Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

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EFFECT OF ADDITIONAL PUMPING ON THE POLYMER DEMAND OF ANAEROBICALLY DIGESTED SLUDGE - A LABORATORY STUDY

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EFFECT OF ADDITIONAL PUMPING ON THE POLYMER DEMAND OF ANAEROBICALLY DIGESTED SLUDGE – A LABORATORY STUDY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

At the request of the Engineering Department in a memorandum dated September 1, 1998, a laboratory simulation study was carried out to determine whether additional pumping of anaerobically digested sludge through a proposed looped piping distribution system would adversely affect the polymer demand for centrifuge dewatering at the Stickney Water Reclamation Plant (WRP). The experimental plan was developed by Consoer Townsend Envirodyne (CTE) Engineers in discussions with personnel of the Environmental Monitoring and Research Division of the Metropolitan Water Reclamation District of Greater Chicago (District).

Measurement of the capillary suction time (CST) of the digested sludge was used to determine the polymer dose needed to effectively condition the sludge for dewatering. A laboratory mixer with a two-inch diameter propeller, at a speed of 500 rpm, was used to mix separate aliquots of the digested sludge for periods ranging from 15 to 120 seconds to provide various mixing energy and detention times to simulate the pumping conditions. The experiments were carried out in September 1998 using digested summer sludge, and repeated in February 1999 using digested winter sludge.

The experiments were repeated on four separate days for each of the two time periods, for a total of 24 sets of dosage data for each type of sludge.

For the summer sludge, the polymer dose for 15- and 30-second mixing was not significantly different from the zero mixing polymer dose. However, the polymer dose of the digested summer sludge mixed for 120 seconds was significantly different from the dosage of the control sludge in all replicates, and was also significantly different in some of the replicates mixed for 90 and 60 seconds.

CTE Engineers estimated that the product of mixing energy and mixing detention times (GT value) for the full-scale additional sludge pumping is equivalent to the 60-second premixing treatment.

On the average, the dosage difference between the digested sludge samples mixed for 60 seconds and the control was 2.8 lbs/ton, or 0.9 percent of the control polymer dosage. When compared to the actual variability of ±6 lbs/ton obtained in full-scale polymer tests on the centrifuges, the mixing of digested sludge at 60 seconds is considered to have no substantial impact on polymer dosage.

With the winter sludge, no increase in polymer dosage was observed at any of the premixing times in the range of 15 to 120 seconds.

Thus, it does not seem that the 60-second premixing treatment, which is expected to simulate the mixing energy that would be imparted to the digested sludge due to additional pumping through the proposed looped pipe distribution system, would have any significant impact on polymer dose for either summer or winter sludge.

The general conclusions given to the Engineering Department were:

1. Pumping of winter sludges showed no additional demand for polymer when subjected to simulated pumping for 15-120 seconds.
2. Neither summer nor winter sludges showed any significant additional demand for polymer when subjected to simulated pumping for 60 seconds.

INTRODUCTION

In September 1998, the Engineering Department requested that the Research and Development (R&D) Department investigate whether additional pumping of anaerobically digested sludge through a proposed looped piping distribution system with a recirculating return line that would feed 21 centrifuges would adversely affect the polymer demand in centrifuge dewatering of the digested sludge at the Stickney WRP (Appendix I). This request was in support of the planned expansion of the centrifuge complex at the Stickney WRP. CTE Engineers, the consulting firm designing the centrifuge facility, proposed an improved centrifuge feed system which would include a wet well, a looped-pipe distribution system for pumping the sludge, and a recirculating return line to feed 21 centrifuges. An experimental plan for a laboratory study was developed by CTE Engineers to study the effect of this additional pumping of sludge, with modifications by the District (Appendix II). The experimental study was carried out in accordance with the modified experimental plan.

The essential points of the modifications were:

1. Include 90 seconds of mixing in the mixing schedule.
2. Replicate each run four times.
3. Repeat the experiment on four separate days.
4. Repeat the study under winter conditions.

These modifications were made in order to provide a more robust database for evaluation. The need to conduct the study under winter as well as summer conditions is due to the fact that the sludges undergo changes in chemical characteristics and polymer performance under winter conditions as compared to summer conditions.

Historically, the performance of the Stickney WRP post digestion centrifuges deteriorates in the winter season. The percent capture and percent cake goes down, while the polymer dose goes up. District studies have shown that this is predominantly due to an increase in alkalinity in the winter season sludge (approximately 5500 mg/L) from what is observed with sludge in the summer season (approximately 3000 mg/L). The anaerobically digested sludge produced at the Stickney WRP from December through May is characterized as winter sludge, while the sludge produced June through November is characterized as summer sludge. The Mannich-type polymers are found to be cost effective and are able to meet performance specifications at the Stickney WRP. They are detrimentally affected by high alkalinity. To partially compensate for this, polymers with different characteristics are used with winter sludge (winter polymer) and summer sludge (summer polymer). Typically, the summer polymer has a lower cationic charge than the winter polymer. Also, the sludge input flow is typically reduced during the winter period, which aids dewatering performance.

The work presented in this report was summarized for a paper which was presented at the WEFTEC '99 Conference in October 1999. The paper is entitled, "Effects of Pump Mixing Dynamics on Polymer Demand During the Dewatering of Digested Sludge," and was authored by M. Halm, D. Zenz, and A. Bouchard of Consoer Townsend Envirodyne Engineers and D. Lordi, S. Soszynski, P. Tata, and C. Lue-Hing of the Metropolitan Water Reclamation District of Greater Chicago.

This paper is attached as <u>Appendix III</u>.

METHODOLOGY

Laboratory Procedure

Treatment dosage curves were determined (CST vs. volume of a 12 percent or 15 percent polymer solution to flocculate 200 mL of anaerobically digested sludge) for sludges premixed prior to flocculation (at 500 rpm) for 15, 30, 60, 90, and 120 seconds. Three different polymer dosages were tested for each premixing time. A blank dosage curve was also determined for the anaerobically digested sludge that was not premixed prior to flocculation with aliquots of polymer solution. Thus, five treatment dosage curves for premixed sludge and one blank dosage curve for the unmixed sludge were determined on four separate days (for a total of 24 curves), with new sludge being used each day, and with each point (polymer dosage) defining a given curve replicated four times (for a total of 12 values for each curve). The data for the dosage curves for the summer sludge was taken so as to straddle a CST of 10 seconds, and for the winter sludge a CST of 15 seconds was chosen. These were the performance criteria chosen to estimate polymer dosage at the centrifuges.

The action sequence for obtaining a data point which is used to define a treatment dosage curve is as follows:

1. Measure 200 mL of anaerobically digested sludge.
2. Premix the sludge (at 500 rpm) for 15, 30, 60, 90, or 120 seconds.

3. Add a volume aliquot of 12 or 15 percent polymer solution to the sludge and mix by hand to flocculate the sludge.

4. Mix the flocculated sludge (at 500 rpm) for 120 seconds.

5. Obtain the CST measurement.

The action sequence for obtaining a data point which is used to define a blank dosage curve is the same, but the premixing is excluded.

Data Analysis

The 24 dosage curves obtained from testing a given type of sludge were linearized by fitting the data to the following model developed at the District using a least squares algorithm for parameter estimation:

$$\mathrm{Log}_{10}(\mathrm{CST}) = K_1 + K_2(\mathrm{ML})^N$$

Where, CST = Capillary suction time (seconds)

ML = Volume of polymer solution (mL)

K_1, K_2, N are fitting parameters.

Each of the 24 equations was solved for the volume of polymer solution (mL) when CST was set equal to either ten seconds for the summer sludge, or 15 seconds for the winter sludge. Then 24 values of polymer dosage were calculated from these 24 polymer volumes as pounds of wet polymer per ton of dry sludge solids (lbs/ton). The dosages were calculated as follows:

$$\text{lbs/ton} = \frac{(ML_P)(\%P)\ 2000}{(ML_S)(\%S)}$$

Where, ML_P = Volume of polymer solution (mL)

$\%P$ = Percent concentration of polymer (12 or 15 percent)

ML_S = Volume of sludge (200 mL)

$\%S$ = Percent concentration of sludge solids

For the data in a given day with a given sludge, five dose differences were obtained by subtracting the blank dosage from the five treatment dosages; and five dose percent differences were obtained using the blank polymer dose as the base for the calculation.

In order to determine statistical significance of the calculated dose differences the Johnson-Neyman technique (Huitema, 1980) is applied to the optimum doses derived from the models. This technique is specifically used to determine if there is a statistically significant difference between the model that represents the blank, and the model that represents one of five treatments given to a common sludge on a given day. The technique does not assume that the models being compared have equal slopes, but instead establishes regions of significant difference and regions of nonsignificant difference (at a specific probability level α) based on the values of a covariate, which is the independent variable (volume of polymer solution) in the models. An example of the dosage curve for the summer sludge obtained for the September 3, 1998, 60-second test is presented in Figure 1.

The region to the left of the dark vertical line shows the region of polymer dosage where the two curves are not significantly different, while in the portion of the curves to the right of the vertical line the curves are significantly different. This figure also shows that at a CST of 10 seconds (Log CST = 1), the two curves were not significantly different.

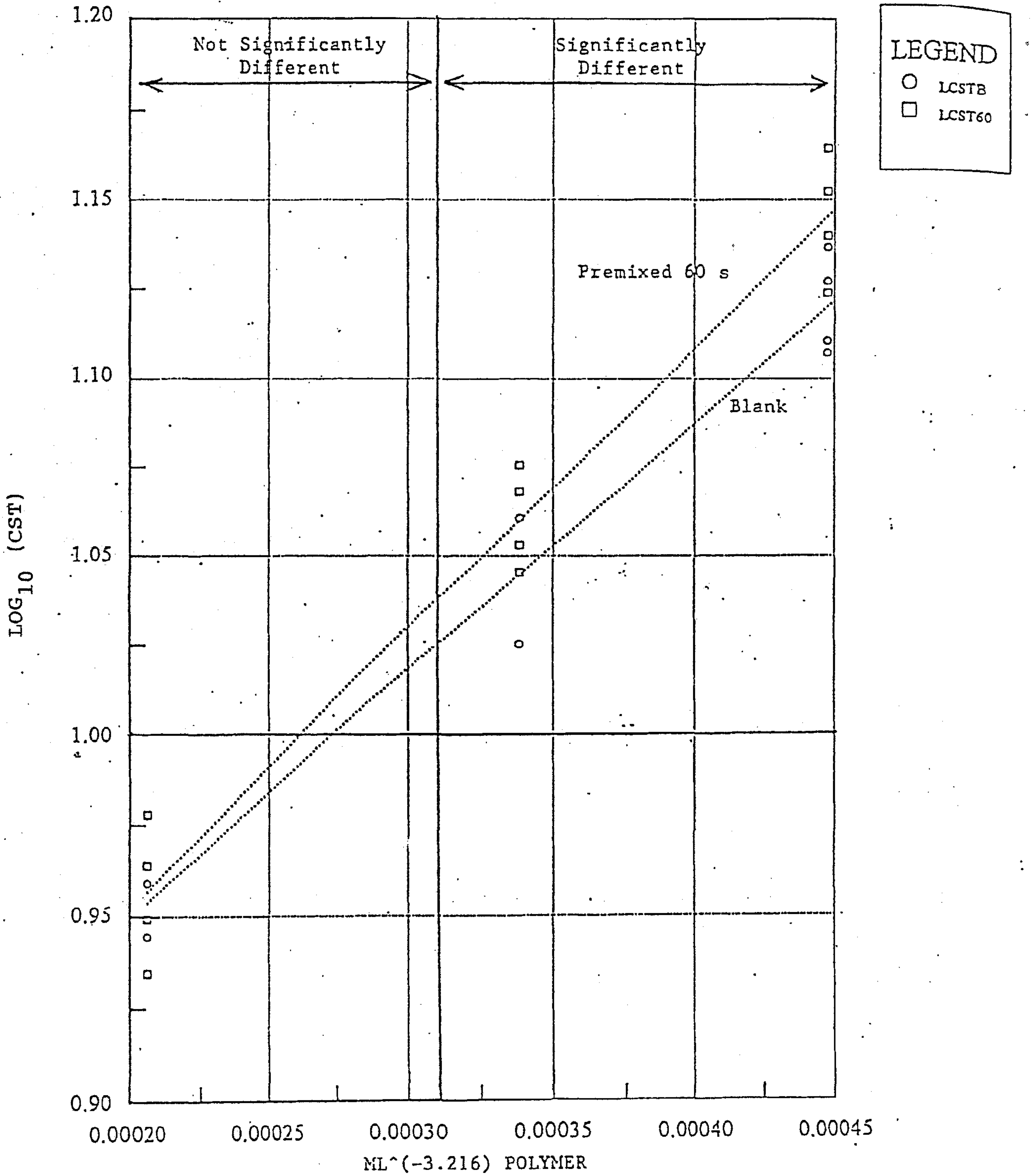
An example of the dosage curves from the winter sludge tests of February 10, 1999, is presented in Figure 2. The blank and treatment curves are not significantly different over the entire range tested.

The Johnson-Neyman technique may be considered as an enhancement, extension, and generalization of the analysis of covariance for a point of reference to more familiar techniques.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 1

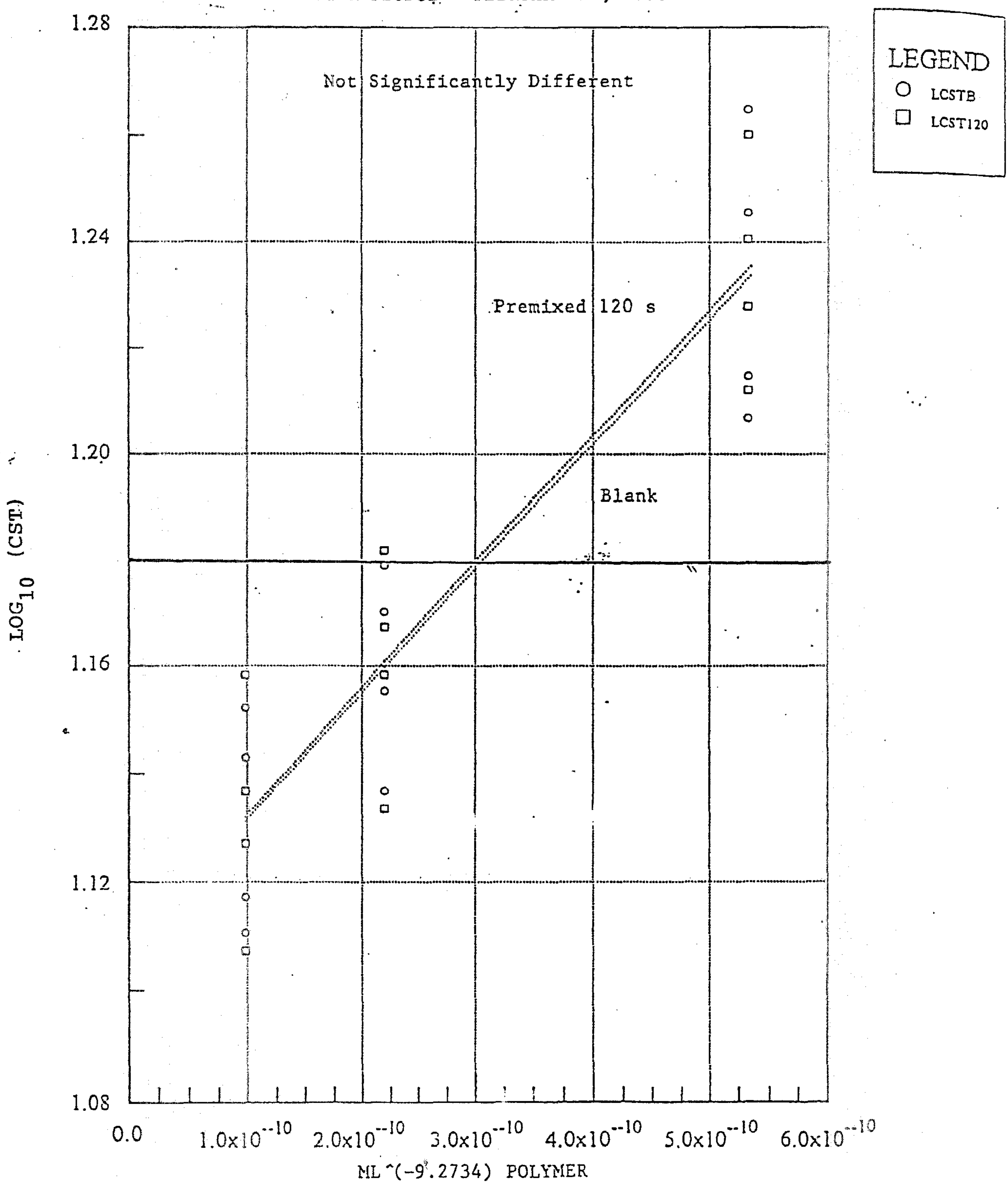
POLYMER DOSAGE CURVE FOR 60-SECOND PREMIXING
SEPTEMBER 3, 1998



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 2

POLYMER DOSAGE CURVE FOR 120-SECOND PREMIXING
WINTER SLUDGE - FEBRUARY 10, 1999



RESULTS

Summer Sludge

Tests using the summer digested sludge were conducted during early September 1998. The experimental data collected on four separate days with four different sludge samples are presented in Table 1 for the summer sludge. This table displays the volume of 12 percent polymer solution used to flocculate 200 mL of sludge along with the resultant CST values arising from the blank and the five premixing treatments, obtained on the four days. Table 2 summarizes the centrifuge feed summer sludge characteristics. The sludge percent total solids concentrations for the four days in sequence were 4.57, 4.2, 4.23, and 4.23 percent, respectively.

The summary of results obtained from the data collected over four days using summer sludge is presented in Table 3. This table displays the polymer dosages obtained from the models, the dose differences obtained by subtracting the blank dosage from the five treatment dosages (in a given day), the dose percent differences using the blank polymer dose as a base, and the statistical significance of the dose differences at the 0.05 probability level using the previously described dosage curves and the Johnson-Neyman technique. The statistical significance is denoted as "NS" (for nonsignificant) or "S" (for significant). When a dose difference is labeled

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1

EXPERIMENTAL DATA COLLECTED (SUMMER)

		CST* (Seconds)					
Date	Polymer (mL)	Blank	15 secs. Mix	30 secs. Mix	60 secs. Mix	90 secs. Mix	120 secs. Mix
9/3/98	11	12.8	13.6	12.8	13.8	14.8	15.1
	11	12.9	13.1	13.2	14.6	15.1	14.7
	11	13.4	12.7	14.1	14.2	14.1	15.8
	11	13.7	13.4	13.7	13.3	13.7	14.1
	12	11.1	10.5	11.4	11.1	11.3	12.0
	12	11.5	10.8	11.7	11.7	12.1	12.7
	12	10.6	11.6	10.8	11.9	12.3	11.8
	12	11.1	11.2	11.0	11.3	11.6	12.3
	14	8.6	8.9	8.5	8.6	8.9	9.6
	14	9.5	8.7	9.3	9.5	9.6	9.3
	14	8.8	9.6	9.6	8.9	9.2	8.7
	14	9.1	9.3	8.8	9.2	8.5	9.1
9/9/98	10	13.7	13.8	14.4	14.2	15.7	16.5
	10	14.1	13.5	14.2	14.8	15.1	16.0
	10	13.5	13.7	13.8	15.3	16.1	17.0
	10	13.6	14.2	13.5	14.5	15.3	15.5
	11	10.3	9.7	9.8	10.6	10.6	11.8
	11	10.4	10.1	10.2	10.9	11.0	11.1
	11	10.0	10.2	10.0	10.4	10.8	10.9
	11	9.8	10.5	10.5	10.2	11.3	11.2
	12	8.1	8.3	8.5	8.1	8.1	9.3
	12	8.2	7.5	7.9	8.8	8.8	8.8
	12	8.0	8.1	8.3	8.4	9.0	8.3
	12	7.6	7.8	7.7	7.9	8.3	8.7
9/10/98	10	13.7	13.8	14.4	14.2	15.7	16.5
	10	14.1	13.5	14.2	14.8	15.1	16.0
	10	13.5	13.7	13.8	15.3	16.1	17.0
	10	13.6	14.2	13.5	14.5	15.3	15.5
	11	10.3	9.7	9.8	10.6	10.6	11.8
	11	10.4	10.1	10.2	10.9	11.0	11.1
	11	10.0	10.2	10.0	10.4	10.8	10.9
	11	9.8	10.5	10.5	10.2	11.3	11.2
	12	8.1	8.3	8.5	8.1	8.1	9.3
	12	8.2	7.5	7.9	8.8	8.8	8.8
	12	8.0	8.1	8.3	8.4	9.0	8.3
	12	7.6	7.8	7.7	7.9	8.3	8.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1 (Continued)

EXPERIMENTAL DATA COLLECTED (SUMMER)

Date	Polymer (mL)	CST* (Seconds)					
		Blank	15 secs. Mix	30 secs. Mix	60 secs. Mix	90 secs. Mix	120 secs. Mix
9/14/98	10	11.9	12.4	12.5	12.9	13.5	14.2
	10	11.7	11.8	12.7	13.2	13.7	13.9
	10	12.5	11.6	12.1	12.5	13.0	13.0
	10	12.1	12.2	11.8	12.3	12.6	13.8
	11	8.8	8.8	8.6	9.9	9.6	11.2
	11	8.5	9.5	9.7	9.3	9.9	11.1
	11	8.8	9.2	9.3	10.2	10.8	10.0
	11	9.4	8.6	9.1	9.4	10.4	10.4
	12	7.9	7.7	8.1	7.8	8.4	8.8
	12	8.2	7.9	7.7	8.3	7.9	8.1
	12	8.1	8.4	8.3	8.6	8.6	8.7
	12	7.7	8.1	7.9	7.9	8.1	8.1

*CST = Capillary Suction Time.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 2

CENTRIFUGE FEED SLUDGE CHARACTERISTICS (SUMMER)

Sample Date	Total Solids (%)	Total Volatile Solids (%)	NH_3-N (mg/L)	TKN (mg/L)	Alkalinity (mg/L)	Ca (mg/Kg)	Mg (mg/Kg)	Conductivity (μmhos/cm)
9/3/98	4.57	50.5	544	2811	3143	36,450	16,300	4180
9/9/98	4.2	50.8	531	2418	3158	35,370	16,860	4175
9/10/98	4.23	52.2	675	2446	3081	35,480	16,300	4090
9/14/98	4.23	53.9	787	2476	3033	34,910	16,120	4150

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3

SUMMARY OF RESULTS USING SUMMER SLUDGE

Date	Sample	Polymer Dose (Lbs/Ton)	Dose Difference (Lbs/Ton)	Dose Difference Percent	Statistical Significance 0.05 Level
9/3/98	Blank	333.9	-	-	-
	15 secs. Mix	335.7	1.8	0.5	NS*
	30 secs. Mix	336.2	2.3	0.7	NS
	60 secs. Mix	338.5	4.7	1.4	NS
	90 secs. Mix	340.4	6.5	1.9	NS
	120 secs. Mix	344.3	10.4	3.1	S**
9/9/98	Blank	322.9	-	-	-
	15 secs. Mix	322.3	-0.6	-0.2	NS
	30 secs. Mix	323.8	0.9	0.3	NS
	60 secs. Mix	326.0	3.1	1.0	NS
	90 secs. Mix	329.2	6.3	2.0	S
	120 secs. Mix	332.0	9.1	2.8	S
9/10/98	Blank	314.3	-	-	-
	15 secs. Mix	314.0	-0.3	-0.1	NS
	30 secs. Mix	315.4	1.1	0.4	NS
	60 secs. Mix	319.2	4.9	1.6	S
	90 secs. Mix	323.2	8.9	2.8	S
	120 secs. Mix	326.3	12.0	3.8	S
9/14/98	Blank	300.0	-	-	-
	15 secs. Mix	300.6	0.6	0.2	NS
	30 secs. Mix	302.0	2.0	0.7	NS
	60 secs. Mix	306.3	6.3	2.1	S
	90 secs. Mix	310.6	10.6	3.5	S
	120 secs. Mix	315.1	15.1	5.0	S

*NS = Not significant.
**S = Significant.

"NS," it is not significantly different from zero; and when it is labeled "S," it is significantly different from zero.

The 15- and 30-second premixing treatments are not significantly different from zero in polymer dose response, in all cases. The 120-second premixing treatment is significantly different from zero in polymer dose response, in all cases. The 90-second premixing treatment is significantly different from zero in polymer dose response, in three out of four cases; and the 60-second premixing treatment is significantly different from zero in polymer dose response, in two out of four cases.

Substituting zero values for dose differences that are not significantly different from zero, and averaging over the four days provides the following data reduction summary:

Pretreatment Mixing	Dose Difference (Lbs/Ton)	Dose Difference (Percent)
15 secs. Mix	0.0	0.0
30 secs. Mix	0.0	0.0
60 secs. Mix	2.8	0.9
90 secs. Mix	6.5	2.1
120 secs. Mix	11.7	3.7

CTE Engineers estimate that the product of mixing energy and mixing detention times (GT value) corresponding to the full-scale additional sludge pumping is equivalent to the 60-second premixing treatment (actual value is 57 seconds; see Appendix III). Thus, greater attention may be placed on this case. As a point of reference, previous experience indicates that the 95 percent confidence limits for polymer dosages from full-scale polymer tests on centrifuges are ± 6 lbs/ton. In this experiment, the increased polymer dosage at a 60-second premixing time was 2.8 lbs/ton when compared to the control. Thus, it does not seem that the 60-second premixing treatment, which is expected to be equivalent to the mixing energy that would be imparted to sludge due to the additional pumping through the proposed looped pipe distribution system has any substantial impact on polymer dose.

Winter Sludge

The experimental data collected for the winter digested sludge on four different days is presented in Table 4. This table displays the volume of 15 percent polymer solution used to flocculate 200 mL of sludge along with the resultant CST values arising from the blank and the five premixing treatments, obtained on the four days. Table 5 summarizes the centrifuge feed winter sludge characteristics. The sludge percent total solids concentrations for the four days in sequence were 4.21, 4.21, 3.97, and 3.89 percent, respectively. The winter sludge alkalinity ranged between 5279 and 5485 mg/L as $CaCO_3$.

A comparison of the data in Table 5 to the data in Table 2 shows that the alkalinity, conductivity, ammonia, and TKN are lower in the summer sludge than in the winter sludge. The calcium and magnesium are higher in the summer sludge as

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4

EXPERIMENTAL DATA COLLECTED (WINTER)

Date	Polymer (mL)	CST* (Seconds) Blank	15 secs. Mix	30 secs. Mix	60 secs. Mix	90 secs. Mix	120 secs. Mix
2/10/99	10	16.1	17.5	16.9	17.2	17.3	17.4
	10	18.4	16.0	16.5	16.8	16.3	16.9
	10	16.4	16.8	17.8	17.7	17.8	16.3
	10	17.6	18.5	17.4	16.4	16.9	18.2
	11	14.8	15.3	14.8	14.1	14.7	15.2
	11	15.1	13.5	14.0	13.5	13.9	14.4
	11	13.7	14.2	14.6	14.8	14.5	14.7
	11	14.3	13.9	15.2	15.0	15.1	13.6
	12	14.2	13.8	13.8	13.8	13.9	12.8
	12	13.9	14.1	12.8	13.0	13.0	13.7
	12	13.1	13.5	14.1	13.4	13.4	14.4
	12	12.9	13.2	13.3	14.3	14.1	13.4
2/11/99	10	18.9	19.5	18.8	18.6	17.8	18.5
	10	18.0	17.9	19.2	19.4	19.7	19.4
	10	19.6	18.5	18.4	18.9	19.2	18.2
	10	19.2	19.2	18.7	18.2	18.4	19.0
	12	15.3	15.6	15.3	14.3	16.0	15.0
	12	16.0	15.9	14.7	15.9	15.5	15.3
	12	14.3	14.7	15.1	15.4	14.1	14.3
	12	14.9	14.2	15.5	14.5	14.7	15.8
	13	13.4	13.8	15.0	14.1	13.5	13.3
	13	14.9	14.5	13.2	13.5	14.6	13.9
	13	14.6	14.9	14.2	14.8	13.7	14.9
	13	13.7	13.4	14.4	14.0	14.3	14.2
2/16/99	10	17.4	18.3	17.9	18.6	17.4	18.8
	10	19.2	18.9	19.1	19.0	19.3	17.7
	10	18.1	18.4	18.7	17.5	17.9	18.2
	10	18.5	17.6	17.6	17.9	18.7	18.6
	11	14.7	16.2	15.6	15.9	16.1	15.4
	11	16.1	16.0	15.4	15.2	15.2	14.8
	11	16.6	15.1	16.4	14.9	15.0	15.7
	11	15.3	15.3	15.0	16.3	16.4	16.5
	12	15.1	13.9	13.8	14.6	15.4	15.7
	12	14.8	15.4	15.7	15.2	14.9	13.7
	12	13.8	14.2	14.4	15.5	14.0	14.3
	12	15.6	15.8	15.5	14.1	14.5	14.9

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4 (Continued)

EXPERIMENTAL DATA COLLECTED (WINTER)

		CST* (Seconds)					
Date	Polymer (mL)	Blank	15 secs. Mix	30 secs. Mix	60 secs. Mix	90 secs. Mix	120 secs. Mix
2/17/99	10	17.4	17.3	17.1	18.2	16.2	17.3
	10	18.1	17.8	17.7	17.5	18.3	16.0
	10	16.7	16.8	16.3	16.2	16.6	17.9
	10	16.1	16.4	17.3	16.6	17.6	16.9
	11	14.3	14.7	15.1	14.5	14.6	15.6
	11	15.5	15.7	14.3	15.2	15.4	13.5
	11	13.8	13.4	14.0	13.8	13.9	14.1
	11	14.8	14.2	14.8	14.7	14.4	14.9
	12	14.5	13.1	14.7	13.4	13.0	13.3
	12	12.5	14.2	13.2	14.4	13.8	14.6
	12	13.8	13.6	12.6	13.1	14.5	14.0
	12	13.2	13.5	14.1	13.7	13.3	13.0

*CST = Capillary Suction Time.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 5

CENTRIFUGE FEED SLUDGE CHARACTERISTICS (WINTER)

Sample Date	Total Solids (%)	Total Volatile Solids (%)	NH_4-N (mg/L)	TKN (mg/L)	Alkalinity* (mg/L)	Ca (mg/Kg)	Mg (mg/Kg)	Conductivity (µmhos/cm)
2/10/99	4.21	51.4	1807	4505	5485	29,300	15,388	7200
2/11/99	4.21	52.6	1749	4552	5682	34,112	15,238	6900
2/16/99	3.97	48.5	1699	4376	5555	31,243	14,651	7000
2/17/99	3.89	50.1	1576	4088	5279	34,516	15,310	6800

*As $CaCO_3$.

compared to the winter sludge. The percent solids are approximately the same for both sludges.

Table 6 presents the results obtained from the data collected for the winter sludge.

Substituting zero values for dose differences that are not significantly different from zero, and averaging over the four days provides the following data reduction summary for the winter sludge:

Pretreatment Mixing	Dose Difference (Lbs/Ton)	Dose Difference (Percent)
15 secs. Mix	0.0	0.0
30 secs. Mix	0.0	0.0
60 secs. Mix	0.0	0.0
90 secs. Mix	0.0	0.0
120 secs. Mix	0.0	0.0

With the winter sludge, no increase in polymer dosage was observed at any of the premixing times.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 6

SUMMARY OF RESULTS USING WINTER SLUDGE

Date	Sample	Polymer Dose (Lbs/Ton)	Dose Difference (Lbs/Ton)	Dose Difference Percent	Statistical Significance 0.05 Level
2/10/99	Blank	379.6	-	-	-
	15 secs. Mix	379.3	-0.3	-0.1	NS*
	30 secs. Mix	380.8	1.2	0.3	NS
	60 secs. Mix	379.0	-0.6	-0.2	NS
	90 secs. Mix	380.4	0.8	0.2	NS
	120 secs. Mix	380.3	0.7	0.2	NS
2/11/99	Blank	431.0	-	-	-
	15 secs. Mix	430.2	-0.8	-0.2	NS
	30 secs. Mix	431.9	0.9	0.2	NS
	60 secs. Mix	428.6	-2.4	-0.6	NS
	90 secs. Mix	428.0	-3.0	-0.7	NS
	120 secs. Mix	429.1	-1.9	-0.4	NS
2/16/99	Blank	441.0	-	-	-
	15 secs. Mix	440.4	-0.6	-0.1	NS
	30 secs. Mix	440.0	-1.0	-0.2	NS
	60 secs. Mix	440.0	-1.0	-0.2	NS
	90 secs. Mix	437.3	-3.7	-0.8	NS
	120 secs. Mix	434.2	-6.8	-1.6	NS
2/17/99	Blank	413.5	-	-	-
	15 secs. Mix	413.6	0.1	0.02	NS
	30 secs. Mix	414.5	1.0	0.2	NS
	60 secs. Mix	414.7	1.2	0.3	NS
	90 secs. Mix	415.1	1.6	0.4	NS
	120 secs. Mix	414.4	0.9	0.2	NS

*NS = Not significant.

REFERENCE

Huitema, B. E., The Analysis of Covariance and Alternatives, John Wiley and Sons, Inc., New York, 1980.

APPENDIX I

ENGINEERING DEPARTMENT MEMORANDUM
SEPTEMBER 1, 1998

142945

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
Engineering
MEMORANDUM

9/1/98

TO: Cecil Lue-Hing
Director of Research and Development

TATA
- [x] FOR YOUR RESPONSE
- [ ] FOR YOUR REVIEW
- [ ] FOR YOUR INFORMATION
- [ ] FOR REVISION

FROM: John C. Farnan
Chief Engineer

SUBJECT: Laboratory Study - Effects of Additional Pumping on the Polymer Demand of Digested Sludge

DATE: September 1, 1998

Engineering is requesting your department to undertake the above mentioned Laboratory Study. Attached is an experimental plan developed by CTE Engineers (the consultant designing the Post-digestion Centrifuge Facility at Stickney WRP) through informal consultation with Dr. Prakasam Tata and Stanley Soszynski.

Please submit the results to Engineering by September 28, 1998, so that CTE Engineers may incorporate the results into their report.

For further information please call Thomas Kunetz, Principal Civil Engineer, at extension 13077.

Please proceed as requested

JTZ:TK
Attachments

DIR. OF R & D
1998 SEP -2 PM 2:45
M.W.R.D.
OF GRTR. CHGO.

APPENDIX II

EXPERIMENTAL PLAN: LABORATORY STUDY TO DETERMINE THE EFFECTS OF ADDITIONAL PUMPING ON THE POLYMER DEMAND OF DIGESTED SLUDGE

CTE ENGINEERS

CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

303 East Wacker Drive

Suite 600

Chicago, Illinois 60601-5212

Phone: (312) 938 0300

Fax: (312) 938 1109

June 25, 1998

Mr. Thomas E. Kunetz, P.E.
Principal Civil Engineer
Metropolitan Water Reclamation District of Greater Chicago
111 East Erie Street
Chicago, Illinois 60611-2802

Reference: MWRDGC Centrifuge Facility Expansion and Electrical Panels Replacement Project

Subject: Experimental Plan: Laboratory Study to Determine the Effects of Additional Pumping on the Polymer Demand of Digested Sludge

Dear Mr. Kunetz:

As per your request, Consoer Townsend Envirodyne Engineers, Inc. (CTE) has prepared an experimental plan for a laboratory study to determine the effects on biosolids dewaterability (if any) of the additional pumping that will occur as a result of the looped pipe distribution system for the centrifuge expansion at the Stickney Water Reclamation Plant. This experimental plan is attached.

The plan was developed through informal consultation with MWRDGC Research and Development staff members at the Stickney Laboratory. They have estimated that the plan will take about 4 days of laboratory work for a Research Chemist and Laboratory Technician.

Upon receipt of the laboratory data, CTE will prepare a report to determine if the pipe loop system proposed for the Stickney Centrifuge expansion would affect polymer demand.

Respectfully Submitted,

CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

James H. Reynolds, Ph.D., P. E. FOR
Vice President
Project Manager

cc: David Zenz
M:\projects\40059\ltr&mems\kunet26.doc

EXPERIMENTAL PLAN
LABORATORY STUDY

Effects of Additional Pumping on The Polymer Demand of Digested Sludge
Stickney Centrifuge Expansion
Metropolitan Water Reclamation District of Greater Chicago

Introduction

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) has decided to expand the existing Centrifuge Complex at the Stickney Water Reclamation Plant (WRP) in order to dewater all digested sludge produced at the plant. As part of the Centrifuge Complex expansion, the existing wetwell will be abandoned and a new wetwell and digested sludge pumping station will be constructed with the ultimate capability to feed sludge to 21 centrifuges located in the expanded facility. The new digested sludge feed system will incorporate a looped distribution piping system with a recirculating return line. That is, digested sludge will be pumped though a pipe loop to each centrifuge and a portion of the feed sludge will be returned to the wetwell. This looped system ensures an equal distribution of digested sludge to each centrifuge, provides operational flexibility with variable speed-drive pumps, and prevents blockages and stagnation in the digested sludge distribution system.

The MWRDGC has raised concerns that the looped distribution system will result in a portion of the digested sludge undergoing additional pumping before reaching the inlet to a centrifuge. Thus, a portion of the digested sludge will be subjected to more shear stress than occurs at the existing centrifuge complex pumping station. The MWRDGC believes that it is possible that this additional shear stress could result in an increase in polymer dose to dewater the digested sludge.

The digested sludge currently being processed at the Stickney Centrifuge Complex undergoes pumping at three pump stations at the Stickney WRP. First, digester drawoff is pumped to a holding tank. From the holding tank, the drawoff is pumped to the existing centrifuge complex wetwell where it is again pumped to individual centrifuges. At the new wetwell and pump station, a portion of the digested sludge will be returned to the wetwell in the looped piping system. Therefore, although digested sludge is now pumped three times, some of the digested sludge will be subjected to additional pump mixing in comparison to the existing pumping system.

The MWRDGC has asked that an experimental plan be prepared describing laboratory tests that will demonstrate the additional polymer demand, if any, that will occur due to additional pumping of digested sludge through the new looped piping system. This document describes such laboratory tests.

Consoer Townsend Envirodyne Engineers, Inc. (CTE) developed the experimental program through informal consultation with the following MWRDGC Research and Development (R & D) Department staff members:

1. Dr. Prakasam Tata, Manager of Research and Technical Services

2. Mr. Stanley Soszynski, Research Chemist II

<u>Shear Forces in the Proposed New Pump Station</u>

Mixing energy imparted to a liquid is defined as the mean velocity gradient, G, which is the difference in velocity at a given distance at right angles to the direction of flow. G is a function of the power input, *P*, the volume of the vessel and the dynamic viscosity of the fluid. G is conveniently applied and widely accepted as a means of computing the mixing energy imparted to a fluid. The velocity gradient may be calculated from the following equation:

Equation 1: $G = [(550(P)/(MV)]^{1/2}$

G = Velocity Gradient, sec^{-1}
P = Applied Horsepower, hp
V = Effective Volume, ft^3
M = Dynamic Viscosity of Fluid, $lb - sec/ft^2$

The power, P, imparted by a mixing device under turbulent flow conditions (Reynolds number exceeding 100,000), is defined as follows:

Equation 2:

$$P = \frac{K}{gc} M N^3 D^5$$

P = Power, ft – lb/sec

K = Constant, depending upon shape of mixing device

gc = Newton Conversion Factor
32.17 ft – lb/sec^2 – lb

p = Mass density of fluid, lb/ft^3

N = Speed of mixer, rev/sec

D = Diameter of Impeller, ft

The pumps to be installed at the new pumping station have a 125 hp motor. The G value can then be calculated directly from Equation 1, since the volume of the pump casing is about 11. ft^3. The G value for the new pump station is 19,258 sec^{-1}.

In order to characterize the mixing energy imparted to liquids for various mixing times, the valu of G is multiplied by the mixing detention time (T, seconds) to produce the dimensionless constant GT. For the new pump station, the detention time of digested sludge in the pump casing is about 3.3 seconds, at a flow of 1500 gpm. Therefore, the GT value for the pump station is about 63,551.

Proposed Laboratory Experiments

For many years, the MWRDGC's R & D Department has used the measurement of capillary section time (CST) to determine in the laboratory the polymer dosages for the existing centrifuge complex. The CST device is a type of miniaturized Buchner Funnel filtration apparatus that measures the time to filter a constant volume of sludge. The CST measurement is a very versatile tool in providing information for all dewatering applications, including centrifuges.

The CST measurement can be used to determine the polymer dosage requirement for a particular sludge. Various polymer dosages are applied to the sludge until a CST of 10 seconds is reached. The MWRDGC R&D Department has found that sludge being fed to the existing centrifuge complex is at an optimal dewatering condition at a CST of 10. Therefore, the CST test can be used in a similar way as the Buchner Funnel test to determine the polymer dose needed to effectively condition sludge for proper dewatering.

CST test procedures would be used to determine the polymer dose requirements for digested sludge subjected to various mixing energy and detention times (GT values). A small laboratory mixer would be used to simulate various GT values.

Mixing Rate and Time for Laboratory Mixing System

Using Equation 2, the power applied by a laboratory mixer was calculated under the following conditions:

Impeller Diameter = 2 inches

K = 1.0

n = 500 rpm

The G value was then calculated based upon Equation 1 and the mixing of 200 ml of sludge. The G value is 1,115/sec. In order to provide a GT value of 63,551 (the GT value for the new pump station), a mixing time of 57 seconds would be required for the laboratory mixer.

Laboratory Testing Procedures

Samples of digested sludge should be gathered from the existing Stickney Centrifuge Complex downstream of the existing wetwell and pump station. This digested sludge should be mixed with a laboratory mixer with a propeller diameter of 2 inches, at a speed of 500-rpm. Separate 200 ml aliquots of the sludge should be mixed for periods of 15 seconds, 30 seconds, 60 seconds, 90 sec and 120 seconds. Next, using the existing centrifuge complex polymer, the polymer dosage needed to achieve a CST of 10 should be determined for each mixed aliquot.

The above experiment procedure should be ~~duplicated~~ REPLICATED using a sample of digested sludge collected from the centrifuge complex on ~~a~~ 4 different days.

It is estimated that the experiments will take about 4 days to complete. The MWRDGC R & D Department would be asked to perform the experiments and prepare a short report listing the results of the laboratory testing. CTE would assemble the R & D data into a final report, and wi determine whether the additional mixing provided by the new pump station and pipe loop woulc negatively affect the polymer usage at the expanded centrifuge complex.

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INTEROFFICE MEMORANDUM

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

DEPARTMENT: Research and Development DATE: September 3, 1998

TO: John C. Farnan
Chief Engineer

FROM: Cecil Lue-Hing

SUBJECT: Laboratory Study - Effects of Additional Pumping on the Polymer Demand of Digested Sludge

RECEIVED BY R & D LAB
98 SEP -8 AM 10:40

Copy to: Coordinator of ... 9/8

We are in receipt of your memorandum of September 1, 1998 (copy attached) and the attachments, which include an Experimental Plan for the Laboratory Study, which was provided by CTE Engineers.

Please be advised that the work will be done promptly, and the information you requested delivered on or about September 28, 1998.

Please be advised also that in consultation with Dr. David Zenz, of CTE Engineers, the experimental design protocol was modified; not to change the experimental design per se, but rather to provide a more robust database for later evaluation.

The modifications agreed upon with Dr. Zenz are as follows:

1. Include 90 seconds of mixing in the mixing schedule.
2. Replicate each run 4 times.
3. Repeat the experiment on 4 separate days.
4. Repeat the study under winter conditions.

While we feel confident that the information and the data obtained from this study during summer conditions will be valid, we are also aware of the fact that these sludges undergo changes in chemical characteristics under winter conditions. Thus, our decision is to examine this material under winter conditions also.

We plan to conduct the "winter conditions" study on such a schedule that the information will be available to the Engineer-

9/3/98 Dr. Tata Pls call me on this as soon as you can JF

Subject: Laboratory Study - Effects of Additional Pumping on the Polymer Demand of Digested Sludge

ing Department and CTE Engineers such that design modifications to the pumping system can be made if warranted. Thus the engineering design of the pumping system can proceed as originally contemplated.

Cecil Lue-Hing
Director
Research and Development

CLH:jp
Attachment
cc w/att: P. Tata
D. Zenz

THIS COPY FOR

APPENDIX III

PAPER ENTITLED, "EFFECTS OF PUMP MIXING DYNAMICS ON POLYMER DEMAND DURING THE DEWATERING OF DIGESTED SLUDGE,"

BY
M. HALM, D. ZENZ, AND A. BOUCHARD

CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.
CHICAGO, IL

AND

D. LORDI, S. SOSZYNSKI, P. TATA, AND C. LUE-HING

RESEARCH AND DEVELOPMENT DEPARTMENT
METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
CHICAGO, IL

PRESENTED AT

WATER ENVIRONMENT FOUNDATION WEFTEC '99
NEW ORLEANS, LA
OCTOBER 1999

Water Environment Federation
WEFTEC'99
New Orleans, LA

EFFECTS OF PUMP MIXING DYNAMICS ON POLYMER DEMAND DURING THE DEWATERING OF DIGESTED SLUDGE

M. HALM, D. ZENZ, A. BOUCHARD, D. LORDI, S. SOSZYNSKI, P. TATA, C. LUE-HING *
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.
303 E. WACKER DRIVE
CHICAGO, IL. 60601

ABSTRACT

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) retained Consoer Townsend Envirodyne Engineers Inc. (CTE) to expand the existing Centrifuge Complex at the Stickney Water Reclamation Plant (WRP) in order to dewater all digested sludge produced at the plant. The capacity of the complex will be increased from approximately 90,000 dry tons per year to 150,000 dry tons per year. As part of the Centrifuge Expansion, the existing digested sludge wetwell and pumping station will be abandoned and an improved centrifuge feed system will be constructed including a new wetwell and looped piping distribution system with a recirculating return line to feed 21 centrifuges. Digested sludge will be pumped through a common pipe loop to each centrifuge and a portion of the feed sludge returned to the wetwell.

There were concerns that the looped distribution system would result in a portion of the digested sludge undergoing additional pumping before entering a centrifuge, and as a result, a portion of the digested sludge would be subjected to more shear stress than occurs in the existing piping system, which does not have a return line. A laboratory study was undertaken to determine the polymer demand of digested sludge subjected to the range of mixing which would be encountered in the expanded centrifuge complex.

*D. Lordi, S. Soszynski, P. Tata, C. Lue-Hing, Metropolitan Water Reclamation District of Greater Chicago.

Two hundred milliliter samples of digested sludge were mixed with a 2-inch laboratory paddle mixer at mixing times of 15, 30, 60, 90 and 120 seconds. In order to provide a mixing energy and detention time (GT) of approximately 64,000, (the GT of the new pump station) a mixing time of about 60 seconds would be required for the laboratory mixer. Using the laboratory measurement of capillary suction time (CST) the polymer demand of the sludge was determined. Sludge samples were taken on eight separate days (4 days in the winter and 4 days in the summer) and 576 separate CST measurements were conducted.

Using the Johnson - Neyman statistical technique it was determined that there was no statistical difference between the polymer demand at the various mixing times for the winter sludge. For the summer sludge, the mixing times of 60, 90 and 120 seconds caused a statistically significant increase in polymer dose of about 3 lbs of polymer per dry ton. Since the 95% confidence limit for polymer dosage on full-scale tests had previously been found to be about ± 6 lbs/ton, it was concluded that the mixing energy imparted to the sludge due to the pipe loop would not have any significant impact upon polymer dose. The pipe loop system will therefore be included in the expanded centrifuge complex.

KEYWORDS

centrifuge, digested sludge, polymer dosing

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) decided to expand the existing Centrifuge Complex at the Stickney Water Reclamation Plant (WRP) in order to dewater all digested sludge produced at the plant. As part of the Centrifuge Complex expansion, the existing wetwell will be abandoned and a new wetwell and digested sludge pumping station will be constructed with the ultimate capability to feed sludge to 21 centrifuges located in the expanded facility. The new digested sludge feed system will incorporate a looped distribution piping system with a recirculating return line. That is, digested sludge will be pumped though a pipe loop to each centrifuge and a portion of the feed sludge will be returned to the wetwell. This looped system ensures an equal distribution of digested sludge to each centrifuge, provides operational flexibility with variable speed-drive pumps, and prevents blockages and stagnation in the digested sludge distribution system.

The MWRDGC raised concerns that the looped distribution system will result in a portion of the digested sludge undergoing additional pumping before reaching the inlet to a centrifuge. Thus, a portion of the digested sludge will be subjected to more shear stress than occurs at the existing centrifuge complex pumping station which does not have a sludge piping distribution system with a return line. The MWRDGC believes that it is possible that this additional shear stress could result in an increase in polymer dose to dewater the digested sludge.

The digested sludge currently being processed at the Stickney Centrifuge Complex undergoes pumping at three pump stations at the Stickney WRP. First, digester drawoff is pumped to a holding tank. From the holding tank, the drawoff is pumped to the existing centrifuge complex wetwell where it is again pumped to individual centrifuges. At the new wetwell and pump station, a portion of the digested sludge will be returned to the wetwell in the looped piping system. Therefore, although digested sludge is now pumped three times, some of the digested sludge will be subjected to additional pump mixing in comparison to the existing pumping system.

The MWRDGC requested that CTE prepare an experimental plan describing laboratory tests that will demonstrate the additional polymer demand, if any, that will occur due to additional pumping of digested sludge through the new looped piping system.

MIXING THEORY

Mixing energy imparted to a liquid is defined as the mean velocity gradient, G, which is the difference in velocity at a given distance at right angles to the direction of flow. G is a function of the power input, P, the volume of the vessel and the dynamic viscosity of the fluid. G is conveniently applied and widely accepted as a means of computing the mixing energy imparted to a fluid. The velocity gradient may be calculated from the following equation:

Equation 1: $G = [550(P)/(MV)]^{1/2}$

G = Velocity Gradient, sec^{-1}
P = Applied Horsepower, hp
V = Effective Volume, ft^3
M = Dynamic Viscosity of Fluid, $lb-sec/ft^2$ (1.67×10^{-5} at 85°F)

The power, P, imparted by a mixing device under turbulent flow conditions (Reynolds number exceeding 100,000), is defined as follows:

Equation 2: $P = \frac{K}{g_c} M' N^3 D^5 = K \rho N^3 D^5$

P = Power, ft – lb/sec

K = Constant, depending upon shape of mixing device

g_c = Newton Conversion Factor 32.17 ft – lb/sec^2 – lb

ρ = Mass density of fluid, $slug/ft^3 = M'/g_c$

N = Speed of mixer, rev/sec

D = Diameter of impeller, ft

M' = Specific weight of fluid, lb/ft^3 (62.17 at 85°F)

The pumps to be installed at the new pumping station have a 125 horsepower motor. The G value can then be calculated directly from Equation 1, since the volume of the pump casing is about 11.1 ft^3. The G value for the new pump station is 19,258sec^{-1}.

In order to characterize the mixing energy imparted to liquids for various mixing times, the value of G is multiplied by the mixing detention time (T, seconds) to produce the dimensionless constant GT. For the new pump station, the detention time of digested sludge in the pump casing is about 3.3 seconds, at a flow of 1,500 gpm. Therefore, the GT value for the pump station is about 63,551.

LABORATORY EXPERIMENTS

For many years, the MWRDGC's Research & Development (R & D) Department has used the measurement of capillary suction time (CST) to determine in the laboratory the polymer dosages for the existing centrifuge complex. The measurement of (CST) is a very simple way to determine the sludge dewatering characteristics and the dosage effects of conditioning agents. CST tests are much quicker to perform than Buchner funnel tests. The instrument used to measure CST consists of a hollow stainless steel well (1 cm in diameter and about 4 cm in height) which serves as a sludge reservoir resting on a filter paper. The filter paper and the sludge holding well rest on a plastic base, which is equipped with two electrodes. When a sludge sample is poured into the reservoir, filtrate is drawn out of the sludge and moves outward as it saturates the filter paper.

When the filtrate reaches the first electrode mounted on the plastic base touching the filter paper, a timer is started. When the filtrate reaches the second electrode touching the paper, the timer stops. The time interval that the filtrate takes to travel the distance (10 mm) between the two electrodes is called CST. The filter paper services as both a filter medium and a filtrate volume container.

In effect, the CST apparatus is a type of miniaturized Buchner funnel filtration apparatus, where the time to filter a constant volume (into a graduated cylinder) is measured. In the case of the CST apparatus, the time to filter a constant volume (in the pores of the filter paper between the electrodes) is measured.

As in the Buchner funnel tests, the conditioner dosage may be varied and the CST measured at each dose. The CST versus the conditioner dosage may then be plotted to find the optimum dosage, and the conditioners may be ranked according to the CST noted at their optimum dosages. A conditioner that yields the lowest CST valves indicates the optimal dose.

The CST measurement can be used to determine the polymer dosage requirement for a particular sludge. Various polymer dosages are applied to the sludge until a CST of 10 to 15 seconds is reached. The MWRDGC R&D Department has found that sludge being fed to the existing centrifuges is at an optimal dewatering condition at a CST of 10 to 15 seconds with appropriate mixing/stirring protocol and appropriate sample size. Therefore, the CST test can be used in a similar way as the Buchner Funnel test to determine the polymer dose needed to effectively condition sludge for proper dewatering.

CST test procedures were used to determine the polymer dose requirements for digested sludge subjected to various mixing energy and detention times (GT values). A small laboratory mixer was used to simulate various GT values.

MIXING RATE AND TIME FOR LABORATORY MIXING SYSTEM

Using Equation 2, the power applied by a laboratory mixer was calculated under the following conditions:

Impeller Diameter = 2 inches

K = 1.0

n = 500 rpm

The G value was then calculated based upon Equation 1 and the mixing of 200 ml of sludge. The G value is 1,115/sec. In order to provide a GT value of 63,551(the GT value for the new pump station), a mixing time of 57 seconds would be required for the laboratory mixer.

LABORATORY PROCEDURE

Treatment dosage curves were determined (CST vs. volume of 12% polymer solution to flocculate 200 mL of sludge) for sludges premixed prior to flocculation (at 500 rpm) for 15, 30, 60, 90, and 120 secs. Three different polymer dosages were tested for each premixing time. A blank dosage curve was also determined for sludge that was not premixed prior to flocculation with aliquots of polymer solution. Thus, five treatment dosage curves for premixed sludge and one blank dosage curve for the unmixed sludge were determined on separate days, with a new sludge being used each day, and with each point (polymer dosage) defining a given curve replicated four times (for a total of 12 values for each curve). The data for all dosage curves was taken so as to straddle a CST of 10 to 15 seconds, which was the performance criterion chosen to estimate polymer dosage at the centrifuges. The action sequent for obtaining a data point which is used to define a treatment dosage curve is as follows:

1. Measure 200 mL of anaerobically digested sludge.
2. Premix the sludge at 500 rpm for 15, 30, 60, 90, or 120 secs.
3. Add a volume aliquot of 12% polymer solution to the sludge and mix by hand to flocculate the sludge.

4. Mix the sludge at 500 rpm for 120 secs.

5. Obtain the CST measurement.

The action sequence for obtaining a data point which is used to define a blank dosage curve is the same, but the premixing is excluded.

SLUDGE SAMPLES

Digested sludge for the laboratory tests was taken from the discharge from the existing pump station at the centrifuge complex. Therefore, all sludge samples were subjected to the mixing energy of the existing pump station.

POLYMER USED

The Stickney WRP employs two polymers used at two separate times of the year. Two different polymers are used because the dewatering characteristics of the centrifuge feed sludge differs significantly from summer to winter seasons. Sludge samples taken during the winter (February 1999) and summer (September, 1998) were used for the CST laboratory tests. The polymer used for these tests are those that were routinely used in 1998 and 1999 at the existing full scale centrifuge.

For the winter polymer, dosages were determined at a CST of 15 seconds. For the summer polymer dosages were determined for a CST of 10 seconds. This was done based upon the CST each polymer was capable of achieving for the sludge being dosed. It simply was not possible to consistently produce a CST less than 15 seconds for the winter sludge using the winter polymer. The summer polymer, however, was capable of producing a CST of 10 seconds for summer sludge.

DATA ANALYSIS

All dosage curves were linearized by fitting the data to the following model using a least squares algorithm for parameter estimation:

Equation 3: $$\mathrm{Log}_{10}(CST) = K_1 + K2\,(ML)^N$$

Where, CST = Capillary suction time (secs)

ML = Volume of polymer solution (mL)

K_1, K_2, N are fitting parameters

Each of the equations was solved for the volume of polymer solution (mL) when CST was set equal to 10 seconds (summer polymer) or 15 seconds (winter polymer). Then values of polymer dosage were calculated from these polymer volumes as pounds of wet polymer per tone of dry sludge solids (lbs/ton). The dosages were calculated as follows:

Equation 4:
$$\text{lbs/ton} = \frac{(ML_p)(\%P)2000}{(ML_s)(\%S)}$$

Where, ML_p = Volume of polymer solution (mL)

%P = Percent concentration of polymer (12%)

ML_s = Volume of sludge (200 mL)

%S = Percent concentration of sludge solids

For the data in a given day with a given sludge, five dose differences were obtained by subtracting the blank dosage from the five treatment dosages; and five dose percent differences were obtained using the blank polymer dose as the base for the calculation.

In order to determine statistical significance of the calculated dose differences, the Johnson-Neyman technique was applied to the models. This technique was specifically used to determine if there was a statistically significant difference between the model that represents the blank and the model that represents one of five treatments given to a sludge on a given day. The technique does not assume that the models being compared have equal slopes, but instead establishes regions of significant difference and regions of non-significant difference (at a specific probability level) based on the values of a covariate, which is the independent variable in the models. The Johnson-Neyman technique may be considered as an enhancement, extension, and generalization of the analysis of covariance, for a point of reference to more familiar techniques.

RESULTS FOR THE SUMMER POLYMER

The experimental data collected on four separate dates with four different sludges is presented in Table 1 (See Table 1, Experimental Data Collected for Summer Polymer). This table displays the volume of 12% polymer solution used to flocculate 200 mL of sludge along with the resultant CST values arising form the blank and the five premixing treatments, obtained on the four days. Table 2 (See Table 2, Centrifuge Feed Sludge Characteristics Used in Summer Polymer Testing), summarizes the centrifuge feed sludge characteristics. The sludge percent total solids concentrations for the four days in sequence were 4.57%, 4.20%, 4.23%, and 4.23%, respectively.

The summary of results obtained from the data collected over four days is presented in Table 3 (See Table 3, Summary of Results Summer Polymer). This table displays the polymer dosage obtained from the models. The dose differences are obtained by subtracting the blank dosage from the five treatment dosages (in a given day), the dose percent differences using the blank polymer dose as a base, and the statistical significance of the dose differences at the 95% confidence level. The statistical significance is denoted as "NS" (for non-significant) or "S" (for significant). When a dose difference is labeled "NS", it is not significantly different from zero; and when it is labels "S", it is significantly different from zero.

RESULTS FOR THE WINTER POLYMER

Table 4 (See Table 4, Experimental Data Collected for Winter Polymer), shows the experimental data collected on four separate days with four difference sludges. This table displays the volume of 15% polymer solution used to flocculate 200 mL of sludge along with the resultant CST values arising from the blank and the five premixing treatments, obtained on the four days. Table 5 (See Table 5, Centrifuge Feed Characteristics Used in Winter Polymer Testing) summarizes the centrifuge feed sludge characteristics. The sludge percent total solids concentrations for the four days in sequence were 4.21%, 4.21%, 3.97%, and 3.89%, respectively.

The results obtained from the data collected over four days is summarized in Table 6 (See Table 6, Summary of Results Winter Polymer). This table displays the polymer dosages obtained from the models, the dose differences obtained by subtracting the blank dosage from the five treatment dosages (in a given day), the dose percent differences using the blank polymer dose as a base, and the statistical significance of the dose differences at the 0.05 probability level. The statistical significance is denoted as "NS" (for non-significant) or "S" (for significant). When a dose difference is labeled "NS", it is not significantly different from zero. When it is labeled "S", it is significantly different from zero. Unlike the case with summer sludge where some of the dose differences were significantly different from zero, none of the dose differences with winter sludge are significantly different from zero.

CONCLUSIONS SUMMER POLYMER

The 15 secs. and 30 secs. premixing treatments are not significantly different from zero in polymer dose response, in all cases. The 120 secs. premixing treatment is significantly different from zero in polymer dose response, in all cases. The 90 secs. premixing treatment is significantly different from zero in polymer dose response, in three out of four cases; and the 60 secs. premixing treatment is significantly different from zero in polymer dose response, in two out of four cases.

Substituting zero values for dose differences that are not significantly different from zero and averaging over the four days provides the following data reduction summary:

Pretreatment Mixing	Dose Difference (lbs/ton)	Dose Difference (percent)
15 secs. Mix	0.0	0.0
30 secs Mix	0.0	0.0
60 secs Mix	2.8	0.9
90 secs Mi[illegible]	6.5	2.1
120 secs Mix	[illegible].7	3.7

The product of mixing energy and mixing detention times (GT value) corresponding to the full-scale additional sludge pumping is equivalent to the 60 secs. premixing treatment. Thus, greater attention may be placed on this case. As a point of reference, previous experience indicates that the 95% confidence limits for polymer dosages from full-scale polymer tests on centrifuges, are ± 6 lbs/ton. In this experiment, the increased polymer dosage at a 60 secs. premixing time was 2.8 lbs/ton when compared to the control. Thus, it does not seem that the 60 secs. premixing treatment, which is expected to be equivalent to the mixing energy that would be imparted to sludge due to the additional pumping through the proposed looped pipe distribution system, has any substantial impact on polymer dose.

CONCLUSIONS FOR THE WINTER POLYMER

Substituting zero values for dose differences that are not significantly different from zero and averaging over the four days provides the following data reduction summary.

Pretreatment Mixing	Dose Difference (lbs/ton)	Dose Difference (percent)
15 secs. Mix	0.0	0.0
30 secs Mix	0.0	0.0
60 secs Mix	0.0	0.0
90 secs Mix	0.0	0.0
120 secs Mix	0.0	0.0

With the winter sludge, no increase in polymer dosage was observed at any of the premixing times.

OVERALL CONCLUSION

The 60 seconds premixing treatment, which is expected to be equivalent to the mixing energy that would be imparted to sludge due to the additional pumping through the proposed looped pipe distribution system, will not have any significant adverse impact on polymer dose for either the summer or winter sludges.

The expanded centrifuge complex has been designed with a looped pipe distribution system with a recirculation return line. Construction of the facility began in May of 1999. Based upon the results of the laboratory tests described here, the pipe loop system should not result in increased polymer costs for the expanded centrifuge complex.

