SECOND QUICKLIME TEST
03-4 BALLING CIRCUIT
NOVEMBER 1994

Plant Demonstration Test
at Minntac
Using Pebble Lime

COLERAINE MINERALS RESEARCH LABORATORY

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Forward

This was the second of two tests run on the 03-4 balling circuit using quicklime as both binding and fluxing agent. The first test was run in May 1994. During that test, operators were not able to make acceptable quality green balls by mixing the quicklime and concentrate and feeding them directly into the circuit. However, they were able to make acceptable quality during that test by mixing batches of the material and allowing it to sit before feeding it to the circuit. Unfortunately, this method is difficult to accomplish during normal plant operation and other methods of producing the desired quality were investigated. Pilot plant tests were run during the May test and indicated that quality could be produced when the material was mixed for 1 minute before being fed to the balling circuit. The mixer on the 03-4 circuit was then modified to do this and the second test was run.

Summary of Results

There were two main goals to the second test; to determine the long term operability of balling circuits using quicklime and to produce green balls equal in quality to those produced using bentonite without allowing the mixed material to sit before balling. Modifications were made to the 03-4 circuit after the May test in order to achieve both of the above and this test was run from November 8 through November 12, 1994. A summary of the results is given below:

The test was a success for two reasons. The 03-4 circuit ran smoothly for 4 days using quicklime instead of bentonite. And, because the circuit ran smoothly, a lot of useful and meaningful data was collected and evaluated.

The test was completed safely. There were no incidents or accidents reported during the preparation for or during the test. Levels of ammonia and fugitive dust were monitored during the test and found to be lower than during the May test. The levels detected in both tests were well below MSHA requirements.

The green ball quality achieved during this test was higher than that achieved during the May test but below desired levels. However, this test, the May test and pilot plant tests all indicate that acceptable quality green balls can be produced using quicklime under the right conditions. Good quality green balls were produced during the May test when the mixed materials were allowed to sit after being mixed, during pilot plant tests when the materials were mixed for 1 minute and during this test when the mixing time exceeded 110 seconds.

There were no unloading or handling problems during the test despite the fact that the pulverized quicklime was contaminated with pebble sized chunks. The supplier, Marblehead Lime Company, indicated that the chunks represented contamination from loading bins at their plant.

The fired pellet quality on the entire line dropped during both tests despite the fact that quicklime was being used on only one of the four circuits on the line. This appears to be indirectly related to the use of quicklime. It appeared that, during the tests, quicklime reacted with the water in the bentonite and negatively affected the water absorbing properties of the bentonite. The circuits using the contaminated bentonite then produced poorer quality green balls than the circuit using quicklime. The slightly lower quality green balls produced using quicklime combined with the significantly lower quality green balls made with contaminated bentonite and resulted in lower quality fired pellets. This was suspected in the May test and verified during this test.

Background

Data from the first test and from pilot plant testing indicated there were two ways acceptable quality green balls could be produced - both involved pushing the hydration reaction closer to completion. Quicklime is a mixture of CaO and MgO. When it is mixed with filter cake a chemical hydration reaction takes place between the quicklime and the water in the filter cake as shown below:

$$CaO + H_2O \;{----}{>}\; Ca(OH)_2 + heat$$

$$MgO + H_2O \;{----}{>}\; Mg(OH)_2 + heat$$

The first test indicated that this reaction was still occurring in the balling drum. It was theorized that if the reaction could be completed before the mixed material entered the balling drum, quality green balls could be produced. This could be done by either allowing the material to sit after it had been mixed or by mixing it longer. Both methods were tried during the May test. Acceptable quality green balls were produced when the material was allowed to sit but not when the mixing time was increased.

However it should be noted that, during the May test only slight increases in mixing time were achieved. The mixing times in the beginning of the May test averaged 17 seconds. After initial attempts to produce good quality green balls in the plant failed (at 17 seconds), a stationary gate was placed on the discharge of the Littleford mixer. This increased the mixing time to 23 seconds. The result was a slight improvement in green ball quality. Data from the pilot plant testing was reviewed and showed that quality green balls were produced with mixing times of approximately 1 minute in the pilot plant.

Discussions were held with Littleford engineers who felt that the plant mixer could be modified to give mixing times in excess of 1 minute but the modifications required several days to make. It was decided not to do this during the May test. Instead, it was decided to produce batches of mixed quicklime and concentrate. The quicklime and concentrate were allowed to sit after they were mixed and before they were added to the balling drum. These batch tests yielded green balls equal in quality to those produced using bentonite. Temperature measurements indicated the hydration reaction had progressed to near completion.

At this point, the direction for further testing had to be established. Should the Littleford mixer be modified to achieved more mixing time or should a full line test be run using central mixing? By using central mixing during a line test, the material could be allowed to sit before balling - similar to what was done during the batch tests. A minimum of 30 minutes and possibly up to 2 hours sitting time could be achieved without changing the plant flow sheet. However, the installation of central mixing was estimated to cost in excess of $1,000,000. When it was estimated the Minntac Littleford mixer could be modified to yield the desired 1 minute mixing time for less than $10,000, it was decided to modify the mixer and run a second single balling circuit test at higher mixing times.

Pre Test Preparation

Increasing the mixing time in the plant Littleford mixer was more difficult than anticipated. Retaining plows were purchased and installed and a sliding gate was installed on the discharge chute to replace the stationary gate installed in May. The sliding gate was adjusted until the desired mixing time was achieved. However, review of the data taken to determine the proper gate setting indicated other problems. When the gate was closed far enough to give desired mixing times, more power was required than the mixer motor was capable of producing. In addition, the power draw on the motor was cyclical in nature. It appeared the mixer was filling up and then releasing its contents. This resulted in variations in mixing times and caused the power draw on the motor to cycle.

To correct the high power draw problem, a larger motor was installed on the mixer. A 200 HP motor was installed replacing the existing 150 HP one. The 200 HP motor was capable of supplying the necessary energy but the power draw continued to cycle. Several attempts were then made to reduce the cycling; different water addition rates were tried, the shape of the discharge opening was changed, a vibrator was attached to the slide gate and finally a scraper type plow was attached to the shaft of the mixer. None the above modifications significantly improved the cycling of the power.

Rather than continue to work on solving the power cycling problem, it was then decided to run the test with the mixer as it was - with the power cycling - so that the minimum mixing time would be 1 minute. The disadvantage of this was that the mixing time varied. At a given gate setting, mixing times varied by almost a minute. Operating at a minimum of 1 minute mixing time yielded a range of mixing times from one to two minutes. It was decided to take advantage of the situation and collect data to calculate the mixing times at the time samples were taken. This way the quality could be evaluated at different mixing times.

Other pre-test preparation focused on eliminating as many of the areas recognized for improvement during the first test as possible. One of the main concerns was the operation of the lime feeder, a weigh auger type. This type of feeder is equipped with a pre-auger which did not have enough power to keep the lime flowing smoothly and plugged frequently (once per hour or more). When discussions with the manufacturer indicated that the feeder could not be modified to eliminate the plugging (by adding more power to the pre-auger), it was decided to try a weigh belt type feeder. This feeder used a rotary valve on the inlet instead of a pre-auger. The performance of this feeder during the second test was excellent. It only plugged twice during the four days of testing and both of the incidents were caused by pebble sized particles (contaminants) jamming in the rotary valve.

Another area recognized for improvement was contamination of the bentonite by the lime. There were two problems associated with this. There were indications that, when bentonite and lime came in contact each other, ammonia was given off. This posed a potential safety problem. It also appeared that the reactivity of the bentonite was reduced when it was exposed to small amounts of lime. This caused the quality of the green balls produced using the contaminated bentonite to be significantly reduced

The contamination occurred two ways, through the dust collection system and from bin to bin. The high bin protection on the 03-4 bentonite day bin failed during the first test. This caused the bin, being used for lime, to overflow and spill lime into adjacent day bins which were being used for bentonite. There was also contamination of the bentonite through the dust collection system. Lime dust was pulled into the dust collector which discharged back into the 03-2 bentonite day bin.. For the second test, the high bin protection was repaired and care was taken to reduce the contamination as much as possible.

Testing and Results

Quicklime was received at Minntac on November 7, 1994 and was dumped without any problems. The test began November 8 and lasted for four days. During the test, there were no injuries, accidents or incidents reported.

During this test, as during the first test, Minntac's industrial hygienist sampled fugitive dust for MgO and CaO and the air for ammonia (NH_3). A copy of her report is attached. Fugitive concentrations of MgO and CaO were less than 5% of MSHA allowable while ammonia was found at less that 2% of the allowable. The ammonia levels were significantly lower than those from the first test which were 9.2% of allowable. It is theorized that the lower ammonia levels were a result of the reduction in bentonite contamination.

One of the primary goals of the second test was to produce quality green balls. To evaluate the green ball quality during this test a variety of comparisons were made. Six different comparisons and the reason they were made are described below:

03-4 vs. 04-1 circuit - to compare the quality of green balls produced using lime to the quality of green balls produced using bentonite.

May vs. November test results - to determine if changes in the quality produced on the 03-4 circuit resulted from factors other than the modifications to the mixer. Changes in ore would be an example. This would show up as changes in both the 03-4 and 04-1 green ball quality.

Lime addition vs. green ball quality - to determine if the quality of the green balls produced during the test was affected by differences in lime addition.

Mixing time vs. green ball quality - to determine if the quality of the green balls produced during the test, using quicklime, was affected by differences in mixing times.

03-4 vs. 03-1, 03-2, and 03-3 circuits - to determine the effect of lime contamination on the circuits using bentonite. This would be further related to fired pellet quality.

03-4 circuit during test vs. 03-4 circuit after test - to compare the quality of green balls produced using lime during the test to those normally produced on the 03-4 circuit using bentonite. The data would also indicate the affect of the lime on green ball size.

Each of the above comparisons is discussed in further detail below.

03-4 vs. 04-1 circuit - Because of the anticipated effect of the lime contaminating the bentonite in the other circuits on line 3, the 04-1 circuit was chosen as the control circuit for this test. During the test, the drops from the green balls produced with quicklime on the 03-4 circuit were lower, the wet compression values were equal and the dry compression values were lower than those produced using bentonite on the 04-1 circuit. Of the above values, the dry compression is the most related to the addition of quicklime since both drops and wet compressions are affected by moisture. The data is given in Table #1 and the comparison is summarized below:

	% lime	mix time secs.	table feeder moist	green ball moist	Drops	wet comp	dry comp
03-4(lime)	4.27	98	9.3	8.6	3.21	1.93	3.60
04-1(bento)	0.00	NA	9.7	9.6	4.82	1.92	6.30

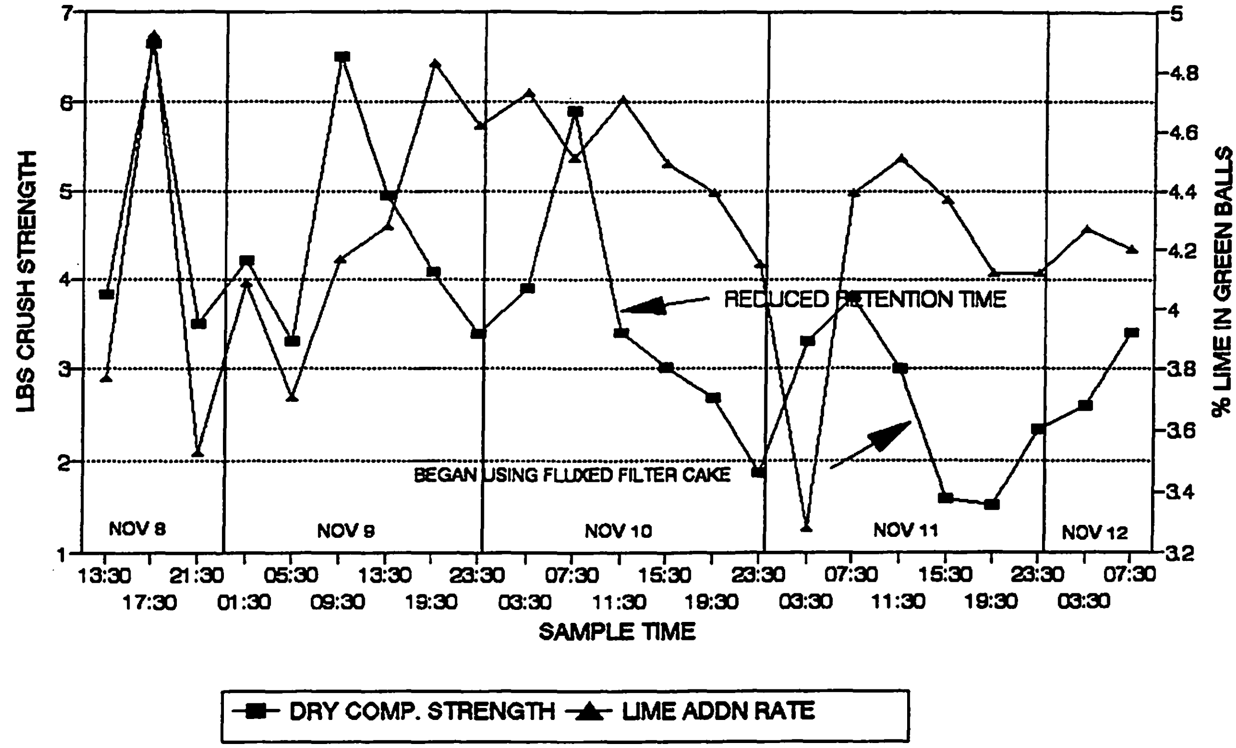
May vs. November test results - When the green ball quality from this test is compared to the green ball quality from the May test, a significant improvement is noted in the dry compression values of the green balls produced using quicklime while the wet compression and drop values remained the same. Because green balls were produced several different ways in May, the data used from that test is the data collected when the mixed material was fed directly from the mixer to the balling drum. The comparison is summarized below:

	% lime	mix time secs.	table feeder moist	green ball moist	Drops	wet comp	dry comp
Nov. test	4.27	98	9.3	8.6	3.21	1.93	3.60
May test	4.00	20	9.4	8.2	3.70	2.80	1.68
Change	.27	78	-.1	.4	-.49	-.87	1.92

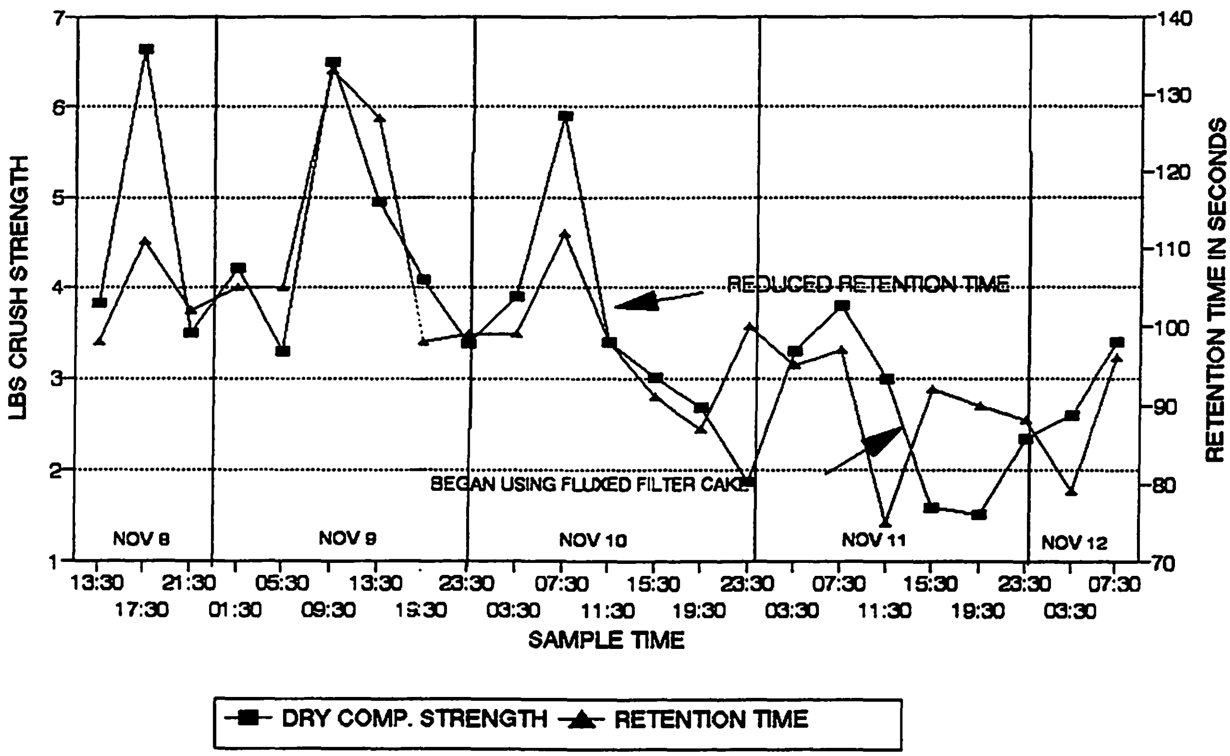
Lime Addition Rate vs. green ball quality - One item cited as possibly causing poor quality green ball production during the first test was insufficient lime addition. Problems with the lime feeder prevented operators from achieving a consistent level of lime in the green balls. During the second test the lime addition rate was higher and more consistent. However, there was still some variability in the second test which allowed a comparison to be made. Graph #1 shows the dry compression strengths and the lime addition rate. The two trend together for the first six samples but after that there appears to be little or no correlation.

Mixing time vs. green ball quality - The reason for the improvement in dry compression strength from the May test was determined to be increased mixing time. Mixing time in the May test was relatively constant at 17 seconds. During this test the mixing time was significantly longer but more variable. A minimum of 60 seconds was the goal. An average of 98 seconds and a minimum of 70 seconds were actually achieved. In addition, mixing times of 130 seconds were calculated during some sampling times. During the test, data was collected to calculate the mixing times at the time the samples were taken. Graph #2 shows the dry compression strengths and retention (mixing) times. Note that when the retention time exceeded 110 seconds, the dry compression strengths average over 6.0, comparable to the 04-1 circuit.

GRAPH #1
DRY COMP. STRENGTH VS LIME ADDITION



GRAPH #2
DRY COMP. STRENGTH VS RETENTION TIME



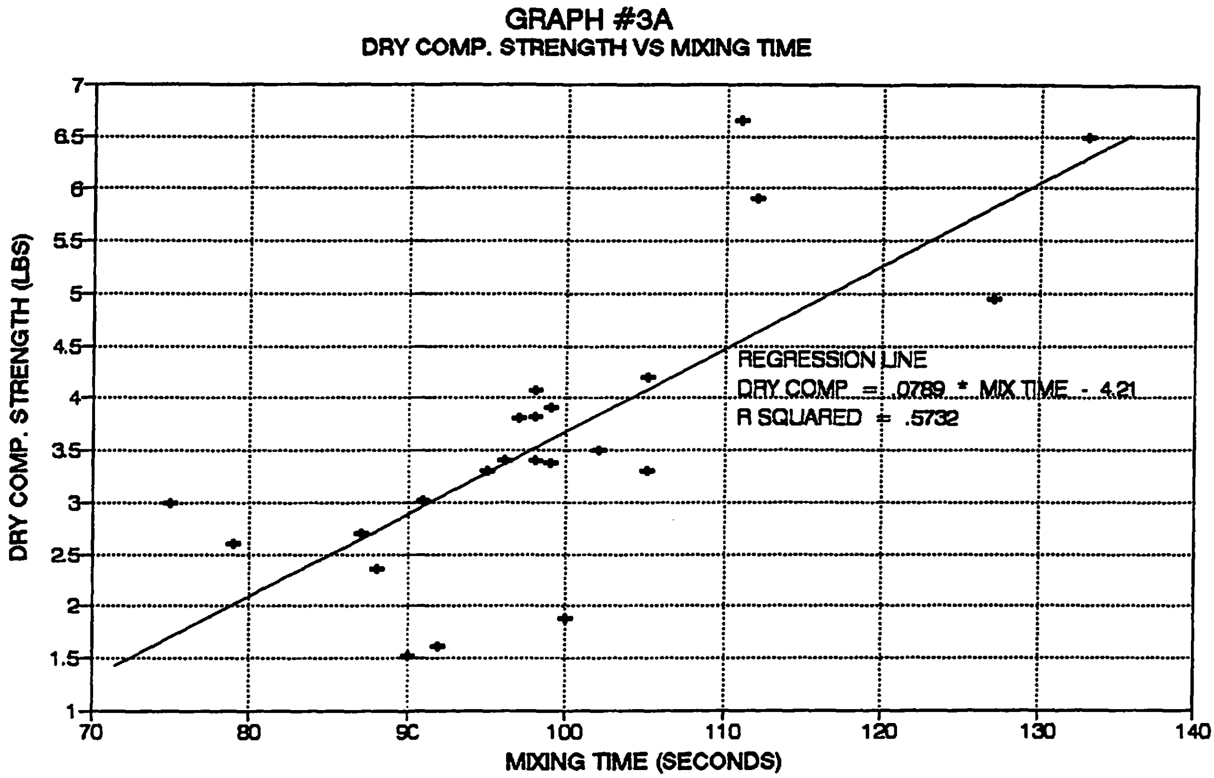
Unfortunately it was not possible to operate the mixer at the same gate setting the entire test. On November 10, an operator noticed the gear reducer and coupling on the mixer were overheating and it was necessary to open the discharge gate and reduce the load on the mixer to keep them cool. This caused a drop in mixing time (retention time inside the mixer). There was a corresponding drop in the dry compression strength when this was done. The time the change is noted on graphs #1 and #2. A comparison of data from November 8 through November 10, when the mixing time was reduced with data from that point on is shown below:

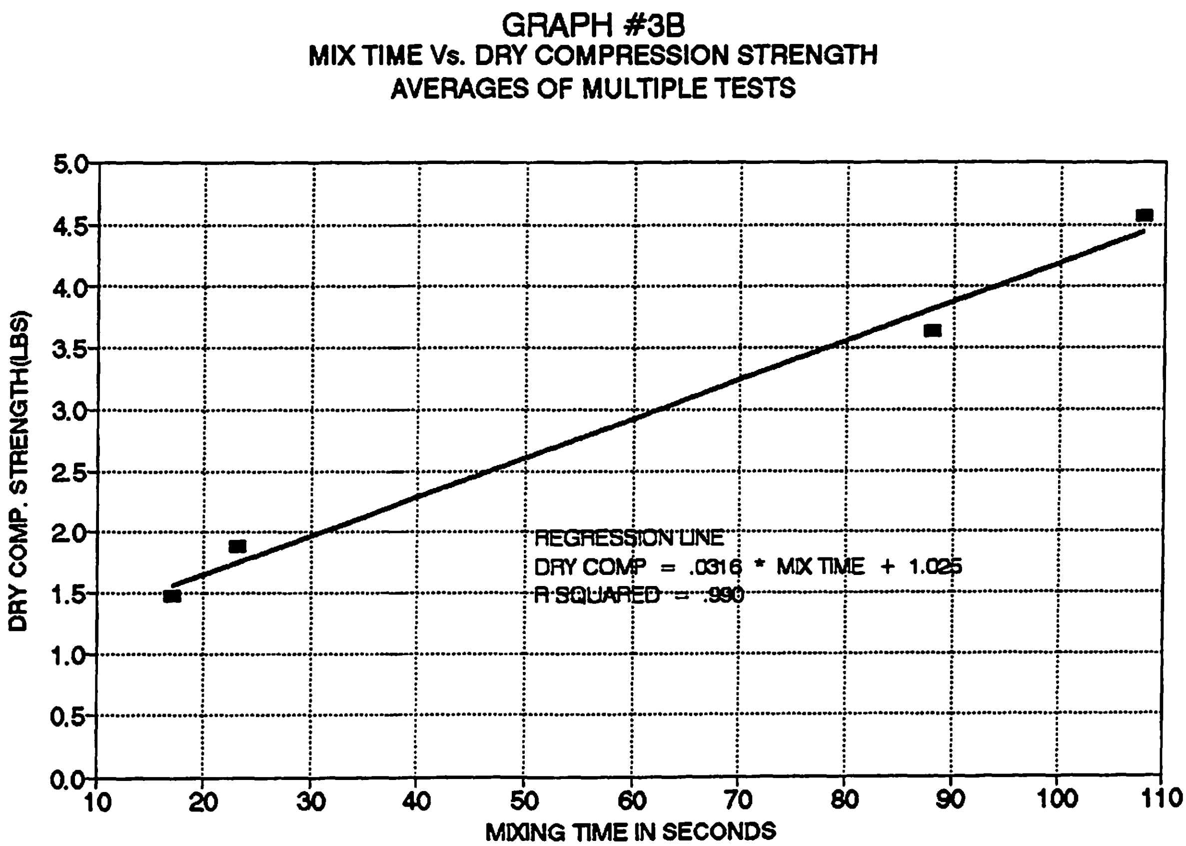
Date	% lime	mix time secs.	table feeder moist	green ball moist	Drops	wet comp	dry comp
Nov. 8-10	4.29	108	9.2	8.6	3.65	2.11	4.56
Nov. 10-12	4.27	89	9.3	8.6	3.23	1.94	3.64
Change	.02	19	-.1	0.0	.42	.17	.92

It can be seen in the above data, that all aspects of green ball quality dropped when the mixing time was reduced. Graph #2 indicates a strong correlation between mixing time and dry compression strength. This relationship is examined further in Graphs #3A and 3B. In Graph #3A, data from the second test is plotted. The coefficient of correlation (R^2) for the data is .57. This is a fairly high value for raw plant data. In Graph #3B, averages of two time periods in the May test are plotted with averages from two periods in the November test. The R^2 for this data is .99.

03-4 vs. 03-1, 03-2, and 03-3 circuits - The first test indicated that when lime came in contact with the bentonite, the reactivity of the bentonite was significantly reduced. To test this, various samples were taken from the 03-1, 03-2 and 03-3 circuits during this test. The 03-3 circuit was sampled five times while the 03-2 and 03-1 circuits were each sampled twice. Test results from these samples showed that when there was lime contamination of the bentonite, the green balls produced with contaminated bentonite were weaker than those produced with quicklime. The data from the 03-3 circuit is compared to all the data from the 03-4 circuit below:

	table feeder moist	green ball moist	Drops	wet comp	dry comp
03-4 circuit (lime)	9.3	8.6	3.21	1.93	3.60
03-3 circuit (contaminated bento)	9.6	9.8	3.34	1.32	1.28
Difference	-.3	-.8	.13	-.61	-2.32


GRAPH #3A
DRY COMP. STRENGTH VS MIXING TIME
REGRESSION LINE
DRY COMP = .0789 * MIX TIME - 4.21
R SQUARED = .5732
DRY COMP. STRENGTH (LBS)
MIXING TIME (SECONDS)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
70
80
90
100
110
120
130
140


GRAPH #3B
MIX TIME Vs. DRY COMPRESSION STRENGTH
AVERAGES OF MULTIPLE TESTS
REGRESSION LINE
DRY COMP = .0316 * MIX TIME + 1.025
R SQUARED = .990
DRY COMP. STRENGTH(LBS)
MIXING TIME IN SECONDS
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
50
60
70
80
90
100
110

03-4 circuit during the test vs, the 03-3 and 03-4 circuits after the test- Samples were taken from the 03-3 and 03-4 balling circuits November 14 through 16. This was after the quicklime had been used up and both circuits used bentonite as binder and mixed with Pekay mixers. There were two purposes to this sampling. The first was to see what kind of quality these two circuits normally produce using bentonite since Line 3 is unique among the lines. The second purpose was to compare the size of the green balls produced using bentonite against the size of the green balls produced using lime. The comparison of green balls produced on 03-4 circuit with lime mixed in the Littleford mixer is compared to green balls produced with bentonite mixed in the Pekay mixer below:

	% $+\frac{1}{2}$"	Drops	wet comp	dry comp
03-4 circuit with lime (Littleford)	8.9	3.21	1.93	3.60
03-4 circuit with bentonite (Pekay)	4.0	4.40	1.97	5.46
Difference	4.9	-1.19	-.04	-1.86

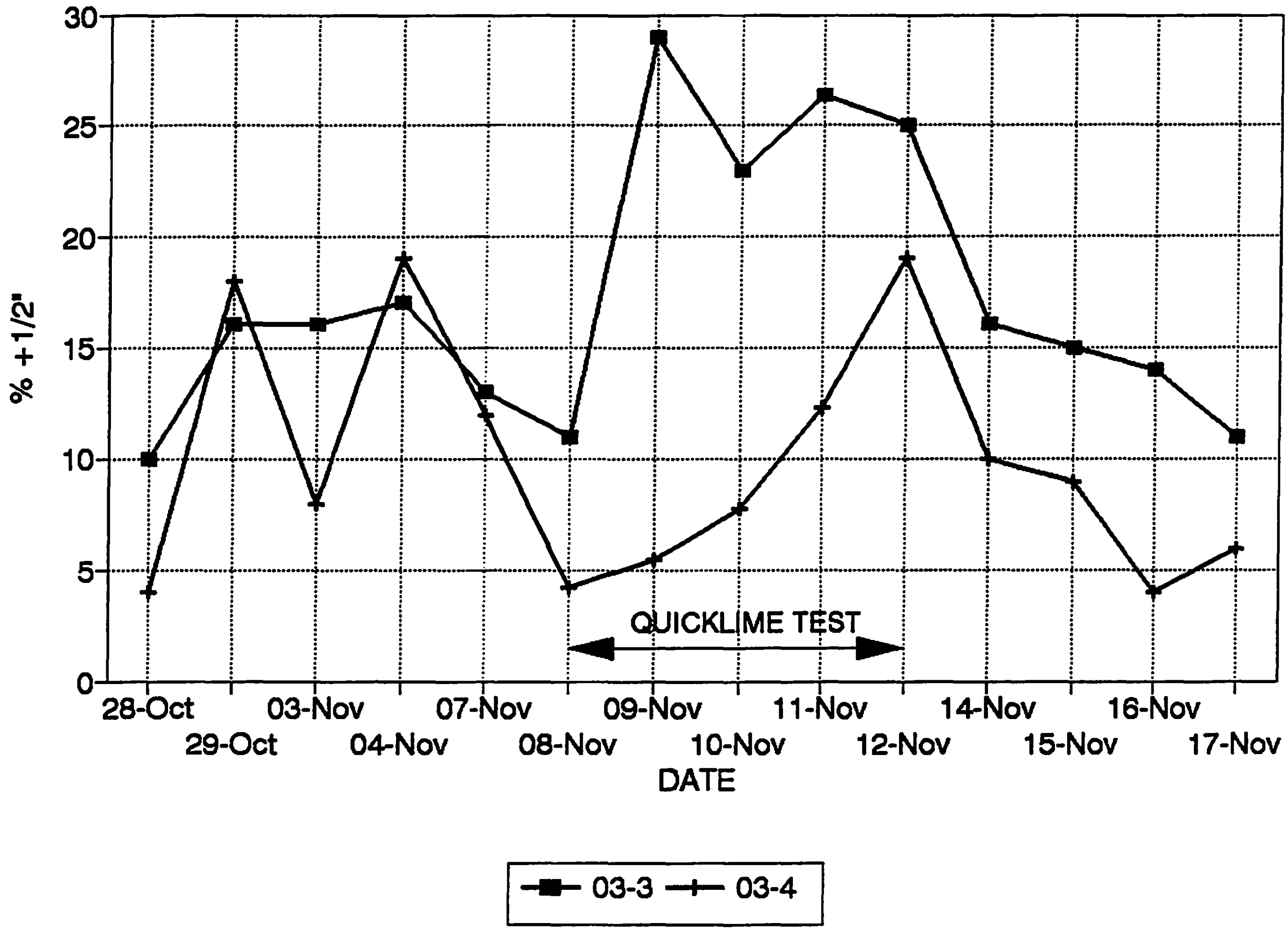
The comparison above is misleading relative to size distribution in that it indicates the ball size increased while using quicklime. Graph #4 shows the change in the +1/2" size distribution on the 03-3 and 03-4 circuits before, during and after the quicklime test. While the 03-4 +1/2" size distribution increased during the test, the increase was significantly less than what occurred the 03-3 circuit. Although not shown graphically, the size of the green balls on all the balling circuits on lines 3, 4 and 5 increased significantly more than on the 03-4. This indicates, as noted in the May test, that the use of quicklime actually decreases green ball size.

Operability of the circuit - The other major goal of this test was to determine the long term operability of a balling circuit using quicklime instead of bentonite. Specifically, could high operating times be achieved and could the circuit be controlled during upsets? This increased the operating time to acceptable levels.

The operability of the circuit was excellent during the test. Problems with erratic lime feed were solved by replacing the weigh auger feeder with a weigh belt feeder. There were only two short delays related to the use of the quicklime and both of them were caused by the chunks in the lime.

Generally operators were able to control the circuit. The drum "looked" good during the entire four days. Most of the time, the circuit looked like it was balling better than the circuits on the other lines at Step 1/2. There were several upsets during the test, but operators were able to recover from them fairly easily.

GRAPH #4
GREENBALL SIZE COMPARISON



Conclusions and Recommendations

The test was a success from two important standpoints. Good operability of the circuit was established during the test. This was considered critical and operators had not been able to accomplish it in the May test because of mechanical problems. Because the operation of the circuit was smooth it was possible to collect meaningful and useful data.

Both of the first two single circuits indicated that quicklime will work as both binding and fluxing agent under the right conditions. Quality green balls can be produced using quicklime two different ways. The quicklime and concentrate can be allowed to sit for 2 hours after they are mixed as during the May test, or the quicklime and concentrate can be mixed for 110 seconds as during the November test. When either of these conditions were present, the green ball quality produced using the quicklime was similar to that produced using bentonite.

During this test it was determined that low fired pellet quality resulted from lime contamination of bentonite. This occurred during both tests on the 03-4 circuit. The contamination decreased the reactivity of the bentonite and caused the quality of the green balls produced using contaminated bentonite to drop below that of the green balls produced using lime. This caused the fired pellet quality on the entire line to drop significantly.

To prevent the quicklime from contaminating the bentonite it will be necessary to run a complete line test (all drums). Central mixing would be the best way to do this. With central mixing, the mixed material would sit in the bins after it had been mixed. The sitting time in this situation might significantly affect the amount of time the materials have to be mixed. If less mixing time is required, the size of mixers and motors required to operate the lines would be reduced. Because of this, it is recommended that a test be done using central mixing on an entire line as soon as possible.

Acknowledgments

Both single circuit quicklime tests have been cooperative efforts between Coleraine Minerals Research Lab and Minntac. The Littleford was installed by the Minntac maintenance and E & I departments. CMRL provided technical assistance, pilot plant testing before, during and after the test, and special testing during the test. The comparison testing at Minntac was done by Minntac laboratory personnel with supervision and technical assistance by the Agglomerator metallurgy department. Synertec provided financial and technical support. Marblehead Lime Company and Littleford provided technical support.

TABLE 1
NOVEMBER QUICKLIME TEST
BALLING – PHYSICAL DATA

		03–4 Circuit							04–1 Circuit					03–3 Circuit				
		Moisture			Wet	Dry	Mix	Addn	Moisture			Wet	Dry	Moisture			Wet	Dry
Date	Time	T. F.	G.B.	Drops	Comp	Comp	time	Rate	T. F.	G.B.	Drops	Comp	Comp	T. F.	G.B.	Drops	Comp	Comp
08–Nov	13:30	9.0	9.0	5.3	2.75	3.82	98	3.77	9.5	9.4	5.0	2.25	7.22					
	17:30	8.9	8.1	3.8	2.10	6.65	111	4.92	9.6	9.4	4.6	1.92	6.28					
	21:30	9.4	8.9	3.4	1.68	3.50	102	3.53	9.7	9.7	6.1	2.05	5.45					
09–Nov	01:30	9.0	8.4	3.0	1.95	4.20	105	4.09	9.5	9.6	5.2	2.08	7.60					
	05:30	9.1	8.6	4.0	2.60	3.30	105	3.71	9.6	9.5	4.3	1.90	6.00					
	09:30	8.9	8.6	3.9	2.10	6.50	133	4.17	9.7	9.8	4.5	2.00	5.70					
	13:30	9.7	8.7	3.3	1.80	4.95	127	4.28	9.7	9.6	4.3	2.00	5.40					
	19:30	9.4	8.4	3.2	1.88	4.08	98	4.83	9.5	9.8	7.0	1.88	7.12					
	23:30	9.4	9.1	3.8	2.02	3.38	99	4.62	9.6	9.6	4.7	1.88	6.45					
10–Nov	03:30	9.1	9.0	3.6	2.20	3.90	99	4.73	9.5	9.4	3.5	1.70	6.00					
	07:30	9.1	7.9	2.8	2.10	5.90	112	4.51	9.7	9.7	4.8	1.70	7.00					
	11:30	9.1	8.2	2.7	2.10	3.40	98	4.71	9.6	9.6	4.2	2.10	6.20					
	15:30	9.1	8.3	2.8	1.68	3.02	91	4.49	9.9	9.8	5.8	1.95	6.52					
	19:30	9.3	8.3	2.7	1.60	2.70	87	4.39	9.6	9.8	4.9	1.68	6.85					
	23:30	9.2	8.3	2.8	1.65	1.88	100	4.15	9.7	9.8	4.8	1.92	7.05					
11–Nov	03:30	9.5	9.0	2.9	1.60	3.30	95	3.28	9.9	9.6	5.2	2.10	6.40					
	07:30	9.4	8.4	2.7	2.00	3.80	97	4.39						9.3	9.4	2.9	1.60	1.40
	11:30	9.2	8.6	2.9	2.00	3.00	75	4.51						10.2	10.1	3.7	1.40	1.40
	15:30	9.2	8.5	3.1	1.92	1.6	92	4.37						9.3	10	3.7	1.18	1.22
	19:30	9.4	8.4	2.5	1.52	1.52	90	4.12						9.4	9.7	3	1.20	1.20
	23:30	9.7	8.9	3.3	1.55	2.35	88	4.12						9.6	9.8	3.4	1.22	1.20
12–Nov	03:30	9.7	8.6	2.9	1.65	2.6	79	4.27	9.7	9.7	4.2	1.65	6.8					
	07:30	9.7	8.7	2.5	2	3.4	96	4.20	9.7	9.7	3.6	1.8	3.4					
average		9.3	8.6	3.21	1.93	3.60	98	4.27	9.7	9.6	4.82	1.92	6.30	9.6	9.8	3.34	1.32	1.28

FLOPPY #52

FILENAME NOVDATA

TABLE #2
NOVEMBER QUICKLIME TEST
GREEN BALL SIZE COMPARISON

		03-3 CIRCUIT					03-4 CIRCUIT					04-1 CIRCUIT				
DATE	TIME	+5/8	+9/16	+1/2	+3/8	+1/4	+5/8	+9/16	+1/2	+3/8	+1/4	+5/8	+9/16	+1/2	+3/8	+1/4
08-Nov	13:30						1	1	2	86	99	0	1	8	88	99
	17:30						0	2	6	93	100	2	6	19	98	100
	21:30						2	3	5	91	98	1	3	11	97	99
09-Nov	01:30						0	0	3	92	98	3	6	18	97	99
	05:30						2	2	4	90	99	3	9	26	97	99
	09:30						3	3	6	91	99	4	8	21	96	100
	13:30						1	2	5	91	99	3	10	27	97	99
	19:30						0	0	3	94	99	0	3	14	95	99
	23:30						4	5	12	91	99	2	7	24	98	99
10-Nov	03:30						3	6	11	92	98	4	12	30	96	98
	07:30						1	2	10	95	98	4	8	24	96	99
	11:30						0	1	5	91	97	2	8	23	95	99
	15:30						0	2	6	92	98	1	5	2	96	99
	19:30						0	2	10	96	100	1	7	27	98	100
	23:30						0	0	5	87	98	0	3	17	98	99
11-Nov	03:30						0	2	6	89	99	3	5	15	97	99
	07:30	1	6	23	93	98	0	1	9	89	98					
	11:30	2	4	12	88	97	1	3	11	91	98					
	15:30	1	7	24	92	97	1	3	12	93	98					
	19:30	5	19	40	93	97	1	6	21	96	99					
	23:30	4	14	33	93	98	1	3	15	94	99					
12-Nov	03:30						1	3	9	86	98	3	14	35	97	99
	07:30						2	9	29	97	99	4	12	32	98	100
AVERAGES		2.6	10.0	26.4	91.8	97.4	1.0	2.7	8.9	91.6	98.6	2.2	7.1	20.7	96.3	99.2

FLOPPY #52
FILENAME NOVSIZE

TABLE 3
BALLING – PHYSICAL DATA
FOLLOWING NOVEMBER QUICKLIME TEST

		03–3 Circuit					03–4 Circuit				
		Moisture			Wet	Dry	Moisture			Wet	Dry
Date	Time	T. F.	G.B.	Drops	Comp	Comp	T. F.	G.B.	Drops	Comp	Comp
14–Nov	08:15	9.3	9.4	4.7	1.90	6.00	9.3	9.4	4.6	1.90	7.10
15–Nov	08:25	9.3	9.2	3.7	2.20	5.50	9.4	9.4	4.1	1.90	5.90
16–Nov	08:05	9.5	9.2	3.4	1.70	2.80	9.5	9.4	4.5	2.10	3.40
AVERAGE		9.4	9.3	3.9	1.93	4.77	9.4	9.4	4.4	1.97	5.47

FLOPPY #52
FILENAME NOVDATA

TABLE 4
NOVEMBER QUICKLIME TEST
CHEMICAL DATA

		03-3 Circuit TABLE FEEDER				03-3 Circuit GREEN BALLS				
Date	Time	SiO2	Al2O3	CaO	MgO	SiO2	Al2O3	CaO	MgO	Addn Rate
08-Nov	13:30									
	16:10									
	17:30									
	21:30									
09-Nov	01:30									
	05:30									
	09:30									
	12:00									
	13:30									
	19:30									
	23:30									
10-Nov	03:30									
	07:30									
	11:30									
	15:30									
	19:30									
	23:30									
11-Nov	03:30									
	07:30	3.89	0.15	3.65	1.13	3.67	0.09	3.63	1.12	0.00
	11:30	3.57	0.07	2.27	0.77	3.82	0.15	2.23	0.78	0.00
	15:30	3.59	0.08	3.26	1.02	3.88	0.17	3.29	1.03	0.00
	19:30	3.56	0.07	3.45	1.05	3.76	0.13	3.45	1.09	0.00
	23:30	3.58	0.09	3.60	1.09	3.79	0.16	3.61	1.09	0.00
12-Nov	03:30									
	07:30									
average		3.64	0.09	3.25	1.01	3.78	0.14	3.24	1.02	0.00

FLOPPY #52

FILENAME CHEMDATA

TABLE 5
NOVEMBER QUICKLIME TEST
CHEMICAL DATA

		03-4 Circuit TABLE FEEDER				03-4 Circuit GREEN BALLS				Addn
Date	Time	SiO2	Al2O3	CaO	MgO	SiO2	Al2O3	CaO	MgO	Rate
08-Nov	13:30	3.68	0.05	0.86	0.41	4.43	0.29	3.55	1.11	3.77
	16:10	3.65	0.06	0.88	0.41	3.55	0.09	4.42	1.36	5.02
	17:30	3.65	0.06	0.89	0.42	3.67	0.12	4.36	1.34	4.92
	21:30	3.62	0.06	0.89	0.42	3.67	0.10	3.41	1.06	3.53
09-Nov	01:30	3.62	0.05	0.91	0.42	3.62	0.11	3.82	1.20	4.09
	05:30	3.60	0.06	0.88	0.42	3.98	0.20	3.53	1.11	3.71
	09:30	3.59	0.06	0.89	0.42	3.55	0.08	3.85	1.22	4.17
	12:00	3.67	0.07	0.91	0.44	3.59	0.09	4.21	1.32	4.67
	13:30	3.65	0.07	0.92	0.44	3.60	0.09	3.96	1.25	4.28
	19:30	3.64	0.07	0.95	0.44	3.55	0.09	4.36	1.35	4.83
	23:30	3.65	0.07	0.97	0.45	3.57	0.09	4.24	1.31	4.62
10-Nov	03:30	3.68	0.08	0.82	0.41	3.61	0.09	4.16	1.30	4.73
	07:30	3.61	0.05	0.82	0.41	3.55	0.07	4.01	1.28	4.51
	11:30	3.64	0.05	0.83	0.41	3.57	0.06	4.16	1.32	4.71
	15:30	3.64	0.06	0.91	0.42	3.56	0.09	4.09	1.27	4.49
	19:30	3.64	0.06	0.88	0.41	3.56	0.08	3.99	1.28	4.39
	23:30	3.74	0.08	0.80	0.37	3.70	0.12	3.75	1.19	4.15
11-Nov	03:30	3.91	0.09	0.80	0.38	3.86	0.11	3.15	1.02	3.28
	07:30	3.79	0.08	0.80	0.37	3.66	0.07	3.91	1.25	4.39
	11:30	3.86	0.08	0.82	0.40	3.69	0.09	4.01	1.28	4.51
	15:30	3.66	0.06	0.91	0.41	3.65	0.09	4.01	1.25	4.37
	19:30	3.52	0.08	3.44	1.07	3.54	0.10	6.37	1.84	4.12
	23:30	3.62	0.19	3.60	1.11	3.46	0.10	6.53	1.89	4.12
12-Nov	03:30	3.58	0.08	3.55	1.10	3.61	0.13	6.58	1.85	4.27
	07:30	3.59	0.07	3.67	1.12	3.45	0.09	6.65	1.91	4.20
average		3.66	0.07	1.30	0.52	3.65	0.11	4.36	1.34	4.31

FLOPPY #52
FILENAME CHEMDATA

TABLE 6
NOVEMBER QUICKLIME TEST
CHEMICAL DATA

		04-1 Circuit TABLE FEEDER				04-1 Circuit GREEN BALLS				Addn
Date	Time	SiO2	Al2O3	CaO	MgO	SiO2	Al2O3	CaO	MgO	Rate
08-Nov	13:30	3.66	0.08	3.38	0.99	4.05	0.19	3.32	1.02	0.00
	16:10	3.61	0.09	3.48	1.04	3.92	0.18	3.42	1.04	0.00
	17:30	3.60	0.09	3.48	1.05	3.96	0.19	3.42	1.04	0.00
	21:30	3.47	0.08	3.58	1.05	3.91	0.18	3.52	1.05	0.00
09-Nov	01:30	3.61	0.09	3.59	1.07	4.02	0.19	3.50	1.04	0.00
	05:30	3.51	0.08	3.51	1.04	3.90	0.18	3.44	1.06	0.00
	09:30	3.44	0.09	3.54	1.07	3.80	0.17	3.44	1.06	0.00
	12:00									
	13:30	3.51	0.08	3.46	1.07	3.87	0.17	3.44	1.07	0.00
	19:30	3.70	0.10	3.58	1.11	4.07	0.20	3.52	1.11	0.00
	23:30	3.67	0.09	3.55	1.11	4.01	0.19	3.49	1.11	0.00
10-Nov	03:30	3.53	0.10	3.62	1.14	3.88	0.18	3.54	1.13	0.00
	07:30	3.54	0.08	3.67	1.15	3.83	0.17	3.65	1.15	0.00
	11:30	3.52	0.07	3.60	1.13	3.84	0.16	3.58	1.14	0.00
	15:30	3.64	0.10	3.57	1.10	3.96	0.19	3.55	1.09	0.00
	19:30	3.78	0.10	3.57	1.10	4.12	0.20	3.52	1.10	0.00
	23:30	3.89	0.10	3.46	1.08	4.25	0.20	3.41	1.07	0.00
11-Nov	03:30	4.08	0.10	3.61	1.11	4.45	0.21	3.57	1.11	0.00
	07:30									
	11:30									
	15:30									
	19:30									
	23:30									
12-Nov	03:30	3.66	0.12	3.64	1.11	4.10	0.22	3.60	1.11	0.00
	07:30	3.61	0.08	3.62	1.10	3.92	0.16	3.64	1.11	0.00
average		3.63	0.09	3.55	1.09	3.99	0.19	3.50	1.08	0.00

U. S. Steel
Minnesota Ore Operations
P.O. Box 417
Mt. Iron, MN 55768

Date: 12-14-94

From: Laurie Potter *Lf*

To: Ray Potts

Subject: Pebble Lime Project

Summary

Attached are the results of the lime testing which was conducted in the Agglomerator, Step 1 Line 3-4, on November 10, 1994. Results indicate that no potential overexposures were found to either CaO, MgO, or NH3, in either area or personal samples. These results concur with sampling which was conducted in May, while pebble lime was also in use.

Calcium and magnesium oxide were found in area samples, in concentrations of less than 5% of the allowable, where 100% or less is acceptable, (in November). Ammonia was found at less than 2% of the allowable, in each of three locations which were sampled. During the testing in May, ammonia was found as high as 9.2% of the allowable, at the discharge end of line 3-2, while the concentration at the same location in November, was 1.67%. These results show a higher degree of control during the November test.

The exposures of the balling attendant to magnesium and calcium oxide, were 0.20 and 1.60%, respectively. Although respiratory protection is not required based on these exposure levels, employees who were observed working on the balling floor, did wear reusable respirators with 2047 filters (HEPA filters with nuisance organic vapor protection).

From an industrial hygiene perspective, the pebble lime project appears to be well controlled. No visible sources of air emissions were observed on the day of sampling. On November 9th, an odor of burning oil was noted, reportedly from a bearing in the little ford mixer. Oil was not sampled, however, during the test.

lime2:wind:lp102

Lime Air Sampling Results
Agglomerator Step 1 Line 3–4

Date/ Sample ID MI94MI940–	Location/ Employee	Description	Analyte	TLV mg/m3	TWA mg/m3	% of All %
257	Area Sample	Balling Drum	MgO	10	0.036	0.36
		03–4	CaO	05	0.146	2.92
256	Area Sample	Feeder Floor	MgO	10	0.059	0.59
		228–03–1	CaO	05	0.164	3.28
255	Area Sample	Filter Floor	MgO	10	0.037	0.37
		298–03–1	CaO	05	0.155	3.1
254	K. Panala	Balling Att'd	MgO	10	0.02	0.20
	477–54–2450		CaO	05	0.08	1.60
261	Area Sample	Balling Drum	NH3	18	0.24	1.31
		03–4				
262	Area Sample	Balling Drum	NH3	18	0.30	1.67
		03–2				
260	Area Sample	Filter Floor	NH3	18	0.16	0.89
		298–03–1				

lotus:lime:102/3.5

Key:

TLV: Threshold limit value-MSHA's proposed 8 hour time weighted average allowable concentration
TWA: Measured exposure based on time
% of All: % of allowable based on TWA/TLV x 100% where 100% or less is acceptable
CaO: Calcium oxide
MgO: Magnesium oxide
Lime: (CaO, MgO)
NH_3: Ammonia-released when ore becomes basic with pH >10.