials

a. sludge sample
b. 1% consistency polymer solution
c. 10% consistency polymer solution

3. Procedure

Scoop 1 liter of the sludge sample up. Pour the liter sample into a liter graduated cylinder adding the desired polymer dose as you go. The small polymer dose can be measured by using a calibrated syringe. Mix the conditioned sludge sample back and forth in the graduated cylinder keeping the open end closed (or from beaker to beaker) for a total of ten times.

Pour the sludge sample into the tester starting the stopwatch at the initial part of the pouring. Write down the time required to reach each of the desired volumes. Record all data.

4. Cleanup

Disassemble all equipment and wash after every test.