Chemco Systems, L.P.
1500 Industrial Drive
Monongahela, PA 15063

Effect of Slaking Water Temperature on Quality of Hydrated Lime Slurry

By: Mohamad Hassibi
Chemco Systems, L.P.
July, 2009
Revised: June 20, 2015

There is a recent debate regarding the impact heated slaking water has on the quality of the slaked lime. This debate has caused a lot of confusion in the industry. The purpose of this paper is to clarify fact from fiction.

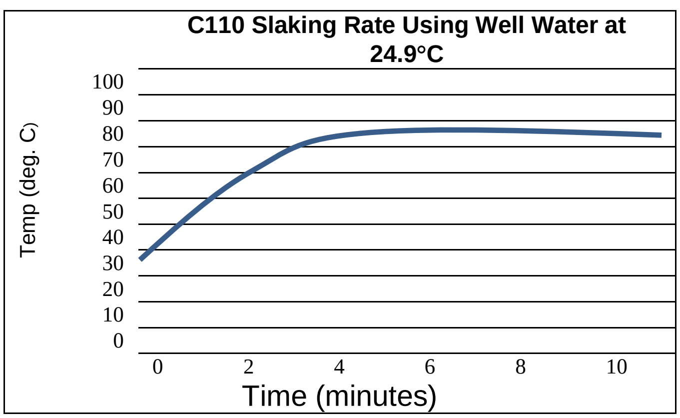
Research has shown that in laboratory tests use of hot water for slaking will increase the temperature rise of the slaking process and reduce the size of the hydrated lime particles.

Test 1, Graph 1 shows the temperature rise in the slaking process when the slaking water temperature is 24.9°C (76.82°F). With this water, the temperature rise in three minutes is 48.7°C (119.7°F).

The slaking test 1 was run in accordance with ASTM C110. The lime was pulverized to a top size near 6 mesh (3.35mm), 100 grams of material was slaked with 400 mL of well water for 15 minutes. A portion of the slurry was immediately poured into containers and sealed.

ASTM C110 Slaking Rate

Starting Temperature	24.9°C
Temp Rise at 0.5 min.	19.6°C
Temp Rise at 1.0 min.	29.6°C
Temp Rise at 3.0 min.	48.7°C
Total Temp Rise	52.2°C
Total Time	5.0 min.
Net Slope (C/min)	10.4
Residue/per 100 g lime	0.64



Test 1, Graph 1

Chemco Systems, L.P.
1500 Industrial Drive
Monongahela, PA 15063

Test 2, Graph 1 is the particle size distribution of the slurry produced in Test 1 above.

lime slurry 6

-

Lime slurry produced during reactivity test at lime company. Water temperature 24.9°C

- FLEX -

Microtrac Inc. A Unit of Nikkiso Co., Ltd

10.4.2

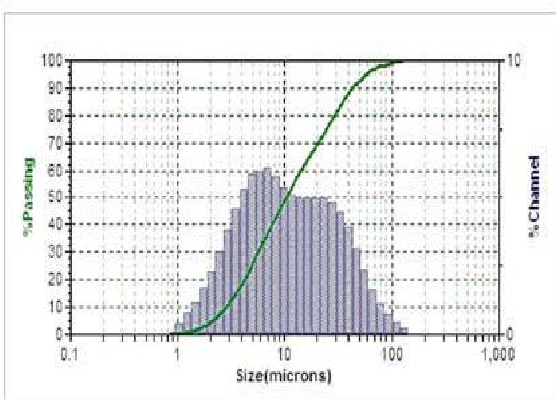
-

-

06/25/2009 15:47

S3000/S3500 S/N:S4192

Distribution:	Volume	Run Time:	30 Sec	Fluid:	IPA		
Progression:	Standard	Run Num:	Avg of 3	Fluid Ref. Index:	1.333	Loading Factor:	0.1212
Up Edge(um):	995.6	Particle:	LIME	Above Residual:	0	Transmission:	0.925
Low Edge(um):	0.687	Transparency:	Transparent	Below Residual:	0	RMS Residual:	1.053%
Residuals:	Disabled	Part. Ref. Index:	1.56			Flow:	35 %
Num. Channels:	42	Part. Shape:	Irregular			Usonic Power:	40 Watts
Analysis Mode:	S3000/3500			Multi-Run Delay:	0 Min.	Usonic Time:	60 Sec.
Filter:	Enabled	DB Record:	496	Recalc Status:	Original	Serial Num:	S4192
Analysis Gain:	Default	Database:	C:\Program Files\Microtrac FLEX 10.4.2\Databases\System Start Up.MDB				



Data Item	Value	%Tile	Size(um)	Dia(um)	Vol%	Width
MV(um):	17.96	10.00	2.838	10.24	100.0	29.84
MN(um):	2.128	20.00	4.19			
MA(um):	6.61	30.00	5.67			
CS:	9.07E-01	40.00	7.55			
SD:	14.92	50.00	10.24			

Size(um)	%Chan	% Pass	Size(um)	%Chan	% Pass
995.6	0.00	100.00	2.750	3.01	9.37
837.2	0.00	100.00	2.312	2.29	6.36
704.0	0.00	100.00	1.945	1.69	4.07
592.0	0.00	100.00	1.635	1.20	2.38
497.8	0.00	100.00	1.375	0.77	1.18
418.6	0.00	100.00	1.156	0.41	0.41
352.0	0.00	100.00	0.972	0.00	0.00
296.0	0.00	100.00	0.818	0.00	0.00
248.9	0.00	100.00			
209.3	0.00	100.00			
176.0	0.00	100.00			
148.0	0.22	100.00			
124.5	0.47	99.78			
104.6	0.71	99.31			
88.00	1.09	98.60			
74.00	1.63	97.51			
62.23	2.33	95.88			
52.32	3.13	93.55			
44.00	3.89	90.42			
37.00	4.48	86.53			
31.11	4.82	82.05			
26.16	4.97	77.23			
22.00	4.99	72.26			
18.50	4.97	67.27			
15.56	4.99	62.30			
13.08	5.11	57.31			
11.00	5.39	52.20			
9.25	5.77	46.81			
7.78	6.10	41.04			
6.54	6.00	34.94			
5.50	5.86	28.94			
4.62	5.30	23.08			
3.89	4.60	17.78			
3.27	3.81	13.18			

Test 2, Graph 1

In this graph, the D50 particle size is 10.24 microns and the D90 is 43.13 microns. The MV value shows half of the particles are smaller than 17.96 microns and half of them are larger.

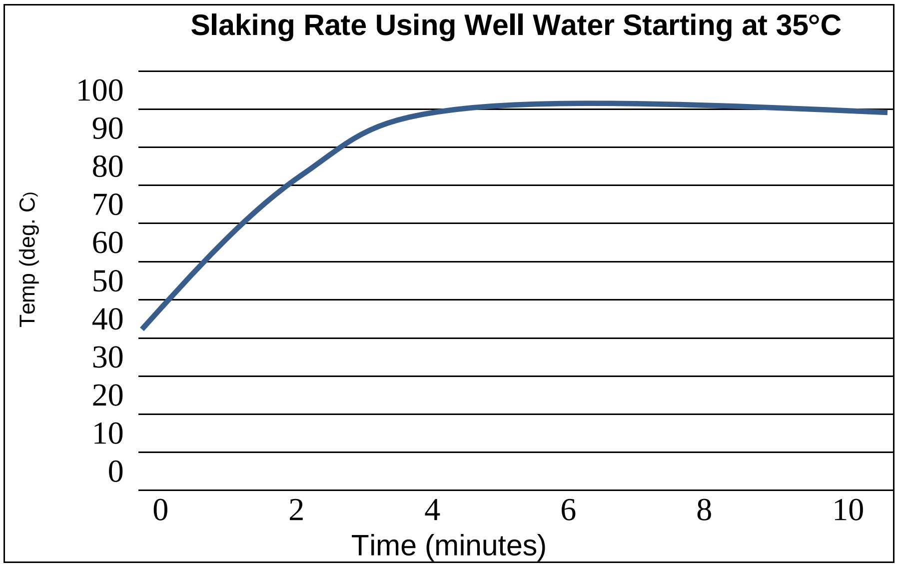
Chemco Systems, L.P.
1500 Industrial Drive
Monongahela, PA 15063

To test the impact of the heated slaking water on the slaking process and particle size distribution, the slaking water was heated to 35.2°C (95.36°F). The slaking test was done in the laboratory per ASTM C110 procedure. The resultant heat rise is shown on Test 2, Graph 2 below.

The second slaking test was run in accordance with ASTM C110 but at an elevated temperature for high calcium lime. The lime was pulverized to a top size near 6 mesh (3.35 mm), 100 grams of material was slaked with 400 mL of well water for 15 minutes. A portion of the slurry was immediately poured into containers and sealed.

ASTM C110 Slaking Rate

Starting Temperature	35.2
Temp Rise at 0.5 min.	21.2
Temp Rise at 1.0 min.	33.2
Temp Rise at 3.0 min.	52.9
Total Temp Rise	54.7
Total Time	4.5
Net Slope (C/min)	12.2



Test 2, Graph 2

As it is shown in the above, the temperature rise is much more rapid and the total temperature rise in three minutes is 52.9°C (127°F) versus the 48.7°C (119°F) with the colder water in Test 1.

The lime slurry in Test 2 above was then analyzed for particle size distribution. The results are shown on Test 2, Graph 3 below.

lime slurry OPPD

Lime test initial water temperature 35°C

- FLEX -

Microtrac Inc. A Unit of Nikkiso Co., Ltd

10.4.2

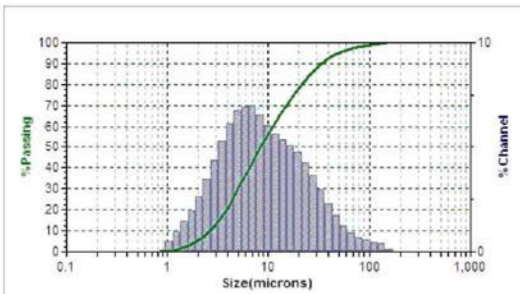
-

-

06/29/2009 14:23

S3000/S3500 S/N:S4192

Distribution:	Volume	Run Time:	30 Sec	Fluid:	WATER		
Progression:	Standard	Run Num:	Avg of 3	Fluid Ref. Index:	1.333	Loading Factor:	0.1413
Up Edge(um):	995.6	Particle:	LIME	Above Residual:	0	Transmission:	0.916
Low Edge(um):	0.687	Transparency:	Transparent	Below Residual:	0	RMS Residual:	1.017%
Residuals:	Disabled	Part. Ref. Index:	1.56			Flow:	35 %
Num. Channels:	42	Part. Shape:	Irregular			Usonic Power:	40 Watts
Analysis Mode:	S3000/3500			Multi-Run Delay:	0 Min.	Usonic Time:	60 Sec.
Filter:	Enabled	DB Record:	512	Recalc Status:	Original	Serial Num:	S4192
Analysis Gain:	Default	Database:	C:\Program Files\Microtrac FLEX 10.4.2\Databases\System Start Up.MDB				



Data Item	Value
MV(um):	14.90
MN(um):	2.103
MA(um):	5.88
CS:	1.021
SD:	10.85
Mz:	12.24
σι:	12.50
Ski:	0.635
Kg:	1.424

%Tile	Size(um)
10.00	2.634
20.00	3.82
30.00	5.04
40.00	6.47
50.00	8.32
60.00	11.01
70.00	15.09
80.00	21.39
90.00	33.51
95.00	48.67

Dia(um)	Vol%	Width
8.32	100.0	21.71

UDef Name	UDef Data

Size(um)	%Chan	% Pass	Size(um)	%Chan	% Pass
995.6	0.00	100.00	2.750	3.46	10.94
837.2	0.00	100.00	2.312	2.64	7.48
704.0	0.00	100.00	1.945	1.98	4.84
592.0	0.00	100.00	1.635	1.44	2.86
497.8	0.00	100.00	1.375	0.93	1.42
418.6	0.00	100.00	1.156	0.49	0.49
352.0	0.00	100.00	0.972	0.00	0.00
296.0	0.00	100.00	0.818	0.00	0.00
248.9	0.00	100.00			
209.3	0.00	100.00			
176.0	0.11	100.00			
148.0	0.37	99.89			
124.5	0.45	99.52			
104.6	0.55	99.07			
88.00	0.69	98.52			
74.00	0.92	97.83			
62.23	1.25	96.91			
52.32	1.72	95.66			
44.00	2.31	93.94			
37.00	2.98	91.63			
31.11	3.65	88.65			
26.16	4.25	85.00			
22.00	4.73	80.75			
18.50	5.08	76.02			
15.56	5.34	70.94			
13.08	5.63	65.60			
11.00	6.03	59.97			
9.25	6.53	53.94			
7.78	6.98	47.41			
6.54	6.95	40.43			
5.50	6.78	33.48			
4.62	6.12	26.70			
3.89	5.28	20.58			
3.27	4.36	15.30			

Test 2, Graph 3

The test result showed that with warmer slaking water the D50 particle size was reduced from 10.24 microns in test 1 to 8.32 microns om test 2 and the D90 was reduced from 43.13 microns to 33.51 microns. This test verified the fact that slaking with warmer water will definitely improve the slaking process by reducing the resultant particle size of hydrated lime.

As indicated above heated slaking water reduces the particle size of calcium hydroxide which in turn increases the surface area of particles of hydrated lime thus increasing efficiency and neutralizing capacity of the hydrated lime.

However in practice there are limitations as to how hot slaking water can be. As we increase the slaking water temperature above 70°F, the percentage of solids in the hydrated lime slurry produced is decreased. This is because for safety reasons we are limited to operate the slaker at below the boiling temperature of water at the particular site. Let us assume that we want to operate a slaker at 185°F for the slaker with a volume of "v" gallons. To bring the "v" gallons of slurry from ambient temperature to 185°F we require "X" BTU of heat input to the slakers. X= Y + Z

Y = BTU's of slaking water input
Z = Heat of reaction of lime and water

In the above formule as "Y" temperature of slaking water increases, the "Z", the heat of reaction must decrease. This means less lime has to be fed to the slaker thus percentage of solid in the slaker is reduced.

These are several reasons that producing a lime slurry with a percentage of solid about 20% is advantageous;

1. Less water is used in the process
2. Storage tanks and pumps will be smaller thus less costly.
3. Some processes cannot tolerate extra water
4. Less energy used for heating slaking water
5. In cases where lime slurry is produced in a different location than site it is used, the shipping costs will be substantially reduced.

As stated above adding lime to heated water will result in better quality hydrated lime, however due to limitations listed above we are limited as to how hot slaking water can be. A solution to this problem is to add lime and water at different locations into the hot slurry so that dry lime is added to hot slurry of about 180°F rather than slaking water of 70°F or lower. This allows the lime slurry of high percent of solids up to 25% solids with slaking temperature of 180 to 185°F.

Chemco slakers adds the cold incoming slaking water to the hot lime slurry and the heat to Warm up the water comes from the excess heat of lime slurry not external energy. Some Slakers such as ball mills premix the lime with cold water prior to entering the slaker. This Causes "drowning" of lime resulting in poor quality hydrated lime with coarse particle size.

Chemco Systems, L.P.
1500 Industrial Drive
Monongahela, PA 15063

To verify the impact of heated water for slaking in the real world, we took a sample of lime slurry from a 14,000#/hr slurry lime slaker operating in a power plant. The lime and water used for this slaker were the same lime and water that was used for our laboratory test. The slurry sample was taken from the discharge of the lime slaker for particle size distribution analysis. The slaker was temperature controlled and the operating temperature at the time this sample was taken was 175°F. The incoming slaking water temperature was 60°F (16°C). Test 3, Graph 1 shows the particle size distribution of this sample.

lime slurry

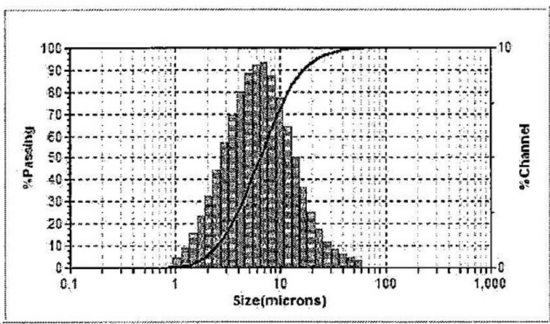
- FLEX -
10.4.2

-
-

06/29/2009 14:15
S3000/S3500 S/N:S4192

Slurry from an operating Chemco slaker

Distribution:	Volume	Run Time:	30 Sec	Fluid:	WATER		
Progression:	Standard	Run Num:	Avg of 3	Fluid Ref. Index:	1.333	Loading Factor:	0.1458
Up Edge(um):	995.6	Particle:	LIME	Above Residual:	0	Transmission:	0.908
Low Edge(um):	0.687	Transparency:	Transparent	Below Residual:	0	RMS Residual:	1.133%
Residuals:	Disabled	Part. Ref. Index:	1.56			Flow:	35 %
Num. Channels:	42	Part. Shape:	Irregular			Usonic Power:	40 Watts
Analysis Mode:	S3000/3500			Multi-Run Delay:	0 Min.	Usonic Time:	60 Sec.
Filter:	Enabled	DB Record:	508	Recalc Status:	Original	Serial Num:	S4192
Analysis Gain:	Default	Database:	C:\Program Files\Microtrac FLEX 10.4.2\Databases\System Start Up.MDB				



Data Item	Value
MV(um):	8.47
MN(um):	2.218
MA(um):	4.94
CS:	1.215
SD:	5.08
Mz:	7.52
σι:	5.61
Ski:	0.455
Kg:	1.263

%Tile	Size(um)
10.00	2.467
20.00	3.40
30.00	4.29
40.00	5.26
50.00	6.35
60.00	7.65
70.00	9.32
80.00	11.78
90.00	16.41
95.00	22.16

Dia(um)	Vol%	Width
6.35	100.0	10.15

UDef Name	UDef Data

Size(um)	%Chan	% Pass	Size(um)	%Chan	% Pass
995.6	0.00	100.00	2.750	4.42	12.91
837.2	0.00	100.00	2.312	3.26	8.49
704.0	0.00	100.00	1.945	2.32	5.23
592.0	0.00	100.00	1.635	1.56	2.91
497.8	0.00	100.00	1.375	0.92	1.35
418.6	0.00	100.00	1.156	0.43	0.43
352.0	0.00	100.00	0.972	0.00	0.00
296.0	0.00	100.00	0.818	0.00	0.00
248.9	0.00	100.00			
209.3	0.00	100.00			
176.0	0.00	100.00			
148.0	0.00	100.00			
124.5	0.00	100.00			
104.6	0.00	100.00			
88.00	0.00	100.00			
74.00	0.00	100.00			
62.23	0.34	100.00			
52.32	0.44	99.66			
44.00	0.59	99.22			
37.00	0.82	98.63			
31.11	1.17	97.81			
26.16	1.72	96.64			
22.00	2.53	94.92			
18.50	3.65	92.39			
15.56	5.00	88.74			
13.08	6.40	83.74			
11.00	7.69	77.34			
9.25	8.71	69.65			
7.78	9.34	60.94			
6.54	9.22	51.60			
5.50	8.84	42.38			
4.62	8.00	33.54			
3.89	6.93	25.54			
3.27	5.70	18.61			

Test 3, Graph 1

In this test, the D50 particle size was 6.35 microns and the D90 was 16.41 microns.

Comparing Test 3, Graph 1 with Test 2, Graph 2, it is obvious that the hydrated lime particles in Test 3, Graph 1 are much finer than the particles in Test 2, Graph 2, despite the fact that the slaking water in Test 3, Graph 1 is 16°C (60°F) versus 35°C (95°F) for Test 2, Graph 2.

The reasons for this contradiction are as follows:

In the laboratory test, the dry lime is added to 95°F (35°C) water directly. In the lime slaker, the 60°F (16°C) water is added to hot slurry and mixed immediately, and the dry lime is added to 175°F (80°C) lime slurry, not 60°F water. The above tests prove that adding dry lime to hot slurry will result in a very fine particle size of hydrate.

The problem of adding dry lime to hot slaking water is that the resultant slurry will be very thin in concentration because the heat of water and the heat of reaction will result in boiling slurry if the lime to water ratio is less than 1 to 6 or 7. Boiling slurry will cause major operating and safety problems.

In FGD systems, typically a minimum of 20% solid slurry is required; therefore, heating slaking water over 60 to 70°F will result in very thin slurry which is not suitable for FGD systems.

In the slaker design, it is very important that the dry lime that is added to the slaker does not come in contact with the cold incoming slaking water. Dry lime must be introduced into hot slurry of 170 to 180°F. Cold water must be introduced into the hot slurry so it is instantly mixed resulting in a uniform slurry temperature. To achieve this, a very vigorous agitation in the slaking chamber is necessary to attain a warm homogeneous mixture where dry lime is added to the slurry.

Published literature states that once the lime is slaked at a high temperature, the particles of hydrate are very small. To prevent agglomeration of fine particles, the lime slurry should be cooled as soon as possible to less than 140°F to prevent agglomeration of fine particles. To prove this point, we took samples of lime slurry from the lime slurry storage tank which was very hot, approximately 150 to 155°F. The lime slurry storage tank had a retention time of several hours at maximum usage. This lime slurry was produced in the slaker at 175°F (same slurry tested in Test 3, Graph 1). Particle size distribution analysis of the slurry from the slurry storage tank is shown below in Test 3, Graph 2 below.

Chemco Systems, L.P.
1500 Industrial Drive
Monongahela, PA 15063

lime slurry

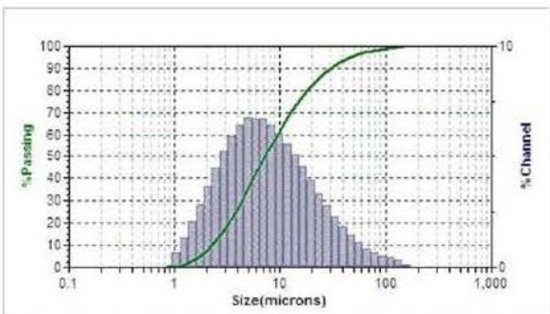
- FLEX -

10.4.2

-
-

06/29/2009 14:06
S3000/S3500 S/N:S4192

Distribution:	Volume	Run Time:	30 Sec	Fluid:	WATER		
Progression:	Standard	Run Num:	Avg of 3	Fluid Ref. Index:	1.333	Loading Factor:	0.1072
Up Edge(um):	995.6	Particle:	LIME	Above Residual:	0	Transmission:	0.933
Low Edge(um):	0.687	Transparency:	Transparent	Below Residual:	0	RMS Residual:	1.075%
Residuals:	Disabled	Part. Ref. Index:	1.56			Flow:	35 %
Num. Channels:	42	Part. Shape:	Irregular			Usonic Power:	40 Watts
Analysis Mode:	S3000/3500			Multi-Run Delay:	0 Min.	Usonic Time:	60 Sec.
Filter:	Enabled	DB Record:	504	Recalc Status:	Original	Serial Num:	S4192
Analysis Gain:	Default	Database:	C:\Program Files\Microtrac FLEX 10.4.2\Databases\System Start Up.MDB				



Data Item	Value
MV(um):	13.45
MN(um):	1.985
MA(um):	5.12
CS:	1.172
SD:	9.44
Mz:	10.60
σι:	11.50
Ski:	0.645
Kg:	1.619

%Tile	Size(um)
10.00	2.258
20.00	3.24
30.00	4.31
40.00	5.59
50.00	7.23
60.00	9.46
70.00	12.75
80.00	18.23
90.00	30.42
95.00	46.50

Dia(um)	Vol%	Width
7.23	100.0	18.89

UDef Name	UDef Data

Size(um)	%Chan	% Pass	Size(um)	%Chan	% Pass
995.6	0.00	100.00	2.750	4.46	15.00
837.2	0.00	100.00	2.312	3.61	10.54
704.0	0.00	100.00	1.945	2.83	6.93
592.0	0.00	100.00	1.635	2.09	4.10
497.8	0.00	100.00	1.375	1.34	2.01
418.6	0.00	100.00	1.156	0.67	0.67
352.0	0.00	100.00	0.972	0.00	0.00
296.0	0.00	100.00	0.818	0.00	0.00
248.9	0.00	100.00			
209.3	0.00	100.00			
176.0	0.10	100.00			
148.0	0.36	99.90			
124.5	0.44	99.54			
104.6	0.53	99.10			
88.00	0.66	98.57			
74.00	0.85	97.91			
62.23	1.11	97.06			
52.32	1.45	95.95			
44.00	1.86	94.50			
37.00	2.30	92.64			
31.11	2.78	90.34			
26.16	3.30	87.56			
22.00	3.89	84.26			
18.50	4.50	80.37			
15.56	5.07	75.87			
13.08	5.57	70.80			
11.00	6.01	65.23			
9.25	6.41	59.22			
7.78	6.71	52.81			
6.54	6.71	46.10			
5.50	6.75	39.39			
4.62	6.43	32.64			
3.89	5.94	26.21			
3.27	5.27	20.27			

Test 3, Graph 2

Review of this chart shows some agglomeration has taken place in the lime slurry storage tank. The D50 of this Test 3, Graph 1 was 6.35 microns compared to the D50 of Test 3, Graph 2 which was 7.23 microns. This slight increase in particle size diameter will have a noticeable impact on the surface area of the particles of hydrated lime.

This test shows that keeping lime slurry hot after exiting the slaker will probably cause some agglomeration of particles of lime hydrate; however, the degree of agglomeration may differ based on the type of instrument used for particle size analysis.

The instrument we used for the particle size analysis was MICROTRAC S3500. This device uses ultrasound to deagglomerate the particle of the slurry; therefore, we do not know if this impacted the particle size measurement. Since agglomeration is a surface reaction between particles, one can assume that MICROTRAC will deagglomerate at least some of the particles by applying ultrasound to prepare the slurry.

Further research is needed to quantify the impact of keeping slaked lime slurry hot for a period of time after completion of slaking on agglomeration of hydrated lime particles.

CONCLUSIONS

Adding quicklime to hot water, compared to cold water, will accelerate slaking and will reduce the average particle size of hydrated lime. Heating the slaking water above 65°F may be necessary based on the type of slaker used and on the feed rate of quicklime in relation to the maximum capacity of the slaker.

In general, with Chemco detention slakers, if the slaking water is 60°F or above, no heating of water is necessary as long as the slaker is run at a minimum of 60% of its maximum rated capacity. At a lower feed rate, warmer water is necessary to reach a slaking temperature of 180°F.

Furthermore, with detention slakers, since quicklime is added to hot slurry, not cold slaking water, heating the incoming water is unnecessary to reach 180° operating temperature unless the slaker is run at less than 60% of its full rated speed.

Heating slaking water above 80°F will result in lime slurry with a final percentage of solid less than 20%, which is generally undesirable particularly FGD with high Sulphur coal.