APPENDIX K-5: Cemented Tailings Paste Characterization and Laboratory Test Results

K5-A. Tailings Characterization and Laboratory Test Results

K5-B. Binder Characterization and Laboratory Test Results

K5-C. Paste Characterization, Mixing Procedures, and Laboratory Test Results

K5-D. Photograph Log Trial Batches 2% Binder: Cylinder and Cone Slump Tests

K5-E. Photograph Log Trial Batches 4% Binder: Cylinder and Cone Slump Tests

APPENDIX K-5

Cemented Tailings Paste Characterization and

Laboratory Test Results

Black Butte Copper Mine Operating Permit Application

Revised March 21, 2017

This section describes the suitability of the Black Butte Copper tailings, and identifies the local cementitious binders available in Montana and incorporated into the cement paste (CP) mix designs tested to date by Amec Foster Wheeler and others in 2015 for use in cemented paste for surface deposition (into the CTF) and for cemented paste backfill (CPB) (into the underground workings).

The following sections will:

- Present the physical, chemical, and strength characteristics of the BBC tailings.
- Present SGS/MSDS sheets for some of the reagents used in the mill.
- Define the physical targets of the paste mix designs for surface deposition and for cemented paste backfill.
- Define the different binder types.
- List the standardized testing methods for the binders, tailings water, and paste,
- Identify the local sources of the different available, sustainable, and cost effective binders.
- Reports the laboratory test results for the binders, tailings water, and two paste mix designs (one containing 2% binder and another containing 4% binder) that are fully presented in Appendix K5 of the MOP Application.
- Include pictures of the cylinder and cone slump tests for the 2% and 4% binder pastes

K5-A. Tailings Characterization and Laboratory Test Results

Black Butte Copper (BBC) tailings samples were prepared by International Metallurgical and Environmental Inc. and shipped to the Amec Foster Wheeler (Amec) laboratory in Hamilton, Ontario for characterization and analysis in order to help in the paste mix designs for surface deposition and back-filling underground workings. The tailings samples originated from one source (related to the BBC Project) and were sent to Amec in two separate batches (shipments).

The first shipment consisted of three buckets containing filter cake packaged in plastic bags and labeled as "LCT tailings" containing ~36 kg of dry tailings (Amec sample number S153-15 A-C) and were received on May 28th, 2015. The second shipment consisted of two buckets containing filter cake packaged in bags labeled as "LCT tailings" containing 43.0 pounds (19.5 kg) of dry tailings (Amec sample number S173-15 A-C) and were received on June 17th, 2015. Process water was decanted from each tailings sample of the as-received filter cake materials and saved.

Tailings samples from each batch were oven dried at 105°C (221°F). The tailings material from the first shipment (S153-15) was used for a full tailings characterization. For the material in the second shipment only basic characterization was conducted in order to verify the consistency of the tailings.

The tailings may be characterized using physical and chemical methods as defined in Table 1 below. Amec Wheeler Foster Laboratory in Hamilton, Ontario, Canada conducted the index and hydraulic conductivity testing. SGS Canada Inc. in Lakefield, Ontario (Canada) conducted the acid-base accounting ABA analyses. MAXXAM Analytics in Hamilton, Ontario (Canada) conducted the water analysis. Other tailings test results from BBC different tailings samples have been previously reported by Knight Piesold (2016) in Appendix K.

Table 1. Physical, Chemical, and Mineralogical Methods for Tailings Materials Characterization

Characterization Type	Method	Method Description
Physical	ASTM D422	Standard Test Method for Particle Size Analysis of Soils (using a hydrometer)
	ASTM D854	Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
	Laser Particle Size Distribution using a Particle Size Analyzer	Malvern Mastersizer 2000 – MIIA 14730: a representative sample was suspended in 20mL of highly purified and deionized (Milli-Q) water manufactured by Millipore Corp. The suspension was immersed in a low-power (47 kHz) ultrasonic bath for 1 minute to aid in disrupting any loosely bound agglomerates, prior to transfer to the measurement cell for analysis and analyzed in Milli-Q water. One measurement performed on the sample.
Chemical	Elemental Analysis	Various
	Acid-Base Accounting (ABA)	SGS Canada Inc.: ABA Modified Sobek
Mineralogical	X-Ray Diffraction (XRD)	XRD of powdered samples

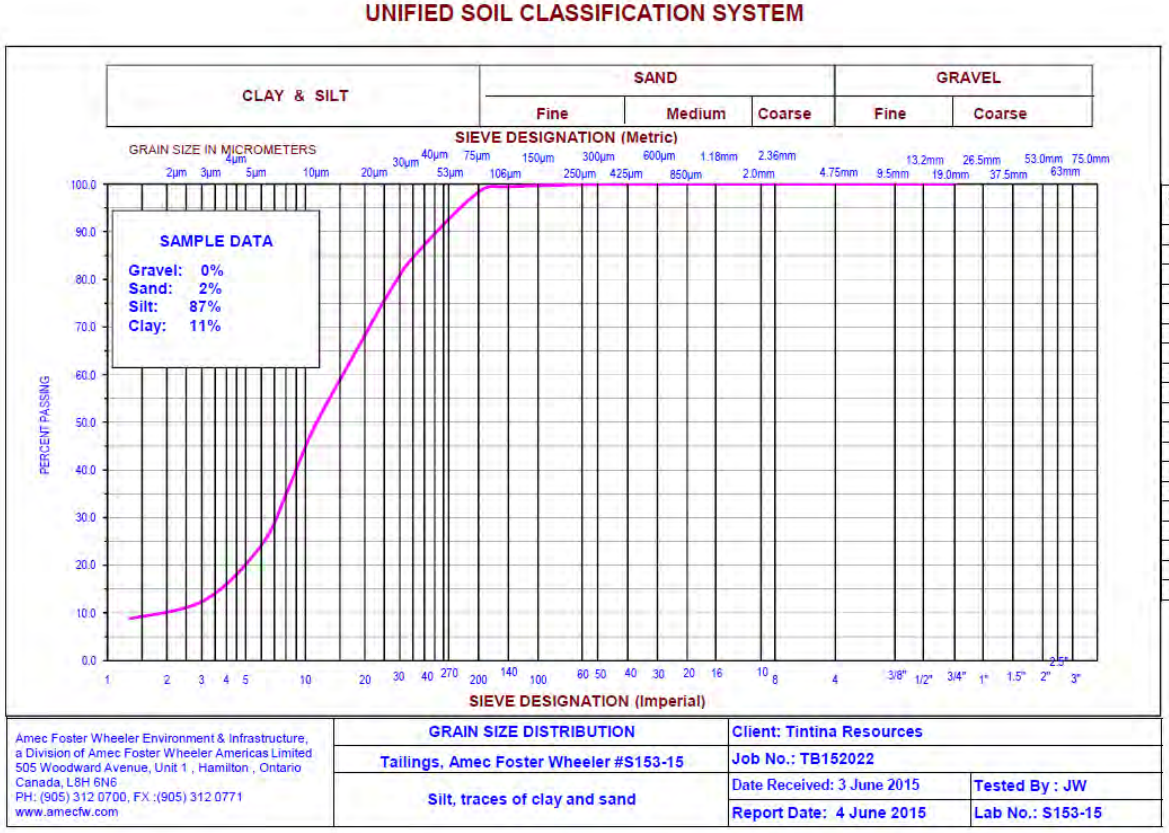
Table 2. Summary of physical test results of tailings.

Tailings sample		**LCT Tailings**	
Sample ID Number		S153-15	S173-15
Test Method	Results		
Hydrometer (ASTM D422)	100% passing	0.85 mm	0.25 mm
	80% passing	~25 μm	~30 μm
	<75 μm	98.3%	99.1%
	<20 μm	~75%	~68%
Laser particle size distribution	P10 (d(0.1))	1.9 μm	1.6 μm
	P50 (d(0.5))	14.4 μm	12.3 μm
	P80 (d(0.8))	40.6 μm	34.2 μm
	<75 μm	94.2%	96.5%
	<20 μm	58.9%	63.6%
Specific gravity (SG) ASTM D854		3.542	3.857

Note: Data from Amec Foster Wheeler in Hamilton, Ontario, Canada

Figures 1 through 2 below show hydrometer particle-size analyses for the tailings samples.

Figures 3 and 4 below show the laser particle size analyses for the two tailings samples.

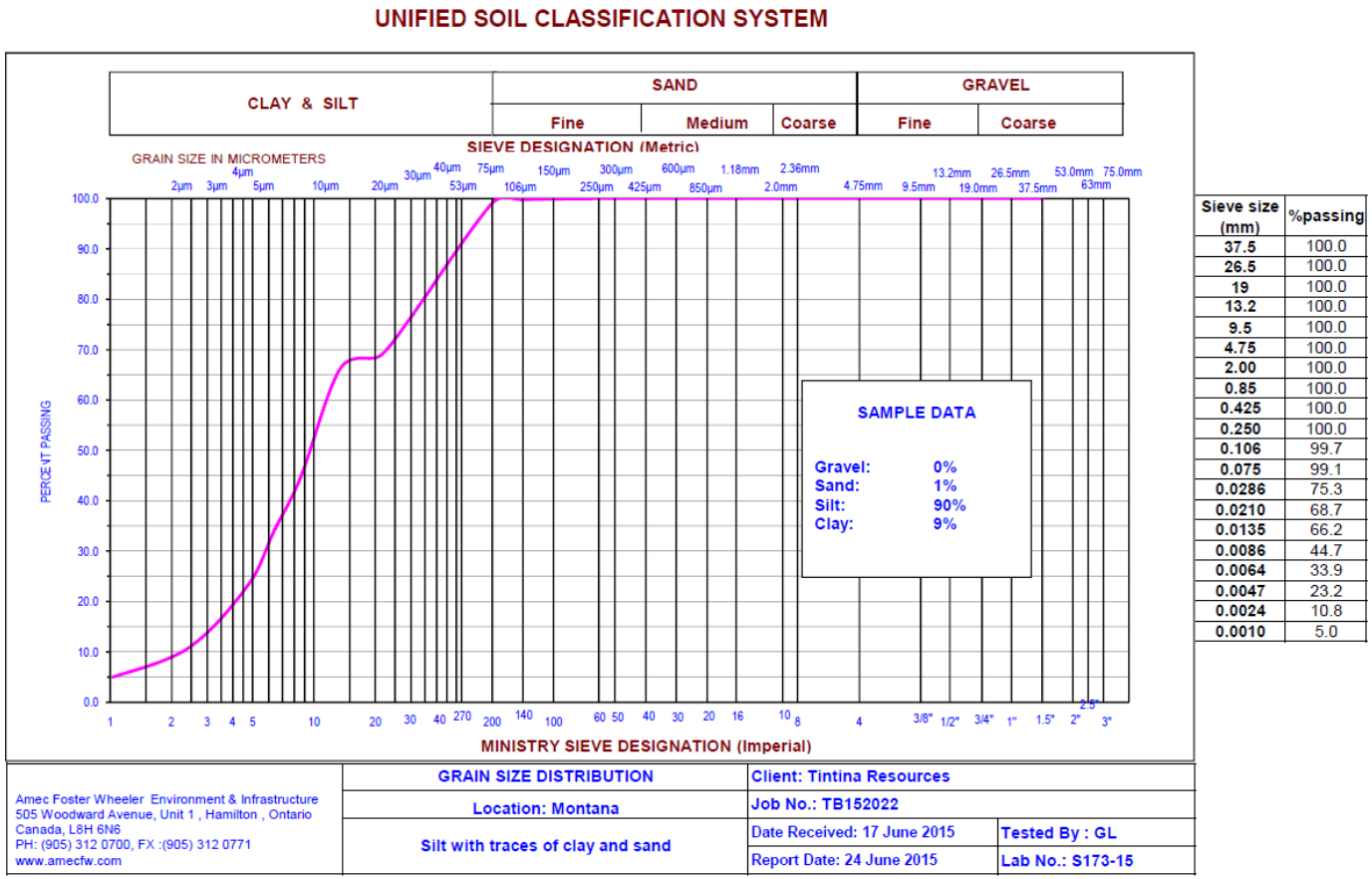


Sieve size (mm)	%passing
26.5	100.0
19	100.0
13.2	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.85	100.0
0.425	99.9
0.250	99.9
0.106	99.4
0.075	98.3
0.0362	85.3
0.0267	77.5
0.0179	64.7
0.0111	49.0
0.0082	36.3
0.0061	24.5
0.0031	12.7
0.0013	8.8

Amec Foster Wheeler Environment & Infrastructure,
a Division of Amec Foster Wheeler Americas Limited
505 Woodward Avenue, Unit 1 , Hamilton , Ontario
Canada, L8H 6N6
PH: (905) 312 0700, FX :(905) 312 0771
www.amecfw.com

GRAIN SIZE DISTRIBUTION	Client: Tintina Resources	
Tailings, Amec Foster Wheeler #S153-15	Job No.: TB152022	
Silt, traces of clay and sand	Date Received: 3 June 2015	Tested By : JW
	Report Date: 4 June 2015	Lab No.: S153-15

Figure 1 Hydrometer particle size analysis of tailings sample (S153-15)



Sieve size (mm)	%passing
37.5	100.0
26.5	100.0
19	100.0
13.2	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.85	100.0
0.425	100.0
0.250	100.0
0.106	99.7
0.075	99.1
0.0286	75.3
0.0210	68.7
0.0135	66.2
0.0086	44.7
0.0064	33.9
0.0047	23.2
0.0024	10.8
0.0010	5.0

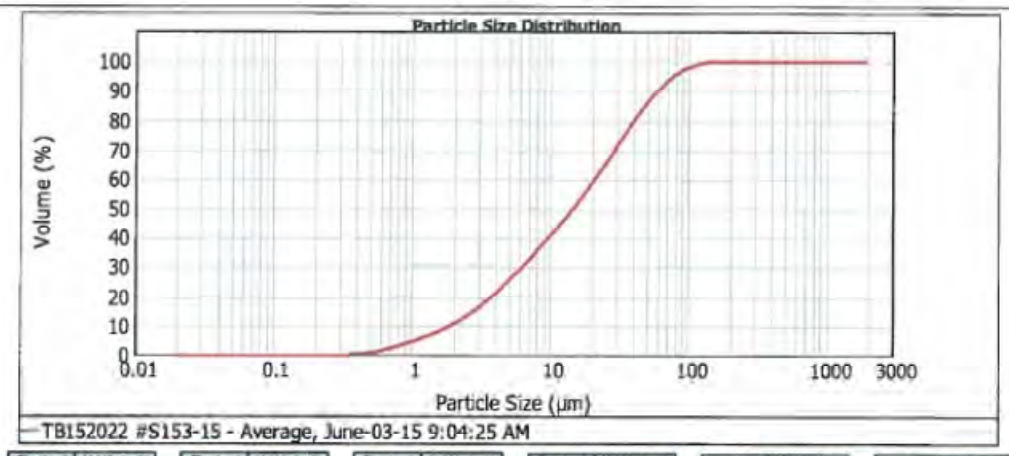
Figure 2 Hydrometer particle size analysis of tailings sample (S173-15)

Sample Name: TB152022 #S153-15 - Average	**SOP Name:** Default#	**Measured:** June-03-15 9:04:25 AM
Sample Source & type: CA02117-JUN15	**Measured by:** LR_Malvern1	**Analysed:** June-03-15 9:04:27 AM
Sample bulk lot ref: ar	**Result Source:** Averaged	

Particle Name: Default	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.520	**Absorption:** 0.1	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 15.83 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.710 %	**Result Emulation:** Off

Concentration: 0.0128 %Vol	**Span :** 4.014	**Uniformity:** 1.26	**Result units:** Volume
Specific Surface Area: 1.23 m²/g	**Surface Weighted Mean D[3,2]:** 4.886 um	**Vol. Weighted Mean D[4,3]:** 23.916 um	

d(0.1): 1.900 um **d(0.5):** 14.412 um **d(0.8):** 40.600 um

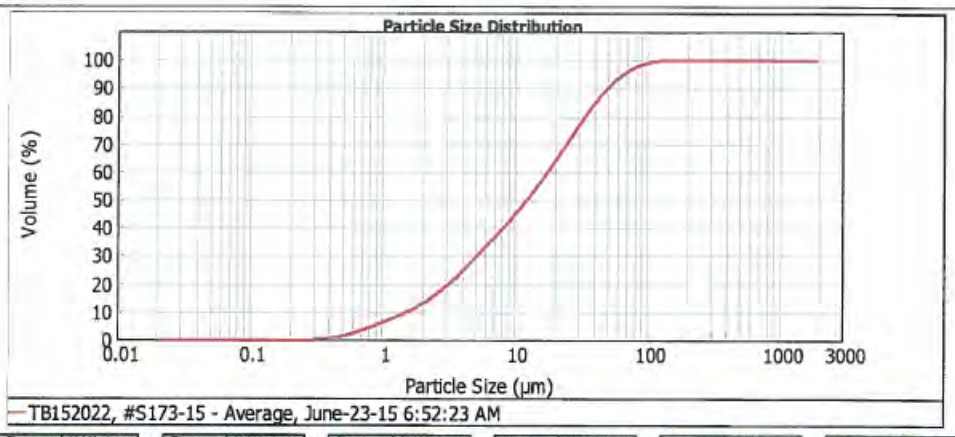


Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.010	0.00	0.105	0.00	1.096	5.18	11.482	44.26	120.226	99.13	1258.925	100.00
0.011	0.00	0.120	0.00	1.259	6.22	13.183	47.71	138.038	99.66	1445.440	100.00
0.013	0.00	0.138	0.00	1.445	7.35	15.136	51.28	158.489	99.90	1659.587	100.00
0.015	0.00	0.158	0.00	1.660	8.61	17.378	55.00	181.970	100.00	1905.461	100.00
0.017	0.00	0.182	0.00	1.905	10.03	19.953	58.86	208.930	100.00	2187.762	100.00
0.020	0.00	0.209	0.00	2.188	11.66	22.909	62.86	239.883	100.00	2511.886	100.00
0.023	0.00	0.240	0.00	2.512	13.50	26.303	66.98	275.423	100.00	2884.032	100.00
0.026	0.00	0.275	0.00	2.884	15.56	30.200	71.16	316.228	100.00	3311.311	100.00
0.030	0.00	0.316	0.00	3.311	17.84	34.674	75.34	363.078	100.00	3801.894	100.00
0.035	0.00	0.363	0.01	3.802	20.31	39.811	79.43	416.869	100.00	4365.158	100.00
0.040	0.00	0.417	0.19	4.365	22.96	45.709	83.34	478.630	100.00	5011.872	100.00
0.046	0.00	0.479	0.54	5.012	25.75	52.481	86.95	549.541	100.00	5754.399	100.00
0.052	0.00	0.550	1.06	5.754	28.64	60.256	90.18	630.957	100.00	6606.934	100.00
0.060	0.00	0.631	1.71	6.607	31.61	69.183	92.95	724.436	100.00	7585.776	100.00
0.069	0.00	0.724	2.47	7.586	34.66	79.433	95.23	831.764	100.00	8709.636	100.00
0.079	0.00	0.832	3.31	8.710	37.77	91.201	96.99	954.993	100.00	10000.000	100.00
0.091	0.00	0.955	4.22	10.000	40.98	104.713	98.28	1096.478	100.00		

Figure 3 Laser particle size analysis of tailings sample (S153-15)

Sample Name: TB152022, #S173-15 - Average	**SOP Name:** Defaultar	**Measured:** June-23-15 6:52:23 AM	
Sample Source & type: CA02753-JUN15	**Measured by:** LR_Malvern1	**Analysed:** June-23-15 6:52:25 AM	
Sample bulk lot ref: ar	**Result Source:** Averaged		
Particle Name: Default	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.520	**Absorption:** 0.1	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 15.18 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.767 %	**Result Emulation:** Off
Concentration: 0.0109 %Vol	**Span :** 3.951	**Uniformity:** 1.26	**Result units:** Volume
Specific Surface Area: 1.45 m²/g	**Surface Weighted Mean D[3,2]:** 4.135 um	**Vol. Weighted Mean D[4,3]:** 20.368 um	

d(0.1): 1.556 um **d(0.5):** 12.339 um **d(0.8):** 34.161 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.010	0.00	0.105	0.00	1.096	6.84	11.482	48.15	120.226	99.56	1258.925	100.00
0.011	0.00	0.120	0.00	1.259	8.02	13.183	51.74	138.038	99.84	1445.440	100.00
0.013	0.00	0.138	0.00	1.445	9.28	15.136	55.50	158.489	99.95	1659.587	100.00
0.015	0.00	0.158	0.00	1.660	10.67	17.378	59.44	181.970	100.00	1905.461	100.00
0.017	0.00	0.182	0.00	1.905	12.23	19.953	63.55	208.930	100.00	2187.762	100.00
0.020	0.00	0.209	0.00	2.188	13.99	22.909	67.78	239.883	100.00	2511.886	100.00
0.023	0.00	0.240	0.00	2.512	15.99	26.303	72.07	275.423	100.00	2884.032	100.00
0.026	0.00	0.275	0.00	2.884	18.21	30.200	76.32	316.228	100.00	3311.311	100.00
0.030	0.00	0.316	0.01	3.311	20.65	34.674	80.43	363.078	100.00	3801.894	100.00
0.035	0.00	0.363	0.12	3.802	23.28	39.811	84.30	416.869	100.00	4365.158	100.00
0.040	0.00	0.417	0.47	4.365	26.07	45.709	87.81	478.630	100.00	5011.872	100.00
0.046	0.00	0.479	1.02	5.012	28.98	52.481	90.89	549.541	100.00	5754.399	100.00
0.052	0.00	0.550	1.74	5.754	32.00	60.256	93.48	630.957	100.00	6606.934	100.00
0.060	0.00	0.631	2.61	6.607	35.08	69.183	95.56	724.436	100.00	7585.776	100.00
0.069	0.00	0.724	3.58	7.586	38.21	79.433	97.16	831.764	100.00	8709.636	100.00
0.079	0.00	0.832	4.62	8.710	41.42	91.201	98.31	954.993	100.00	10000.000	100.00
0.091	0.00	0.955	5.71	10.000	44.72	104.713	99.09	1096.478	100.00		

Figure 4 Laser particle size analysis of tailings sample (S173-15)

Table 3 below shows hydraulic conductivity results from the tailings sample.

Table 3. Hydraulic Conductivity of Tailings.

Sample Tested		**Filtered tailings**
Sample Number		**S**173-15
Test Method	Results	(cm/s)
Hydraulic conductivity (k)	Average inflow (run #1)	4.93×10^{-07}
	Average outflow (run #1)	2.86×10^{-07}
	Average of inflow and outflow (run #1)	3.90×10^{-07}
	Average inflow (run #2)	2.21×10^{-07}
	Average outflow (run #2)	1.87×10^{-07}
	Average of inflow and outflow (run #2)	2.04×10^{-07}
	Overall Average	**2.9×10^{-07}**

Note: Hydraulic conductivity testing conducted by Amec Foster Wheeler in Hamilton, Ontario

The chemistry of the tailings is shown in Table 4 and was conducted by Amec Foster Wheeler. Acid Base accounting results from the tailings are reported in Table 5 and Table 6.

Table 4. Chemical Composition of the Tailings.

Tailings sample	**LCT Tailings**
Sample Number	**S153-15**
Element Oxide (%)	(%)
SiO_2	37.2
Al_2O_3	1.83
Fe_2O_3	27.6
MgO	0.30
CaO	0.39
Na_2O	0.10
K_2O	0.80
TiO_2	0.07
P_2O_5	0.06
MnO	0.03
Cr_2O_3	0.06
V_2O_5	<0.01
C(t)	0.36
LOI*	18.4
S	24.8
SO_3	-
Sum	**86.8**

Notes: (1) Data from Amec Foster Wheeler in Hamilton, Ontario, Canada
(*) Value affected by large percentage of pyrite in sample

Table 5. Acid Base Accounting Results of the Tailings.

Tailings sample	**LCT Tailings**
Sample Number	**S153-15**
Total sulfur (%)	25.5
Sulphide minerals (%)	25.7
Sulphate minerals (%)	<0.01
Acid generating potential (AP, t $CaCO_3$/1000t)	802.00
Neutralization potential (NP, t $CaCO_3$/1000t)	2.00
Net neutralization potential (Net NP, t $CaCO_3$/1000t)	-799.88

Note: Data from SGS Canada Inc. Laboratory in Lakefield, Ontario Canada

Table 6. Acid Base Accounting Analysis Laboratory Certificate for the Tailings Sample.

SGS

ABA - Modified Sobek

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

16-June-2015

AMEC Earth & Environmental Limited
Attn : Corina Aldea

505 Woodward Avenue, Unit 1, Hamilton
, L8H 6N6
Phone: (905)312-0700, Fax:(905)312-0771

Date Rec. : 04 June 2015
LR Report: **CA12185-JUN15**
Reference: PO# TB152022*U

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	3: Analysis Approval Date	4: Analysis Approval Time	5: TB152022 #S153-15
Sample Date & Time			NA
Paste pH	11-Jun-15	14:22	3.23
Fizz Rate [---]	11-Jun-15	14:22	1
Sample weight [g]	11-Jun-15	14:22	2.01
	11-Jun-15	14:22	20.00
HCl [Normality]	11-Jun-15	14:22	0.10
NaOH [Normality]	11-Jun-15	14:22	0.10
NaOH to pH=8.3 [mL]	11-Jun-15	14:22	19.20
Final pH	11-Jun-15	14:22	1.17
NP [t CaCO3/1000 t]	11-Jun-15	14:22	2.0
AP [t CaCO3/1000 t]	—	—	802
Net NP [t CaCO3/1000 t]	—	—	-799.88
NP/AP [ratio]	—	—	0.00
Sulphur (total) [%]	12-Jun-15	14:56	25.5
Acid Leachable SO4-S [%]	—	—	<0.01
Sulphide [%]	12-Jun-15	14:56	25.7
Carbon (total) [%]	11-Jun-15	14:22	0.372
Carbonate [%]	11-Jun-15	14:22	0.220

Brian Graham B.Sc.
Project Specialist
Environmental Services, Analytical

Material Safety Data Sheets (MSDS) or Safety Data Sheets (SDS) are provided below for the following flotation reagents:

- Aerophine 3418A (copper collector) listed on pages 14 through 18,
- Sodium Isopropyl Xanthate (SIPX) (copper collector) listed on pages 19 through 24, and
- Methyl Isobutyl Carbinol (MIBC) (flotation frother) listed on pages 25 through 36.

In addition, example MSDS sheets for both Quick Lime (a flotation pH modifier) and listed on pages 37 through 43, and a flocculent type (Rheomax 1054) is listed on pages 44 through 52. These are examples of Quick Lime and a flocculent type that were used in the locked-cycle metallurgy testwork that generated the tailings samples.

CYTEC MATERIAL SAFETY DATA

Date: 10/14/97
MSDS No: 1787
Supersedes: 07/01/97
CAS No: 013360-78-6

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **AEROPHINE ® 3418A Promoter**
SYNONYMS: Sodium diisobutyldithiophosphinate, 50% aqueous solution
CHEMICAL FAMILY: Dithiophosphinate
MOLECULAR FORMULA: C8H18PS2.Na
MOLECULAR WGT: 232
CYTEC INDUSTRIES INC., FIVE GARRET MOUNTAIN PLAZA, WEST PATERSON, NEW JERSEY 07424, USA
For Product Information call 1-800/652-6013. Outside the USA and Canada call 973/357-3193.
EMERGENCY PHONE: For emergency involving spill, leak, fire, exposure or accident call CHEMTREC: 1-800/424-9300. Outside the USA and Canada call 703/527-3887.

2. COMPOSITION / INFORMATION ON INGREDIENTS

OSHA REGULATED COMPONENTS

COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
Sodium diisobutyldi-Thiophosphinate	013360-78-6	50-52	not established	

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

APPEARANCE AND ODOR: Colorless to light yellow mobile liquid; odorless
STATEMENTS OF HAZARD:
WARNING! CAUSES EYE IRRITATION
MAY CAUSE SKIN IRRITATION

POTENTIAL HEALTH EFFECTS

EFFECTS OF OVEREXPOSURE:
The acute oral (rat) and acute dermal (rabbit) LD50 values for this material are 3.35 g/kg and greater than5.0 g/kg, respectively. Mild skin and moderate eye irritation were produced during primary irritation studies in rabbits. Skin irritation was increased after repeated exposures in rabbit studies.

4. FIRST AID MEASURES

In case of skin contact, immediately wash affected areas with soap and plenty of water. Remove contaminated clothing and shoes. Obtain medical attention. Destroy or thoroughly clean shoes before reuse. Do not reuse contaminated clothing without laundering.
In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Obtain medical attention if irritation persists.
Material is not expected to be harmful if inhaled. If inhaled, remove to fresh air.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

FLASH POINT: >200 F; 93 C
METHOD: Pensky-Martens Closed Cup

FLAMMABLE LIMITS (% BY VOL): Not applicable
AUTOIGNITION TEMP: 819 F; 437 C
DECOMPOSITION TEMP: >662 F; 350C

EXTINGUISHING MEDIA AND FIRE FIGHTING INSTRUCTIONS

Use water spray, carbon dioxide or dry chemical to extinguish fires. Use water to keep containers cool. Wear self-contained, positive pressure breathing apparatus and full fire-fighting protective clothing. See Section 8 (Exposure Controls/Personal Protection) for special protective clothing.

6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Where exposure level is not known, wear NIOSH approved, positive pressure, self-contained respirator. Where exposure level is known, wear NIOSH approved respirator suitable for level of exposure. In addition to the protective clothing/equipment in Section 8 (Exposure Controls/Personal Protection), wear impervious boots.
Cover spills with some inert absorbent material; sweep up and place in a waste disposal container. Flush area with water.

7. HANDLING AND STORAGE

Avoid contact with eyes, skin, and clothing. Wash thoroughly after handling.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT (PPE)
Where this material is not used in a closed system, good enclosure and local exhaust ventilation should be provided to control exposure. Food, beverages, and tobacco products should not be carried, stored, or consumed where this material is in use. Before eating, drinking, or smoking, wash face and hands with soap and water. Avoid skin contact. Protective clothing such as impervious gloves, apron, workpants, long sleeve work shirt, or disposable coveralls are recommended to prevent skin contact. For operations where eye or face contact can occur, wear eye protection such as chemical splash proof goggles or face shield. Eyewash equipment and safety shower should be provided in areas of potential exposure. For operations where inhalation exposure can occur, a NIOSH approved respirator recommended by an industrial hygienist may be necessary. A full facepiece respirator also provides eye and face protection.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR: Colorless to light yellow mobile liquid; odorless
BOILING POINT: 223 F; 106 C
MELTING POINT: 23-32 F; -5-0 C; (crystallization point)
VAPOR PRESSURE: 17.5 mm Hg @ 20 C; (value for water)
SPECIFIC GRAVITY: 1.14 @ 24 C
VAPOR DENSITY: Not applicable
% VOLATILE (BY WT): ~50; (water)
pH: Slightly alkaline
SATURATION IN AIR (% BY VOL): Not applicable
EVAPORATION RATE: Not applicable
SOLUBILITY IN WATER: Complete

10. STABILITY AND REACTIVITY

STABILITY: Stable
CONDITIONS TO AVOID: None known
POLYMERIZATION: Will Not Occur
CONDITIONS TO AVOID: None known
INCOMPATIBLE MATERIALS: Strong mineral acids and strong oxidizing agents.
HAZARDOUS DECOMPOSITION PRODUCTS: oxides of carbon; oxides of phosphorus; oxides of sulfur (includes sulfur di and tri oxides)

11. TOXICOLOGICAL INFORMATION

Toxicological information for the product is found under Section 3. HAZARDS IDENTIFICATION.
Toxicological information on the OSHA regulated components of this product is as follows:
Sodium diisobutyldithiophosphinate causes moderate eye and skin irritation.

12. ECOLOGICAL INFORMATION

Algae (Selenastrum capricornutum), 96 hr EbC50 = 35.1 mg/L; 96 hr ErC50 = 115 mg/L

LC50

BLUEGILL, 96 HOUR: 375 mg/L
DAPHNIA, 48 HOUR: 149 mg/L

BOD

28 Day: 78.8 %
OCTANOL/H_2O PARTITION COEF.: Not applicable

13. DISPOSAL CONSIDERATIONS

The information on RCRA waste classification and disposal methodology provided below applies only to the Cytec product, as supplied. If the material has been altered or contaminated, or it has exceeded its recommended shelf life, the guidance may be inapplicable. Hazardous waste classification under federal regulations (40 CFR Part 261 et seq) is dependent upon whether a material is a RCRA "listed hazardous waste" or has any of the four RCRA "hazardous waste characteristics." Refer to 40 CFR Part 261.33 to determine if a given material to be disposed of is a RCRA "listed hazardous waste"; information contained in Section 15 of this MSDS is not intended to indicated if the product is a "listed hazardous waste." RCRA Hazardous Waste Characteristic. There are four characteristics defined in 40 CFR Section 261.21-61.24: Ignitability, Corrosivity, Reactivity, and Toxicity. To determine Ignitability, see Section 5 of this MSDS (flash point). For Corrosivity, see Sections 9 and 14 (pH and DOT corrosivity). For Reactivity, see Section 10 (incompatible materials). For Toxicity, see Section 2 (composition). Federal regulations are subject to change. State and local requirements, which may differ from or be more stringent than the federal regulations, may also apply to the classification of the material if it is to be disposed. Cytec encourages the recycle, recovery and reuse of materials, where permitted, as an alternate to disposal as a waste. Cytec recommends that organic materials classified as RCRA hazardous wastes be disposed of by thermal treatment or incineration at EPA approved facilities. Cytec has provided the foregoing for information only; the person generating the waste is responsible for determining the waste classification and disposal method.

14. TRANSPORT INFORMATION

This section provides basic shipping classification information. Refer to appropriate transportation regulations for specific requirements.

	D.O.T. SHIPPING INFORMATION	IMO SHIPPING INFORMATION
SHIPPING NAME:	NOT APPLICABLE/NOT REGULATED	NOT APPLICABLE/NOT REGULATED
HAZARD CLASS/ PACKING GROUP:	Not Applicable	Not Applicable
UN NUMBER:	Not Applicable	Not Applicable
IMDG PAGE:	Not Applicable	Not Applicable
D.O.T. HAZARDOUS SUBSTANCES: (PRODUCT REPORTABLE QUANTITY)	Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:	None Required	None Required

	ICAO / IATA	TRANSPORT CANADA
SHIPPING NAME:	NOT APPLICABLE/NOT REGULATED	NOT APPLICABLE/NOT REGULATED
HAZARD CLASS:	Not Applicable	Not Applicable
SUBSIDIARY CLASS:	Not Applicable	Not Applicable
UN / ID NUMBER:	Not Applicable	Not Applicable
PACKING GROUP:	Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:	None Required	None Required
PACKING INSTR:		
PASSENGER	Not Applicable	Not Applicable
CARGO	Not Applicable	
MAX NET QTY:		
PASSENGER	Not Applicable	Not Applicable
CARGO	Not Applicable	

ADDITIONAL TRANSPORT INFORMATION

TECHNICAL NAME (N.O.S.):
Not Applicable

15. REGULATORY INFORMATION

INVENTORY INFORMATION

US TSCA: This product is manufactured in compliance with all provisions of the Toxic Substances Control Act, 15 U.S.C. 2601 et. seq.
CANADA DSL: Components of this product have been reported to Environment Canada in accordance with subsection 25 of the Canadian Environmental Protection Act and are included on the Domestic Substances List.

EEC EINECS: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) in compliance with Council Directive 67/548/EEC and its amendments.

OTHER ENVIRONMENTAL INFORMATION

The following components of this product may be subject to reporting requirements pursuant to Section 313 of CERCLA (40 CFR 372), Section 12(b) of TSCA, or may be subject to release reporting requirements (40 CFR 307, 40 CFR 311, etc.) See Section 13 for information on waste classification and waste disposal of this product.

COMPONENT CAS. NO. % TPQ(lbs) RQ(lbs) S313 TSCA 12B
This product does not contain any components regulated under these sections of the EPA

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA
ACUTE (Y) CHRONIC (N) FIRE (N) REACTIVE (N) PRESSURE (N)

16. OTHER INFORMATION

NFPA HAZARD RATING (National Fire Protection Association)

Fire1
Health 2
Reactivity 0
Special —

FIRE: Materials that must be preheated before ignition can occur.
HEALTH: Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given
REACTIVITY: Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

REASON FOR ISSUE:

Revised Sections 2, 3, 9 & 10

Randy Deskin, Ph.D., DABT

CYTEC MATERIAL SAFETY DATA

MSDS No: 00293
Date: 07/31/2000

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **AERO 343 Xanthate**
SYNONYMS: Sodium isopropyl xanthate
CHEMICAL FAMILY: Xanthate
MOLECULAR FORMULA: C4H8OS2Na
MOLECULAR WGT: 158.2
CYTEC INDUSTRIES INC., FIVE GARRET MOUNTAIN PLAZA, WEST PATERSON, NEW JERSEY 07424, USA
For Product Information call 1-800/652-6013. Outside the USA and Canada call 1-973/357-3193.
EMERGENCY PHONE: For emergency involving spill, leak, fire, exposure or accident call CHEMTREC: 1-800/424-9300. Outside the USA and Canada call 1-703/527-3887.

2. COMPOSITION / INFORMATION ON INGREDIENTS

OSHA REGULATED COMPONENTS

COMPONENT	CAS. NO.	% T	WA/CEILING	REFERENCE
Carbonodithioic acid, O-Isopropyl ester, sodium salt	000140-93-2	87-89	not established	
Sodium hydroxide	001310-73-2	0-1	2 mg/m3 2 mg/m3 ceiling	OSHA ACGIH
Sodium sulfide	001313-82-2	0-1	not established	
Isopropanol	000067-63-0	0-1	400 ppm 500 ppm STEL	OSHA/ACGIH ACGIH

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

APPEARANCE AND ODOR: Pellets or powder, pale yellow to green, slight disagreeable odor.
STATEMENTS OF HAZARD:

WARNING! SELF-HEATING MATERIAL
MAY BE SPONTANEOUSLY COMBUSTIBLE
MAY FORM EXPLOSIVE DUST - AIR MIXTURES
DUST IRRITATING
CAUSES EYE IRRITATION
MAY CAUSE ALLERGIC SKIN REACTION

POTENTIAL HEALTH EFFECTS

EFFECTS OF OVEREXPOSURE:
The acute oral (rat) LD50 and acute dermal (rabbit) LD50 value for this material are estimated to be >800 mg/kg and >1000 mg/kg, respectively. Airborne dust may cause significant eye, skin or respiratory tract irritation.
Skin or eye contact with solutions of this product may cause moderate eye and skin irritation.
Repeated or prolonged dermal contact with this material may cause allergic skin reactions.
Refer to Section 11 for toxicology information on the OSHA regulated components of this product.

4. FIRST AID MEASURES

If swallowed, call a physician immediately. ONLY induce vomiting at the instructions of a physician. Never give anything by mouth to an unconscious person.
In case of skin contact, immediately wash affected areas with soap and plenty of water. Remove contaminated clothing and shoes. Obtain medical attention. Destroy or thoroughly clean shoes before reuse. Do not reuse contaminated clothing without laundering.
In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Obtain medical attention if irritation persists or if otherwise necessary.
If vapor or dust of this material is inhaled, remove from exposure. Administer oxygen if there is difficulty in breathing. Obtain medical attention immediately if necessary.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

FLASH POINT:	Not applicable
FLAMMABLE LIMITS (% BY VOL):	Not applicable
AUTOIGNITION TEMP:	Not available
DECOMPOSITION TEMP:	>428 F; 220C

EXTINGUISHING MEDIA AND FIRE FIGHTING INSTRUCTIONS

Use carbon dioxide, dry chemical or large quantities of water to extinguish fires. Heat causes decomposition to vapor of carbon disulfide. Wear self-contained, positive pressure breathing apparatus and full firefighting protective clothing. Solid xanthates are stable when kept cool and dry. However, exposure to heat and moisture can cause decomposition to flammable and explosive vapor of carbon disulfide. Since xanthates decompose in solution, even at room temperature, fire and explosion hazards can develop with aging. The moisture precautions do not apply to the product when diluted according to the Cytec Product Bulletin.

6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Where exposure level is not known, wear NIOSH approved, positive pressure, self-contained respirator. Where exposure level is known, wear NIOSH approved respirator suitable for level of exposure. Wear same protective clothing/equipment as in Section 8 (Exposure Controls/Personal Protection). Sweep up spills and place in a waste disposal container. Flush area with water.

7. HANDLING AND STORAGE

Avoid excessive heat or moisture. May contain finely divided material. Dust suspended in air may ignite with static discharge, sparks or flame. Equipment, including venting systems, should be grounded. Provide adequate ventilation in areas of use to remove dust. Avoid breathing dust. Keep container closed. Use non-sparking tools and do not smoke when opening drum. Avoid contact with eyes. Avoid prolonged or repeated contact with skin. Wash thoroughly after handling.
Heating or overexposure to moisture of solid xanthates or heating or aging of xanthate solutions causes some decomposition to poisonous and flammable carbon disulfide. Maintain good housekeeping to control dust accumulations. Special precautions against fire and explosion must be observed in (1) pumping xanthate solutions, (2) draining mobile tanks, (3) cleaning mobile tanks, and (4) performing maintenance work on storage tanks and pipelines leading to and from tanks. Storage tanks should have certain design features for maximum safety, and the vapor space should be free of sources of ignition. Use nonsparking tools and do not smoke when opening drums of xanthate. Do not use xanthate products until you have read the "Safety Discussion" in the AERO Xanthate Handbook from this Company.

DUST EXPLOSION HAZARD CLASS -1 Handling of material should be in accordance with NFPA-68. If handled with flammable or combustible materials the explosion hazard may increase.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT (PPE)
Where this material is not used in a closed system, good enclosure and local exhaust ventilation should be provided to control exposure. Food, beverages, and tobacco products should not be carried, stored, or consumed where this material is in use. Before eating, drinking, or smoking, wash face and hands with soap and water. Avoid skin contact. Protective clothing such as impervious gloves, apron, workpants, long sleeve work shirt, or disposable coveralls are recommended to prevent skin contact. For operations where eye or face contact can occur, wear eye protection such as chemical splash proof goggles or face shield. Eyewash equipment and safety shower should be provided in areas of potential exposure. Where exposures are below the Permissible Exposure Limit (PEL), no respiratory protection is required. Where exposures exceed the PEL, use respirator approved by NIOSH for the material and level of exposure. See "GUIDE TO INDUSTRIAL RESPIRATORY PROTECTION" (NIOSH).

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR: Pellets or powder, pale yellow to green, slight disagreeable odor.
BOILING POINT: Not applicable
MELTING POINT: Not available
VAPOR PRESSURE: Not applicable
SPECIFIC GRAVITY: 1.35 @ 20 C
VAPOR DENSITY: Not applicable
% VOLATILE (BY WT): Not available
pH: Not applicable
SATURATION IN AIR (% BY VOL): Not applicable
EVAPORATION RATE: Negligible
SOLUBILITY IN WATER: 37 g/100 g @ 20 C
VOLATILE ORGANIC CONTENT: Not available

10. STABILITY AND REACTIVITY

STABILITY: Stable
CONDITIONS TO AVOID: See Section 7 (Handling and Storage).
POLYMERIZATION: Will Not Occur
CONDITIONS TO AVOID: None known
INCOMPATIBLE MATERIALS: Strong oxidizing agents, acidic material and high temperatures.
HAZARDOUS DECOMPOSITION PRODUCTS: carbon disulfide; carbon monoxide; carbon dioxide; oxides of sulfur (includes sulfur di and tri oxides)

11. TOXICOLOGICAL INFORMATION

Toxicological information for the product is found under Section 3. HAZARDS IDENTIFICATION.
Toxicological information on the OSHA regulated components of this product is as follows:
Sodium isopropyl xanthate has an acute oral (rat) and acute dermal (rabbit) LD50 values of >800 mg/kg and >1,000 mg/kg, respectively. Direct contact with this material may cause irritation to skin, eyes, mucous membrane and respiratory tract. It has been reported direct contact may cause moderate skin sensitation. Sodium isopropyl xanthate tested negative for Ames test.

Acute overexposure to sodium hydroxide mists or dusts causes severe respiratory irritation. A solution of sodium hydroxide can produce irreversible damage to eyes and skin.
Sodium sulfide has an acute oral (rat) LD50 value of 208 mg/kg. Sodium sulfide severely irritates the skin and eyes, as well as, mucous membranes. This material liberates hydrogen sulfide upon contact with acids. Isopropanol has acute oral (rat) and dermal (rabbit) LD50 values of 5.0 g/kg and 12.8 g/kg, respectively. The 4-hour inhalation LC50 (rat) for isopropanol is >16,000 ppm (40.86 mg/L). Acute overexposure to isopropanol vapor may cause mild irritation of the eyes and respiratory tract. Chronic overexposure to isopropanol vapors may cause central nervous system depression, headaches, dizziness, nausea, and staggered gait. Liquid isopropanol is a severe eye irritant.

12. ECOLOGICAL INFORMATION

This material is not readily biodegradable.

LC50

TROUT 96 HOUR: 595 mg/L

BOD

28 Day: 1.9 %

OCTANOL/H_2O PARTITION COEF.: Not applicable

13. DISPOSAL CONSIDERATIONS

The information on RCRA waste classification and disposal methodology provided below applies only to the Cytec product, as supplied. If the material has been altered or contaminated, or it has exceeded its recommended shelf life, the guidance may be inapplicable. Hazardous waste classification under federal regulations (40 CFR Part 261 et seq) is dependent upon whether a material is a RCRA "listed hazardous waste" or has any of the four RCRA "hazardous waste characteristics." Refer to 40 CFR Part 261.33 to determine if a given material to be disposed of is a RCRA "listed hazardous waste"; information contained in Section 15 of this MSDS is not intended to indicate if the product is a "listed hazardous waste." RCRA Hazardous Waste Characteristics: There are four characteristics defined in 40 CFR Section 261.21-61.24: Ignitability, Corrosivity, Reactivity, and Toxicity. To determine Ignitability, see Section 5 of this MSDS (flash point). For Corrosivity, see Sections 9 and 14 (pH and DOT corrosivity). For Reactivity, see Section 10 (incompatible materials). For Toxicity, see Section 2 (composition). Federal regulations are subject to change. State and local requirements, which may differ from or be more stringent than the federal regulations, may also apply to the classification of the material if it is to be disposed. Cytec encourages the recycle, recovery and reuse of materials, where permitted, as an alternate to disposal as a waste. Cytec recommends that organic materials classified as RCRA
hazardous wastes be disposed of by thermal treatment or incineration at EPA approved facilities. Cytec has provided the foregoing for information only; the person generating the waste is responsible for determining the waste classification and disposal method.

14. TRANSPORT INFORMATION

This section provides basic shipping classification information. Refer to appropriate transportation regulations for specific requirements.

	D.O.T. SHIPPING INFORMATION	**IMO SHIPPING INFORMATION**
SHIPPING NAME:	XANTHATES	XANTHATES
HAZARD CLASS/	DIVISION 4.2	4.2
PACKING GROUP:	II	II
UN NUMBER:	UN3342	3342
IMDG PAGE:	Not Applicable	4266-2

D.O.T. HAZARDOUS SUBSTANCES:	(PRODUCT REPORTABLE QUANTITY)	
	Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:		
	Spontaneously Combustible	Spontaneously Combustible

	ICAO / IATA	**TRANSPORT CANADA**
SHIPPING NAME:	XANTHATES	SELF-HEATING SUBSTANCES, SOLID, N.O.S.
HAZARD CLASS:	4.2	4.2
SUBSIDIARY CLASS:	-	-
UN / ID NUMBER:	3342	3088
PACKING GROUP:	II	II
TRANSPORT LABEL REQUIRED:	Spontaneously Combustible	Spontaneously Combustible
PACKING INSTR:		
PASSENGER	415	Not Applicable
CARGO	417	
MAX NET QTY:		
PASSENGER	15kg	Not Applicable
CARGO	50kg	

ADDITIONAL TRANSPORT INFORMATION

TECHNICAL
NAME (N.O.S.): (Contains sodium isopropyl xanthate)

15. REGULATORY INFORMATION

INVENTORY INFORMATION

US TSCA: All components of this product are included on the TSCA Inventory in compliance with the Toxic Substances Control Act, 15 U. S. C. 2601 et. seq.
This product contains a chemical substance that is subject to export notification under Section 12 (b) of the Toxic Substances Control Act, 15 U. S. C. 2601 et. seq. (This requirement applies to exports from the United States only.)
CANADA DSL: Components of this product have been reported to Environment Canada in accordance with subsection 25 of the Canadian Environmental Protection Act and are included on the Domestic Substances List.
EEC EINECS: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) in compliance with Council Directive 67/548/EEC and its amendments.

OTHER ENVIRONMENTAL INFORMATION

The following components of this product may be subject to reporting requirements pursuant to Section 313 of CERCLA (40 CFR 372), Section 12(b) of TSCA, or may be subject to release reporting requirements (40 CFR 307, 40 CFR 311, etc.) See Section 13 for information on waste classification and waste disposal of this product.

COMPONENT	CAS. NO.	%	TPQ(lbs)	RQ(lbs)	S313	TSCA 12B
Isopropanol	000067-63-0	0-1	NONE	NONE	NO	YES

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA
ACUTE (Y) CHRONIC (N) FIRE (Y) REACTIVE (Y) PRESSURE (N)

16. OTHER INFORMATION

NFPA HAZARD RATING (National Fire Protection Association)

Fire2
Health 2
Reactivity 2
Special —

FIRE: Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.
HEALTH: Materials that, under emergency conditions, can cause temporary incapacitation or residual injury.
REACTIVITY: Materials that readily undergo violent chemical change at elevated temperatures and pressures.

REASON FOR ISSUE:

Revised All Sections

Randy Deskin, Ph.D., DABT

Product name	Methyl isobutyl carbinol		NAGH/EN
MSDS number	80063	**Revision Date**	Sep.18.2015
Revision Number	6.02	**Issuing date**	Aug.16.2016

1. Product and company identification

Trade Name

Methyl isobutyl carbinol

Manufacturer, importer, supplier
Celanese Ltd.
222 W. Las Colinas Blvd., Suite 900N
Irving, TX 75039
United States
Phone: 972 443 4000
Internet: www.celanese.com

Celanese Group, S de R.L. de C.V:
Freeway Coatzacoalcos-Villahermosa Km. 12.3 C.P. 96400
Coatzacoalcos, Ver
Mexico
Phone: (921) 211-5000/211-5048
Fax: (921) 211-5003

Transportation emergency phone numbers:
In USA, call 800 424 9300
Outside USA, call 703 527 3887, collect calls accepted.
In Mexico, call (921) 211-5048, 211-5000

Identified uses
Solvent

2. Hazard Identification

GHS Classification

Hazards	**Category**
Flammable liquid	Category 3
Skin corrosion/irritation	Category 2
Serious eye damage/eye irritation	Category 2B
Specific target organ systemic toxicity (single exposure)	Category 3 Respiratory

Label elements

Signal Word Warning

Hazard Statements

Flammable liquid and vapor
Causes skin irritation
Causes eye irritation
May cause respiratory irritation

Precautionary statements

Keep away from heat/sparks/open flames/hot surfaces. - No smoking.
Keep container tightly closed.
Ground/bond container and receiving equipment.
Use explosion-proof electrical/ ventilating/ lighting/ equipment.
Use only non-sparking tools.
Take precautionary measures against static discharge.
In case of fire:
Use water spray, dry powder, carbon dioxide (CO2) to extinguish.
Wear protective gloves/ eye protection/ face protection.
Wash face, hands and any exposed skin thoroughly after handling.
Avoid breathing dust/fume/gas/mist/vapors/spray
Use only outdoors or in a well-ventilated area.
IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/ shower.
If skin irritation occurs: Get medical advice/attention.
Wash contaminated clothing before reuse.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
If eye irritation persists: Get medical advice/attention.
IF INHALED: Remove person to fresh air and keep comfortable for breathing.
Call a POISON CENTER or doctor if you feel unwell.
Store locked up.
Store in a well-ventilated place. Keep cool.
Dispose of contents/ container to an approved landfill

3. Composition/information on ingredients

Components	CAS-No	Percent %
4-Methylpentan-2-ol	108-11-2	min 99

4. First aid measures

General Information

Remove contaminated, soaked clothing immediately and dispose of safely. Pay attention to own protection. In any case show the physician the Safety Data Sheet.

Skin

Clean moistened skin with water and soap, preferentially with polyethylene glycol (Lutrol).. Obtain medical attention.

Eyes

Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Call a physician immediately.

Inhalation
Keep at rest. Move to fresh air. Call a physician immediately.

Ingestion
Rinse with plenty of water. If conscious, drink plenty of water. If swallowed, do not induce vomiting - seek medical advice.

5. Fire-fighting measures

NFPA: **Health:** 2 **Flammability:** 2 **Instability:** 0

Suitable extinguishing media
Water spray, Dry powder, Carbon dioxide (CO2)

Extinguishing media which must not be used for safety reasons
Do not use a solid water stream as it may scatter and spread fire.

Special exposure hazards arising from the substance or preparation itself, its combustion products, or released gases
Under conditions giving incomplete combustion, hazardous gases produced may consist of
Carbon oxides (COx)
Vapors are heavier than air and may spread along floors
VAPORS MAY SPREAD LONG DISTANCES AND IGNITE
This material creates a fire hazard because it floats on water

Special protective equipment for fire-fighters
Wear self-contained breathing apparatus and protective suit.

Environmental precautions
Dike and collect water used to fight fire

Other Information
Cool containers / tanks with water spray. Move containers from fire area if you can do it without risk

6. Accidental release measures

Personal precautions
Avoid inhalation, ingestion and contact with skin and eyes. Keep away from heat and sources of ignition. Provide adequate ventilation.

Environmental precautions
Should not be released into the environment. Do not discharge into the drains/surface waters/groundwater. Prevent further leakage or spillage.

Methods for cleaning up
Remove all sources of ignition. Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder, sawdust). Dispose of in accordance with local regulations. Shovel or sweep up. Keep in suitable, closed containers for disposal.

7. Handling and storage

7. Handling and storage

Advice on safe handling

Use with adequate ventilation. Keep containers closed when not in use. Always open containers slowly to allow any excess pressure to vent. Avoid breathing vapor. Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling. Decontaminate soiled clothing thoroughly before re-use. Destroy contaminated leather clothing..

Protection - fire and explosion:

Keep away from sources of ignition - No smoking. Take necessary action to avoid static electricity discharge. Ground and bond containers when transferring material. In case of fire, emergency cooling with water spray should be available.

Technical measures/Storage conditions

Keep container tightly closed in a dry and well-ventilated place. Take measures to prevent the build up of electrostatic charge. Handle an open container with care.

Material storage

Store locked up. Store in a cool/low-temperature, well-ventilated, dry place away from heat and ignition sources. Take measures to prevent the build up of electrostatic charge.

Incompatible products

strong oxidizing agents

8. Exposure controls / personal protection

OSHA Exposure Limits

Components	TWA
4-Methylpentan-2-ol	25 PPM

Components	STEL
4-Methylpentan-2-ol	40 PPM

ACGIH Exposure Limits

Components	TWA
4-Methylpentan-2-ol	25 PPM

Components	STEL
4-Methylpentan-2-ol	40 PPM

Components	2005 NIOSH IDLH
4-Methylpentan-2-ol	400 PPM

Mexico National Exposure Limits

Components	LMPE - PPT	
4-Methylpentan-2-ol	100 mg/m^3	25 PPM

Components	STEL	
4-Methylpentan-2-ol	165 mg/m^3	40 PPM

Exposure controls

Engineering measures
General or dilution ventilation is frequently insufficient as the sole means of controlling employee exposure. Local ventilation is usually preferred. Explosion-proof equipment (for example fans, switches, and grounded ducts) should be used in mechanical ventilation systems.

Protective equipment
A safety shower and eyebath should be readily available.

General advice
Avoid contact with skin and eyes. Do not breathe vapors or spray mist. Use only in an area equipped with a safety shower. Hold eye wash fountain available.

Respiratory protection
Based on workplace contaminant level and working limits of the respirator, use a respirator approved by NIOSH. The following is the minimum recommended equipment for an occupational exposure level. To estimate an occupational exposure level see Section 8 and Section 11.

For concentrations > 1 and < 10 times the occupational exposure level: Use air-purifying respirator with full facepiece and organic vapor cartridge(s) or air-purifying full facepiece respirator with an organic vapor canister or a full facepiece powered air-purifying respirator fitted with organic vapor cartridge(s). The air purifying element must have an end of service life indicator, or a documented change out schedule must be established. Otherwise, use supplied air.

For concentrations more than 10 times the occupational exposure level and less than the lower of either 100 times the occupational exposure level or the IDLH: Use Type C full facepiece supplied-air respirator operated in positive-pressure or continuous-flow mode.

For concentrations > 100 times the occupational exposure level or greater than the IDLH level or unknown concentrations (such as in emergencies): Use self-contained breathing apparatus with full facepiece in positive-pressure mode or Type C positive-pressure full facepiece supplied-air respirator with an auxiliary positive-pressure self-contained breathing apparatus escape system.

Skin protection:
Wear impervious clothing and gloves when there is a reasonable chance for skin contact..

Eye/face protection:
In addition to goggles, wear a face shield if there is a reasonable chance for splash to the face..

9. Physical and chemical properties

9. Physical and chemical properties

Appearance

Form	liquid
Color	colourless
Odor	mild
Molecular Weight	102.18
Combustible material.	41°C(105.8°F)
Method	open cup
Ignition temperature	335°C (635°F)
Method	DIN 51794
Decomposition Temperature	Not determined
Lower explosion limit	1 Vol. %
Upper explosion limit	5.5 Vol. % (-130°F)
Boiling point/range	131.6°C @ 1013 hPa (266 - 269.6°F)
Density	0.808 g/ml @ 20°C
pH	not determined
Viscosity	4.074 mPa*s @ 25°C
Vapor pressure	3.7 hPa @ 20°C 34 hPa @ 50°C
Vapor density	3.52 (Air=1)
Evaporation Rate	0.26 (n-Butyl acetate = 1)
Water solubility	21.8 g/l @ 20°C
Solubility in other solvents	soluble in, Ethanol, Diethyl ether
Partition coefficient (n-octanol/water)	1.43 (measured)

10. Stability and reactivity

Chemical stability
Stable under normal conditions of handling, use and transportation.

Conditions to avoid
Avoid contact with heat, sparks, open flame, and static discharge. Avoid any source of ignition.

Incompatible Materials
Keep away from:
strong oxidizing agents
strong acids

Hazardous Combustion or Decomposition Products:
Thermal decomposition products may include oxides of carbon.

Possibility of hazardous reactions
Hazardous polymerization does not occur.

11. Toxicological information

Potential health effects

Routes of exposure Skin, eyes, inhalation, ingestion.

Immediate effects

Skin Causes skin irritation. Symptoms of overexposure include: Redness or discoloration, swelling, itching, burning or blistering of skin.

Eyes Exposure to vapors and liquid May cause eye irritation. Symptoms of exposure may include: Eye irritation, burning sensation, pain, watering, and/or change of vision. Eye injury which may persist for several days.

Inhalation Symptoms of exposure may include: Nasal discharge, hoarseness, coughing, chest pain and breathing difficulty. Central nervous system depression with nausea, dizziness, headache, stupor, uncoordinated or strange behavior or unconsciousness.

Ingestion Symptoms of exposure may include: Nausea, vomiting, loss of appetite, gastrointestinal irritation and/or diarrhea. Central nervous system depression with nausea, dizziness, headache, stupor, uncoordinated or strange behavior, or unconsciousness.

Target organ effects Irritation of the respiratory tract
Local irritation at the site of exposure

Medical conditions which may be aggravated by exposure: Medical conditions which may be aggravated by exposure: Skin
Eyes
Respiratory Tract

4-Methylpentan-2-ol

Acute oral toxicity	LD50: 2590 mg/kg
Acute dermal toxicity	LD50: 2870 mg/kg
Acute inhalation toxicity	LC50 (4h): > 16000 mg/m³
Method	OECD 403
Skin corrosion/irritation	irritating
Species	rabbit
Method	OECD 404
Skin Sensitization	nonsensitizer
Species	guinea pig
Method	OECD 406
Serious eye damage/eye irritation	irritant
Species	rabbit eye
Method	OECD 405
Carcinogenic effects	No evidence of carcinogenicity

in vitro Mutagenicity	Ames Test: negative - with and without metabolic activation - Method: OECD 471 In vitro Mammalian Chromosome Aberration Test in rat cells: negative - without metabolic activation - Method: OECD 473 Saccharomyces cerevisiae, Gene Mutation Assay: negative with and without metabolic activation - Method: OECD480 Mouse lymphoma cell gene-mutation: negative - with and without metabolic activation - Method: OECD 476
Reproductive toxicity	No toxicity to reproduction (Reference substance: Methyl isobutyl ketone)
Routes of exposure	inhalation
Species	rat
	NOAEL: 4093 mg/kg bw/day
Developmental effects	No teratogenetic, maternal or develomental effects
Routes of exposure	Inhalation
Species	rat and mouse
	NOAEL: 4106 mg/kg bw/day
Developmental effects	No developmental or reproductive effects (Reference substance: 4-Hydroxy-4-methyl-2-pentanone)
Routes of exposure	oral gavage
Species	rat
	NOAEL: 300 mg/kg bw/day
Repeated exposure	No adverse effects (Reference substance: Methyl isobutyl ketone)
Routes of exposure	Inhalation
Species	rat
Method	OECD 451
	NOAEC: 1840 mg/m³
Repeated Exposure	No adverse effects
Routes of exposure	Inhalation
Species	rat
Method	OECD 412
	NOAEC: 3698 mg/m³

12. Ecological Information

4-Methylpentan-2-ol

Acute fish toxicity	LC50: > 92.4 mg/l (96h)
Species:	Pimephales promelas (Fathead minnow)
Method	OECD 203
Acute daphnia toxicity	EC50: 337 mg/l (48h)
Species:	Daphnia magna
Method	OECD 202
	NOEC (21 d): 30 mg/l (Reference substance: Methylisobutyl ketone)
Species:	Daphnia magna
Method	OECD 211

12. Ecological Information

Toxicity to aquatic plants	EC50: 334 mg/l (96h)
Species:	Pseudokirchneriella subcapitata
Method	OECD 201
Toxicity to bacteria	EC50 (3h): > 100 mg/l
Species:	in activated sludge
Method	OECD 209
Biodegradation	Readily biodegradable 85 % (28d)
Method	OECD 301 F
Other potential hazards	The substance does not meet the criteria for PBT / vPvB according to REACH, Annex XIII

13. Disposal considerations

Disposal considerations
Dispose of spilled material in accordance with state and local regulations for waste that is non-hazardous by Federal definition. Note that this information applies to the material as manufactured; processing, use, or contamination may make this information inappropriate, inaccurate, or incomplete.

Note that this handling and disposal information may also apply to empty containers, liners and rinsate. State or local regulations or restrictions are complex and may differ from federal regulations. This information is intended as an aid to proper handling and disposal; the final responsibility for handling and disposal is with the owner of the waste. Landfill in accordance with federal, state and local regulations

14. Transport information

US Department of Transportation

UN/NA Number:	UN 2053
Proper Shipping Name	Methyl isobutyl carbinol
Hazard class	3
Packing Group	III
Emergency Resp. Guide	129

TDG

UN/NA Number:	UN 2053
Proper Shipping Name	METHYL ISOBUTYL CARBINOL
Class:	3
Packing Group:	III

Mexico Transport Information

UN-No.	UN 2053
Proper Shipping Name	Methyl isobutyl carbinol
Hazard Class	3
Packing Group	III

ICAO/IATA

UN-No.	UN 2053
Proper Shipping Name	Methyl isobutyl carbinol
Hazard Class	3
Packing group	III

IMDG

UN/ID No.	UN 2053
Proper Shipping Name	Methyl isobutyl carbinol
Hazard Class	3
Packing group	III
Marine pollutant	no
EmS Code	F-E, S-D

15. Regulatory Information

US State Regulations

Chemicals associated with the product which are subject to the state right-to-know regulations are listed along with the applicable state(s):

4-Methylpentan-2-ol 108-11-2

Pennsylvania	Listed
New Jersey	Listed
Illinois	Listed
Massachusetts	Listed

U.S. FEDERAL REGULATIONS

Environmental Regulations:

SARA 311:

Acute health:	Yes
Chronic health:	No
Fire:	Yes
Sudden release of pressure:	No
Reactive:	No

INTERNATIONAL REGULATIONS

International Inventories
Listed on the chemical inventories of the following countries or qualifies for an exemption:
Australia (AICS)
Canada (DSL)
China (IECSC)
Europe (EINECS)
Japan (ENCS)
Japan (ISHL)
Korea (KECI)
New Zealand (NZIoC)
Philippines (PICCS)
United States (TSCA)

16. Other information

NFPA:	Health: 2	Flammability: 2	Instability: 0
HMIS:	Health: 2	Flammability: 2	Physical Hazard: 0

Prepared By
Product Stewardship Department
Celanese

Sources of key data used to compile the datasheet
Information contained in this safety data sheet is based on Celanese owned data and public sources deemed valid or acceptable.. The absence of data elements required by ANSI or 1907/2006/EC indicates that no data meeting these requirements is available..

Other Information:
Observe national and local legal requirements
Changes against the previous version are marked by ***

This information is based on our present state of knowledge. It shall describe our products regarding safety requirements and shall not be construed as a guarantee or statement of condition and/or quality.

Abbreviation and Acronym:

ADR = Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
CAS = Chemical Abstracts Service (division of the American Chemical Society)
CLP = Classification, Labelling and Packaging
DNEL = Derived No Effect Level
EINECS = European Inventory of Existing Commercial Chemical Substances
GHS = Globally Harmonized System of Classification and Labelling of Chemicals
IATA = International Air Transport Association
ICAO = International Civil Aviation Organization
IMDG = International Maritime Code for Dangerous Goods
LC50 = Lethal Concentration
LD50 = Lethal Dose
LOAEC = Low Observed Adverse Effect Concentration
LOAEL = Low Observed Adverse Effect Level
LOEL = Low Observed Effect Level
NOAEC = No Observed Adverse Effect Concentration
NOAEL = No Observed Adverse Effect Level
NOEC = No Observed Effect Concentration
NOEL = No Observed Effect Level
PBT = Persistent, Bioaccumulative and Toxic
PNEC = Predicted No Effect Concentration
RCR = Risk Characterization Ratio
RID = Règlement international concernant le transport des marchandises dangereuses par chemin de fer (Regulations Concerning the International Transport of Dangerous Goods by Rail)
STOT RE = Specific Target Organ Toxicity Repeated Exposure
STOT SE = Specific Target Organ Toxicity Single Exposure
STP = Sewage Treatment Plant
vPvB = very Persistent and very Bioaccumulative

GRAYMONT

MATERIAL SAFETY DATA SHEET

SECTION I - CHEMICAL PRODUCT AND COMPANY INFORMATION

Product Name: **HIGH CALCIUM QUICKLIME**	**WHMIS – CLASSIFICATION: D2A: MATERIALS CAUSING OTHER TOXIC EFFECTS E: CORROSIVE MATERIAL**

MANUFACTURER'S AND SUPPLIER'S NAME:

GRAYMONT (NB) INC	4634, Route 880, Havelock, New Brunswick, E4Z 5K8.
GRAYMONT (PA) INC.	194, Match Factory Place, Bellefonte, Pennsylvania, 16823
GRAYMONT (QC) INC.	25 – 206, rue De Lauzon, Boucherville, Québec, J4B 1E7.
GRAYMONT (WESTERN CANADA) INC.	#260 – 4311, 12th Street N.E., Calgary, Alberta, T2E 4P9
GRAYMONT WESTERN LIME INC.	206 N. 6th Avenue, West Bend, Wisconsin, 53095
GRAYMONT (WESTERN US) INC.	3950 South, 700 East, Suite 301, Salt Lake City, Utah, 84107
GRAYMONT (WI) INC.	Foot of Hill Avenue, Superior, Wisconsin, 54880

EMERGENCY TEL. No.: (613) 996 – 6666 CANUTEC (Canada) (800) 424 – 9300 CHEMTREC (US)

Chemical Name	Chemical Family	Chemical Formula
Calcium oxide	**Alkaline earth oxide**	**Complex mixture - mostly CaO**
Molecular Weight	Trade Name and Synonyms	Material Use
CaO = 56.08	**High Calcium Quicklime, Lime, Quicklime, Calcium Oxide, Burnt Lime, Unslaked Lime, Fluxing Lime.**	**Neutralization, Flocculation, Flux (met.), Caustic agent, absorption**

SECTION II - COMPOSITION AND INFORMATION ON INGREDIENTS

Hazardous Ingredients	Approximate Concentration	C.A.S. Number	Exposure limits (mg/m^3)					
			OSHA PEL	ACGIH TLV	RSST VEMP	MSHA PEL	NIOSH REL	NIOSH IDLH
(Complex Mixture)	**(% by weight)**		**(TWA) 8/40h**	**(TWA) 8/40h**	**(TWA) 8/40h**	**(TWA) 8/40h**	**(TWA) 10/40h**	
Calcium Oxide	**90 to 100**	**1305-78-8**	**5**	**2**	**2**	**5**	**2**	**25**
Crystalline Silica, Quartz	**0 à 0.1 Or 0.1 à 1 (Note 1)**	**14808-60-7**	**$30/(\%SiO_2)+2$ (T) $10/(\%SiO_2)+2$ (R)**	**0.025 (R)**	**0.1 (R)**	**$30/(\%SiO_2)+2$ (T) $10/(\%SiO_2)+2$ (R)**	**0.05 (R)**	**50**

(**Note 1**) : Concentration of crystalline silica in a series of lime products will vary from source to source. It was not detected on some samples (< 0.1% w/w). Therefore two ranges are being disclosed. (**Note 2**) : **ACGIH TLV** Version 1973 has been adopted by the Mine Safety Health Administration (**MSHA**) as the regulatory Exposure Standard. (**Note 3**): (**T**) Total Dust; (**R**): Respirable Dust.

SECTION III - PHYSICAL AND CHEMICAL DATA

Physical State	Odor and Appearance		Odor Threshold (p.p.m.)	Specific Gravity
Gas ☐ Liquid ☐ Solid ☑	**Slight earthy odor - White crystalline substance**		**Not applicable**	**3.25 - 3.38**
Vapor Pressure (mm)	Vapor Density (Air = 1)	Evaporation Rate	Boiling Point (°C)	Melting Point (°C)
Not applicable	**Not applicable**	**Not applicable**	**2850**	**2570 - 2625**
Solubility in Water (20°C)	Volatiles (% by volume)	pH (25 °C)	Bulk Density (kg/m^3)	Coefficient of water/oil distribution
0.125g/100g Solution	**Not applicable**	**Sat. soln CaO 12.45**	**720 - 1200**	**Not applicable**

SECTION IV - FIRE OR EXPLOSION HAZARD DATA

Flammability

Yes ☐ No ☑ If yes, under which conditions?

Extinguishing Media

Quicklime does not burn. Use extinguisher appropriate for material burning.

Special Fire Fighting Procedures

Avoid using water unless necessary for other materials, in which case, flood to absorb heat generated. (Contact with water will evolve heat and could cause ignition of paper, cardboard, etc.). Wear self-contained breathing equipment approved by NIOSH.

Flash point (° C) and Method	Upper flammable limit (% by volume)	Lower flammable limit (% by volume)
Not applicable	**Not applicable**	**Not applicable**
Auto Ignition Temperature (°C)	TDG Flammability Classification	Hazardous Combustion Products
Not applicable	**Non-flammable**	**None**

Dangerous Combustion Products **None**

EXPLOSION DATA

Sensitivity to Chemical Impact	Rate of Burning	Explosive Power	Sensitivity to Static Discharge
Not applicable	**Not applicable**	**Not applicable**	**Not applicable**

SECTION V - REACTIVITY DATA

Chemical Stability Yes ☐ No ☑	If no, under which conditions?	**Absorbs moisture and carbon dioxide in the air to form calcium hydroxide and calcium carbonate.**
Incompatibility to other substances Yes ☑ No ☐	If so, which ones?	**Boron tri-fluoride, chlorine tri-fluoride, ethanol, fluorine, hydrogen fluoride, phosphorus pentoxide; water and acids (violent reaction with generating heat and possible explosion in confined area).**
Reactivity Yes ☑ No ☐	If so, under which conditions?	**Reacts violently with strong acids. Reacts with water to form calcium hydroxide. The heat generated when mixed with water or moist air is sufficient enough to ignite surrounding materials such as paper, wood or cloth.**
Hazardous Decomposition Products		**None.**
Hazardous Polymerization Products		**Will not occur.**

SECTION VI - TOXICOLOGICAL PROPERTIES

Route of Entry

☑ Skin Contact ☐ Skin Absorption ☑ Eye Contact ☑ Acute Inhalation ☐ Chronic Inhalation ☑ Ingestion

Effects of Acute Exposure to Product

Skin	**Severe irritation or burning of mucous and skin. Dehydration of tissues.**
Eyes	**Severe eye irritation and burning, intense watering of the eyes, possible lesions, possible blindness when exposed for prolonged period. (Draize >80).**
Inhalation	**If inhaled in form of dust: nose, oral cavity and throat irritation, cough, sneezing, inflammation of breathing passages, ulceration and perforation of nasal septum, bronchitis, possible pneumonia.**
Ingestion	**If ingested, burning and edema of digestive tracts, abundant salivation, difficulties in swallowing and breathing, vomiting blood, drop in blood pressure (indicates perforation of esophagus or stomach).**

Effects of Chronic Exposure to Product:

Contact dermatitis. Following repeated or prolonged contact, this product can cause redness, desquamation and fissures. This product may contain trace amounts of crystalline silica. Excessive inhalation of respirable crystalline silica dust may result in respiratory disease, including silicosis, pneumoconiosis and pulmonary fibrosis.

LD_{50} of Product (Specify Species and Route) **3059 mg/kg (Mouse/Intraperitoneal)**	Irritancy of Product **Severe to moist tissues**	Exposure limits of Product **Unavailable**
LC_{50} of Product (Specify Species) **Unavailable**	Sensitization to Product **None**	Synergistic materials **None reported**

SECTION VI - TOXICOLOGICAL PROPERTIES (Cont'd)

☑ Carcinogenicity ☐ Reproductive effects ☐ Tératogenicity ☐ Mutagenicity

Quicklime is not listed as a carcinogen by ACGIH, MSHA, OSHA, NTP, DFG, RSST or IARC. It may, however, contain trace amounts of Crystalline Silica listed carcinogens by these organizations.

Crystalline Silica, which inhaled in the form of quartz or crystobalite from occupational sources, is classified by IARC as carcinogenic to humans. (Group 1)

Silica, crystalline (Airborne particles of respirable size) is regulated under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). Crystalline silica is listed as a chemical known to the State to cause cancer.

NIOSH considers crystalline silica to be potential occupational carcinogen as defined by the OSHA carcinogen policy [29 CFR 1990]. (Ca).

NTP lists respirable Crystalline Silica as known to be human carcinogens based on sufficient evidence of carcinogenicity in humans. (K).

ACGIH lists respirable Crystalline Silica (quartz) as suspected human carcinogen. (A2).

DFG lists respirable Crystalline Silica as a substance that causes cancer in man (1)

RSST lists respirable Crystalline Silica (quartz) as suspected human carcinogen.

SECTION VII - PREVENTIVE MEASURES

Personal Protective Equipment (PPE)	**Wear clean, dry gloves, full length pants over boots, long sleeved shirt buttoned at the neck, head protection and approved eye protection selected for the working conditions.**
Gloves (Specify)	**Gauntlets Cuff style.**
Respiratory (Specify)	**NIOSH approved respirator. Up to 10 mg/m^3: (APF = 5) Any quarter-mask respirator. Up to 20 mg/m^3: (APF = 10) Any particulate respirator equipped with an N95, R95 or P95 filter except quarter-mask respirator. Any supplied-air respirator. Up to 25 mg/m^3: (APF = 25) Any supplied-air respirator operated in a continuous-flow mode. Any powered, air purifying respirator with a high-efficiency particulate filter. For respirable quartz levels that exceed or are likely to exceed an 8-hr TWA of 0.1 mg/m^3, a NIOSH approved (N/R/P95) dust respirator is recommended. For respirable quartz levels that exceed or are likely to exceed an 8-hr TWA of 0.5 mg/m^3, a NIOSH approved HEPA (N/R/P100) filter respirator is recommended. For respirable quartz levels that exceed or are likely to exceed an 8-hr TWA of 5.0 mg/m^3, a NIOSH approved positive pressure (SAR), full face respirator or equivalent is recommended.**
Eyes (Specify)	**ANSI, CSA or ASTM approved safety glasses with side shields. Tight fitting dust goggles should be worn when excessive (visible) dust conditions are present. Do not wear contact lenses without tight fitting goggles when handling this chemical.**
Footwear (Specify)	**Resistant to caustics.**
Clothing (Specify)	**Fully covering skin. Remove when wet or contaminated. Change daily.**
Other (Specify)	**Evaluate degree of exposure and use PPE if necessary. After handling lime, employees must shower. If exposed daily, use oil, Vaseline, silicone base crème etc. to protect exposed skin, particularly neck, face and wrists.**

SECTION VII - PREVENTIVE MEASURES (Cont'd)

Engineering Controls (e.g. ventilation, enclosed process, specify)

Enclose dust sources; use exhaust ventilation (dust collector) at handling points, keep levels below Max. Concentration Permitted.

Leak and Spill Procedure

Limit access to trained personnel. Use industrial vacuums for large spills. Ventilate area.

Waste Disposal

Transport to disposal area or bury. Review Federal, Provincial and local Environmental regulations.

Handling Procedures and Equipment

Avoid skin and eye contact. Minimize dust generation. Wear protective goggles and in cases of insufficient ventilation, use NIOSH approved dust respirator. An eye wash station and safety shower should be readily available where this material or its water dispersions are used. Contact lenses should not be worn when working with this chemical.

Storage Requirements

Keep tightly closed containers in a cool, dry and well ventilated area, away from acids. Keep out of reach of children.

Special Shipment Information

Quicklime is neither regulated by the Transportation of Dangerous Goods (TDG) Regulations (Canada) nor by the Hazardous Materials Regulations (USA) unless this material is offered or intended for transportation by aircraft.

SECTION VIII - FIRST AID MEASURES

Skin

Carefully and gently brush the contaminated body surfaces in order to remove all traces of lime. Use a brush, cloth or gloves. Remove all lime-contaminated clothing. Rinse contaminated area with lukewarm water for 15 to 20 minutes. Consult a physician if exposed area is large or if irritation persists.

Eyes

Immediately rinse contaminated eye(s) with gently running lukewarm water (saline solution is preferred) for 15 to 20 minutes. In the case of an embedded particle in the eye, or chemical burn, as assessed by first aid trained personnel, contact a physician.

Inhalation

Move source of dust or move victim to fresh air. Obtain medical attention immediately. If victim does not breathe, give artificial respiration.

Ingestion

If victim is conscious, give 300 ml (10 oz) of water, followed by diluted vinegar (1 part vinegar, 2 parts water) or fruit juice to neutralize the alkali. Do not induce vomiting. Contact a physician immediately.

General Advise

Consult a physician for all exposures except minor instances of inhalation.

SECTION IX - REGULATORY INFORMATION

Superfund Amendments and Reauthorization Act of 1986 (**SARA Title III**). / The Emergency Planning and "Community Right-to-Know" Act (**EPCRA**). / Comprehensive Environmental Response, Compensation and Liability Act (**CERCLA**). / Resource Conservation and Recovery Act (**RCRA**).

Component Calcium Oxide has been reviewed against the following regulatory listings:

- **SARA Section 302 – Emergency Planning Notification. Extremely Hazardous Substances (EHS) List and Threshold Planning Quantity (TPQ). (40 CFR, Part 355, Section 30): Not listed.**
- **SARA Section 304 – Emergency Release Notification. Extremely Hazardous Substances (EHS) and Reportable Quantity (RQ) List. (40 CFR, Part 355, Section 40): Not listed.**
- **SARA Section 311/312 – Hazard Categories (40 CFR, Part 370): This product is regulated under CFR 1910.1200 (OSHA Hazard Communication) as Immediate (Acute) Health Hazards – Irritant.**
- **SARA Section 313 – Toxics Release Inventory (TRI). Toxic Chemical List (40 CFR, Part 372). Not listed.**
- **CERCLA – Hazardous Substance (40 CFR, Part 302): Not listed in Table 302.4.**
- **RCRA – Hazardous Waste Number (40 CFR, Part 261, Subpart D): Not listed.**
- **RCRA – Hazardous Waste Classification (40 CFR, Part 261, Subpart C): Not classified.**

CWA 311. - Clean Water Act List of Hazardous Substances.

Calcium Oxide has been withdrawn from the Clean Water Act (CWA) list of hazardous substances. (11/13/79) (44FR65400)

California Proposition 65.

Component Calcium Oxide does not appear on the above regulatory listing. This product may contain small amounts of crystalline silica. Silica, crystalline (Airborne particles of respirable size) is regulated under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). Crystalline silica is listed as a chemical known to the State to cause cancer.

Transportation - Hazardous Materials Regulations (USA) & Transportation of Dangerous Goods (TDG) Regulations (Can).

Calcium Oxide is listed in both table 172.101 of Title 49 CFR 172 and in schedule 18 D.G. List (Chapter 34 TDG ACT, SOR/DORS 93-525). Application of requirements is restricted to material offered or intended for transportation by aircraft. - Calcium oxide. By aircraft only. Class 8 - Corrosives. PIN UN1910. Packing group III. Maximum net quantity per package - passenger vehicles, 25kg.

Toxic Substances Control Act (TSCA).

All naturally occurring components of this product are automatically included in the USEPA TSCA Inventory List per 40 CFR 710.4 (b). All other components are listed on the USEPA TSCA Chemical Substances Inventory. Calcium Oxide is subject to inventory update reporting (IUR).

Canadian Environmental Protection Act 1999 (CEPA) – Substances Lists (DSL/NDSL).

Calcium Oxide is specified on the public Portion of the Domestic Substances List (DSL).

ANSI/NSF 60 - Drinking Water Treatment Additives.

Quicklime has been investigated with respect to elements identified by EPA as toxic and it has been classified for use in direct contact with drinking water. (In accordance with Standard ANSI/NSF 60). For a list of classified products, refer to Underwriters Laboratories Inc.'s Online Certifications Directory.

FDA - U.S. Food and Drug Administration, Department of Health and Human Services.

Calcium Oxide has been determined as "Generally Recognized As Safe" (GRAS) by FDA. See 21CFR184.1210. (CFR Title 21 Part 184 - - Direct food substances affirmed as generally recognized as safe).

SECTION X - OTHER INFORMATION

Hazardous Materials Identification System (U.S.)

National Fire Protection Association (U.S.) NFPA 704

WHMIS – Classification:	WHMIS – Classification:
"E" Corrosive Material.	**"D2A": Materials causing other toxic effects.**
Symbol: 	Symbol: 

Additional Information/Comments:

The technical data contained herein is given as information only and is believed to be reliable. GRAYMONT makes no guarantee of results and assumes no obligation or liability in connection therewith.

Sources Used:

NFPA, NLA, TDG, CSST, RSST, (LSRO-FASEB), Hazardous Products Act, Environment Canada, Enviroguide, OSHA, ACGIH, IARC, NIOSH, CFR, NTP, HSDB, EPA SRS, RTECS, DFG, Chemistry and Technology of Lime and Limestone (John Wiley and Sons, Inc.), Lime and Limestone (WILEY-VCH).

SECTION XI - PREPARATION INFORMATION

Prepared by:	Telephone number:	Date :
GRAYMONT (QC) INC. **Quality Assurance & Technical Services**	**(450) 449-2262**	**May 2012**

An electronic version of this MSDS is available at: www.graymont.com under the PRODUCTS section.

Safety data sheet

1. Identification of the substance/mixture and of the company/undertaking

Product identifier

RHEOMAX® 1050 (Flocculent)

Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses: flocculation agent

Details of the supplier of the safety data sheet

Company:
BASF SE
67056 Ludwigshafen
GERMANY

Contact address:
BASF plc
PO Box 4, Earl Road, Cheadle Hulme,
Cheadle, Cheshire
SK8 6QG, UNITED KINGDOM

Telephone: +44 161 485-6222
E-mail address: product-safety-north@basf.com

Emergency telephone number

International emergency number:
Telephone: +49 180 2273-112

2. Hazards Identification

Label elements

According to Regulation (EC) No 1272/2008 [CLP]

Globally Harmonized System, EU (GHS)

The product does not require a hazard warning label in accordance with GHS criteria.

According to Directive 67/548/EEC or 1999/45/EC

Directive 1999/45/EC ('Preparation Directive')

The product does not require a hazard warning label in accordance with EC Directives.

Classification of the substance or mixture

According to Regulation (EC) No 1272/2008 [CLP]

No need for classification according to GHS criteria for this product.

According to Directive 67/548/EEC or 1999/45/EC

Possible Hazards:
May cause some eye irritation which should cease after removal of the product.
May cause some irritation to the respiratory system if dust is inhaled.
Prolonged contact with the product can result in skin irritation.
This type of product has a tendency to create dust if roughly handled. It does not burn readily but as with many organic powders, flammable dust clouds may be formed in air.
Very slippery when wet.

Other hazards

According to Regulation (EC) No 1272/2008 [CLP]

Other Hazards (GHS):
If applicable information is provided in this section on other hazards which do not result in classification but which may contribute to the overall hazards of the substance or mixture.

3. Composition/Information on Ingredients

Mixtures

Chemical nature

polyacrylamide, anionic

4. First-Aid Measures

Description of first aid measures

Remove contaminated clothing.

If inhaled:
If difficulties occur after dust has been inhaled, remove to fresh air and seek medical attention.

On skin contact:
Wash thoroughly with soap and water.

On contact with eyes:

Wash affected eyes for at least 15 minutes under running water with eyelids held open.

On ingestion:
Rinse mouth and then drink plenty of water. Check breathing and pulse. Place victim in the recovery position, cover and keep warm. Loosen tight clothing such as a collar, tie, belt or waistband. Seek medical attention. Never induce vomiting or give anything by mouth if the victim is unconscious or having convulsions.

Most important symptoms and effects, both acute and delayed

Symptoms: The most important known symptoms and effects are described in the labelling (see section 2) and/or in section 11., Further important symptoms and effects are so far not known.

Indication of any immediate medical attention and special treatment needed

Treatment: Treat according to symptoms (decontamination, vital functions), no known specific antidote.

5. Fire-Fighting Measures

Extinguishing media

Suitable extinguishing media:
dry powder, foam

Unsuitable extinguishing media for safety reasons:
water jet

Additional information:
If water is used, restrict pedestrian and vehicular traffic in areas where slip hazard may exist.

Special hazards arising from the substance or mixture

carbon oxides, nitrogen oxides
The substances/groups of substances mentioned can be released in case of fire. Very slippery when wet.

Advice for fire-fighters

Special protective equipment:
Wear a self-contained breathing apparatus.

Further information:
The degree of risk is governed by the burning substance and the fire conditions. Contaminated extinguishing water must be disposed of in accordance with official regulations.

6. Accidental Release Measures

Personal precautions, protective equipment and emergency procedures

Use personal protective clothing.

Environmental precautions

Do not discharge into drains/surface waters/groundwater.

Methods and material for containment and cleaning up

For small amounts: Pick up with suitable appliance and dispose of.

For large amounts: Contain with dust binding material and dispose of.
Spilled product which becomes wet or spilled aqueous solution create a hazard because of their slippery nature. Avoid raising dust.

Reference to other sections
Information regarding exposure controls/personal protection and disposal considerations can be found in section 8 and 13.

7. Handling and Storage

Precautions for safe handling
Breathing must be protected when large quantities are decanted without local exhaust ventilation.
Handle in accordance with good industrial hygiene and safety practice. Forms slippery surfaces with water.

Conditions for safe storage, including any incompatibilities
Further information on storage conditions: Store in unopened original containers in a cool and dry place. Avoid wet, damp or humid conditions, temperature extremes and ignition sources.

Storage stability:
Avoid extreme heat.

Specific end use(s)
For the relevant identified use(s) listed in Section 1 the advice mentioned in this section 7 is to be observed.

8. Exposure Controls/Personal Protection

Control parameters

Components with workplace control parameters

Particles, not otherwise specified, respirable
TWA value 4 mg/m3 (EH40 (UK)), Respirable dust
Particles, not otherwise specified, inhalable
TWA value 10 mg/m3 (EH40 (UK)), Inhalable dust

Exposure controls

Personal protective equipment

Respiratory protection:
Suitable respiratory protection for lower concentrations or short-term effect: Particle filter with medium efficiency for solid and liquid particles (e.g. EN 143 or 149, Type P2 or FFP2)

Hand protection:
Chemical resistant protective gloves (EN 374)
Suitable materials also with prolonged, direct contact (Recommended: Protective index 6, corresponding > 480 minutes of permeation time according to EN 374):
e.g. nitrile rubber (0.4 mm), chloroprene rubber (0.5 mm), polyvinylchloride (0.7 mm) and other
Supplementary note: The specifications are based on tests, literature data and information of glove manufacturers or are derived from similar substances by analogy. Due to many conditions (e.g.

temperature) it must be considered, that the practical usage of a chemical-protective glove in practice may be much shorter than the permeation time determined through testing.
Manufacturer's directions for use should be observed because of great diversity of types.

Eye protection:
Safety glasses with side-shields (frame goggles) (e.g. EN 166)

Body protection:
light protective clothing

General safety and hygiene measures
Handle in accordance with good industrial hygiene and safety practice. Ensure adequate ventilation. Wearing of closed work clothing is recommended. Hands and/or face should be washed before breaks and at the end of the shift. Take off immediately all contaminated clothing. Wash contaminated clothing before reuse.

9. Physical and Chemical Properties

Information on basic physical and chemical properties

Form:	powder
Colour:	off-white
Odour:	odourless
Melting point:	
	The substance / product decomposes therefore not determined.
Flash point:	
	not applicable
Solubility in water:	Forms a viscous solution.
Fire promoting properties:	not fire-propagating

Other information

Bulk density: approx. 0.75 g/cm3

Other Information:
If necessary, information on other physical and chemical parameters is indicated in this section.

10. Stability and Reactivity

Reactivity
No hazardous reactions if stored and handled as prescribed/indicated.

Corrosion to metals:	No corrosive effect on metal.	
Formation of flammable gases:	Start temperature:	220 °C

Chemical stability
The product is stable if stored and handled as prescribed/indicated.

Peroxides: 0 %
The product does not contain peroxides.

Possibility of hazardous reactions
The product is not a dust explosion risk as supplied; however the build-up of fine dust can lead to a risk of dust explosions.

Conditions to avoid
Avoid extreme temperatures. Avoid humidity.

Incompatible materials

Substances to avoid:
strong acids, strong bases, strong oxidizing agents

Hazardous decomposition products

No hazardous decomposition products if stored and handled as prescribed/indicated.

11. Toxicological Information

Information on toxicological effects

Acute toxicity

Experimental/calculated data:
LD50 rat (oral): > 2,000 mg/kg (OECD Guideline 401)

Irritation

Experimental/calculated data:
Skin corrosion/irritation rabbit: non-irritant (OECD Guideline 404)

Serious eye damage/irritation rabbit: non-irritant

Respiratory/Skin sensitization

Experimental/calculated data:
Non-sensitizing.

Other relevant toxicity information

The product has not been tested. The statements on toxicology have been derived from products of a similar structure and composition.

12. Ecological Information

Toxicity

Toxicity to fish:
LC50 (96 h) > 100 mg/l, Oncorhynchus mykiss (static)
(under static conditions in the presence of 10 mg/L humic acid)

Aquatic invertebrates:
LC50 (48 h) > 100 mg/l, Daphnia magna

Persistence and degradability

Elimination information:
Not readily biodegradable (by OECD criteria).

Bioaccumulative potential

Assessment bioaccumulation potential:
Based on its structural properties, the polymer is not biologically available. Accumulation in organisms is not to be expected.

Mobility in soil (and other compartments if available)

Information on: Anionic polyacrylamide
Assessment transport between environmental compartments:
Adsorption to solid soil phase is expected.

Results of PBT and vPvB assessment

According to Annex XIII of Regulation (EC) No.1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH): The product does not contain a substance fullfilling the PBT (persistent/bioaccumulative/toxic) criteria or the vPvB (very persistent/very bioaccumulative) criteria.

Additional information

Other ecotoxicological advice:
The product has not been tested. The statements on ecotoxicology have been derived from products of a similar structure and composition.

13. Disposal Considerations

Waste treatment methods

The UK Environmental Protection (Duty of Care) Regulations (EP) and amendments should be noted (United Kingdom).

Contaminated packaging:
Packs that cannot be cleaned should be disposed of in the same manner as the contents.
Uncontaminated packaging can be re-used.

14. Transport Information

Land transport

ADR

Not classified as a dangerous good under transport regulations

RID

Not classified as a dangerous good under transport regulations

Inland waterway transport
ADN

Not classified as a dangerous good under transport regulations

Sea transport
IMDG

Not classified as a dangerous good under transport regulations

Air transport
IATA/ICAO

Not classified as a dangerous good under transport regulations

15. Regulatory Information

Safety, health and environmental regulations/legislation specific for the substance or mixture

If other regulatory information applies that is not already provided elsewhere in this safety data sheet, then it is described in this subsection.

The data should be considered when making any assessment under the Control of Substances Hazardous to Health Regulations (COSHH), and related guidance, for example, 'COSHH Essentials' (United Kingdom).

Chemical Safety Assessment

Chemical Safety Assessment not yet performed due to registration timelines

16. Other Information

Due to the merger of CIBA and BASF Group all Material Safety Data Sheets have been reassessed on the basis of consolidated information. This may have resulted in changes of the Material Safety Data Sheets. In case you have questions concerning such changes please contact us at the address mentioned in Section I.

Vertical lines in the left hand margin indicate an amendment from the previous version.

If you have any queries relating to this MSDS, it's contents or any other product safety related questions, please write to the following e-mail address: product-safety-north@basf.com

The data contained in this safety data sheet are based on our current knowledge and experience and describe the product only with regard to safety requirements. The data do not describe the product's properties (product specification). Neither should any agreed property nor the suitability of the product for any specific purpose be deduced from the data contained in the safety data sheet. It is the responsibility of the recipient of the product to ensure any proprietary rights and existing laws and legislation are observed.

K5-B. Binder Characterization and Laboratory Test Results

1.0 INTRODUCTION

This section identifies the local cementitious binders available in Montana, some of which were incorporated into the cement paste (CP) mix designs tested to date for use in cemented paste for surface deposition (into the CTF) and for cemented paste backfill (CPB) (into the underground workings).

The following sections will:

- Define the different binder types,
- List the standardized testing methods for the binders and tailings water, and
- Identify the local sources of the different available, sustainable, and cost effective binders

2.0 BINDER TYPES AVAILABLE FOR CEMENTED TAILINGS PASTE

Binder is defined as any cementing material, either hydrated cement or a product of cement or lime and reactive siliceous materials. The kinds of cement and the curing conditions determine the general type of binder formed. Economic considerations are the primary driving force behind the research and use of supplementary cementitious materials (SCM), such as slag, fly ash and natural pozzolans which can be added to the fill as a partial replacement of Portland Cement (PC). The mixes with SCM have good engineering performance and reduce costs. Among other benefits of using slag, or FA, as partial cement replacement compared to PC is their improved resistance to sulfate attack.

Cement is defined as a powdery substance made with calcined lime and clay. It is mixed with water to form mortar or mixed with sand, gravel, and water to make concrete; a binder, a substance used in construction that sets and hardens and can bind other materials together.

Portland cement (PC) is used as a binder in paste backfill where structural strength is required of the backfill and where resistance to liquefaction is necessary.

Slag is a non-metallic binder product, consisting of silicates and alumino-silicates of calcium, magnesium and other bases, developed in a molten condition simultaneously with iron in a blast furnace; when rapidly cooled it forms a glassy granular material that is ground and used as a supplementary cementaceous material additive to cement; as an additive it provides good engineering performance at reduced costs and has significant improved resistance to sulfate attack over cement.

Slag cement is defined as a hydraulic cement formed when finely ground granulated blast furnace slag is mixed with cement.

Fly ash (FA) is “the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases” as defined by *ASTM C618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”*. ASTM C618 covers coal FA and raw and calcined natural pozzolan for use in concrete, where cementitious and pozzolanic action is desired.

Pozzolans are a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.

3.0 TESTING METHODS FOR THE BINDERS AND TAILINGS WATER

The different binders may be characterized using the following testing methods: physical, chemical, mineralogical, and strength tests. Table 3-1 lists the physical testing methods for Portland Cement and Fly Ash. Table 3-2 below lists the standardized chemical, mineralogical, and strength testing methods used to characterize the different binders

Table 3-1. Physical Testing Methods for PC and Fly Ash Binder Materials Characterization

Binder Type(2)	Characterization Type	Method	Method Description
PC	Physical - PC	ASTM C150	Standard Specification for Portland Cement
		ASTM C1038	Standard Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
FA	Physical - FA	ASTM C311	Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
		ASTM C430	Standard Test Method for Fineness of Hydraulic Cement by the 45-um (No. 325) Sieve
		ASTM C109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-inch or [50-mm] Cube Specimens
		ASTM C151	Standard Test Method for Autoclave Expansion of Hydraulic Cement
		ASTM C604	Standard Test Method for True Specific Gravity of refractory Materials by Gas-Comparison Pycnometer
		ASTM C618	Standard Specification for Coal Fly Ash and raw or Calcined Natural Pozzolan for Use in Concrete
		ASTM D4326	Standard Test Method for Major and Minor Elements in Coal and Coke Ash By X-Ray Fluorescence
		AASHTO M295	Standard Test Method for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

Notes: PC = Portland Cement; FA = fly ash

Table 3-2. Standardized Chemical, Mineralogical, and Strength Testing Methods

Binder Type	Characterization Type	Method	Method Description
FA and Slag	Chemical - PC, FA, and Slag	Major elemental analysis: whole rock analysis using ICP-AES	SiO2, Al203, Fe203, SO3,CaO,MgO, Na2O, K2O, moisture, LOI
Slag	Chemical - Slag	ASTM C989/C989M	Standard Specification for Slag Cement for Use in Concrete and Mortars
PC, FA, and Slag	Mineralogical - PC, FA, and slag from various sources	X-ray diffraction	Various mineral identification
FA and Slag	Cement, Pozzolanic, and Slag Activity Tests – FA and slag from various sources	ASTM C109/C109M	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars
		ASTM C778	Standard Specification for Standard Sand

Notes: PC = Portland cement, FA = fly ash, LOI = Loss on ignition; XRD = X-ray diffraction

Table 3-3 lists the chemical characterization testing methods for the tailings water.

Table 3-3. Tailings Water(1) Materials Characterization using Chemical Methods

Method	Method Description
Ph	MAXXAM (MT): by AT CAM-SOP00413
Dissolved Sulfate (SO_4)	MAXXAM (MT): by Automated Colourimetry/ Kone - CAM-SOP00464
Dissolved Chloride (Cl)	MAXXAM (MT) by Automated Colourimetry/ Kone - CAM-SOP00463
Metals	MAXXAM (MT): by ICPMS CAM-SOP00447

Notes: (1) Decant Water from the filter cake;

ICPMS = Inductively coupled Plasma Mass Spectroscopy;

MAXXAM is an accredited laboratory

4.0 BINDER SELECTION AND SOURCING FOR USE IN THE BBC PASTE

Selection and sourcing of potential binders for the Black Butte Copper project included the following:

- Identifying commercially suitable binder types for the mine operating permit application.
- Identifying suitable existing binder manufacturers and sources (plants). This activity focused on identifying sustainable and cost effective binder sources for the proposed paste fill plant.
- Review of cementing materials mill test certificates and mineralogy (X-Ray Diffraction analyses) for the following types of local binders: Portland cement, fly ash and slag available in Montana.
- Sourcing of potential binders identified.
- Evaluation of binder candidates identified.

The following binders listed in Table 4-1 are available locally at the cement terminals in Missoula, Montana or Three Forks, Montana and could be used in the Black Butte Copper cemented paste mix designs. Geochemical certificates for each binder type listed in Table 4-1 are included in Section 5.0 below.

Table 4-1. List of Acceptable Locally-Sourced Binders Available for Use in the BBC Paste

Binder Type	Supplier	Type	Binder Source	Cement Plant Source
Portland Cement	Lafarge	Type I/II	Richmond B.C., Canada	Missoula, Montana
	Holcim	Type I/II	Three Forks, Montana	Trident Plant in Three Forks, Montana
	Holcim	Envirocore Hydraulic Cement Type GU	Three Forks, Montana	Trident Plant in Three Forks, Montana
Slag	Lafarge	Grade 100 NewCem	Seattle (via Asia)	Missoula, Montana
Fly Ash	Lafarge	Type F	Centralia, WA Power Plant	Missoula, Montana

Notes: (1) Geochemical certificates for each binder type are included in Section 5.0 below; (2) The Lafarge Portland Cement (Type I/II) and the Lafarge Grade 100 NewCem slag were used as the binders for the BBC paste experimental program

5.0 LAB TEST RESULTS FOR BINDER MATERIALS AND TAILINGS WATER

The Standardized test results for the binders and tailings water are presented below and in Appendix K5. The binder index tests and strength characterization tests were completed by Amec Foster Wheeler in Hamilton, Ontario, Canada and are included below in Tables 5-1, 5-2, and 5-3. Plots showing strength activity index of mortar cubes and compressive strength of mortar cubes using various blend ratios of slag and Portland Cement Type I/II (Slag/PC) from Lafarge are shown in Figures 5.1 and 5.2, respectively.

The binder chemical tests have been conducted by several different accredited laboratories. Water may be characterized using chemical methods as defined below in Table 5-4. Maxxam Analytics Laboratory in Hamilton, Ontario conducted the water chemical analyses.

Table 5-1. Results of Strength Development Testing for Portland Cements

		Compressive strength (MPa)			
Cement type		GU*	Lafarge Type I/II	Holcim Type I/II	Holcim Envirocore
Sample No.		NA	S122-15	S134-15	S135-15
Age (days)	3	13.00	27.82	31.15	19.56
	7	20.00	35.42	43.06	26.42
	28	28.00	45.60	47.41	29.89
7-day/28-day (%)		71.43	77.67	90.83	88.39

Notes: (1) *ASTM C1157 standard requirements for hydraulic cements; (2) Data from Amec Foster Wheeler Laboratory in Hamilton, Ontario, Canada; GU = general use

Table 5-2. Results of Pozzolanic activity testing for Lafarge Fly Ash (Sample # S123-15)

FA/PC blend ratio	Flow	Age	Compressive strength		Density		Strength activity index	Compressive strength 7-day/28-day
(%)	%	days	MPa	psi	kg/m^3	lbs/ft^3	%	%
0/100	108	1	17.4	2524	2168	135.4	-	-
		3	27.8	4034	2157	134.5	-	-
		7	35.4	5136	2132	133.1	-	77.73
		28	45.6	6607	2163	135.0	-	-
20/80	>130	1	13.0	1890	2157	134.6	75	-
		3	25.6	3707	2163	135.0	92	-
		7	33.9	4921	2174	135.7	96	74.99
		28	45.3	6563	2183	136.3	99	-
40/60	>130	1	7.6	1105	2172	135.6	44	-
		3	19.6	2837	2164	135.1	70	-
		7	27.5	3981	2159	134.8	78	66.31
		28	41.4	6004	2217	138.4	91	-
60/40	>130	1	3.4	494	2210	138.0	20	-
		3	10.1	1459	2243	140.0	36	-
		7	16.2	2356	2169	135.4	46	65.58
		28	24.8	3593	2214	138.2	54	-

Note: Data from Amec Foster Wheeler Laboratory in Hamilton, Ontario, Canada

Table 5-3. Results of Slag Activity Testing of Lafarge Slag (Sample S124-15).

Slag/PC blend ratio	Flow	Age	Compressive strength		Density		Strength activity index	Compressive strength 7-day/28-day
	%	days	MPa	psi	kg/m^3	lbs/ft^3	%	%
0/100	111	1	17.4	2,524	2,168	135.4	-	-
		3	27.8	4,034	2,157	134.7	-	-
		7	35.4	5,136	2,132	133.1	-	77.73
		28	45.6	6,607	2,163	135.0	-	-
25/75	76	1	13.8	2,001	2,162	135.0	79	-
		3	25.6	3,707	2,163	135.0	92	-
		7	35.3	5,120	2,174	135.7	100	77.81
		28	45.4	6,580	2,206	137.7	100	-
50/50	87	1	9.0	1,301	2,139	133.6	52	-
		3	19.6	2,837	2,164	135.1	70	-
		7	32.9	4,768	2,166	135.2	93	72.37
		28	45.4	6,588	2,185	136.4	100	-
75/25	93	1	5.2	759	2,142	133.7	30	-
		3	10.1	1,459	2,243	140.0	36	-
		7	16.2	2,536	2,169	135.4	46	45.77
		28	35.5	5,148	2,168	135.3	78	-

Note: Data from Amec Foster Wheeler Laboratory in Hamilton, Ontario, Canada

Figure 5.1. Strength Activity Index of Mortar Cubes Using Various Blend Ratios of Slag and Cement Type I/II (Slag/PC) from Lafarge.

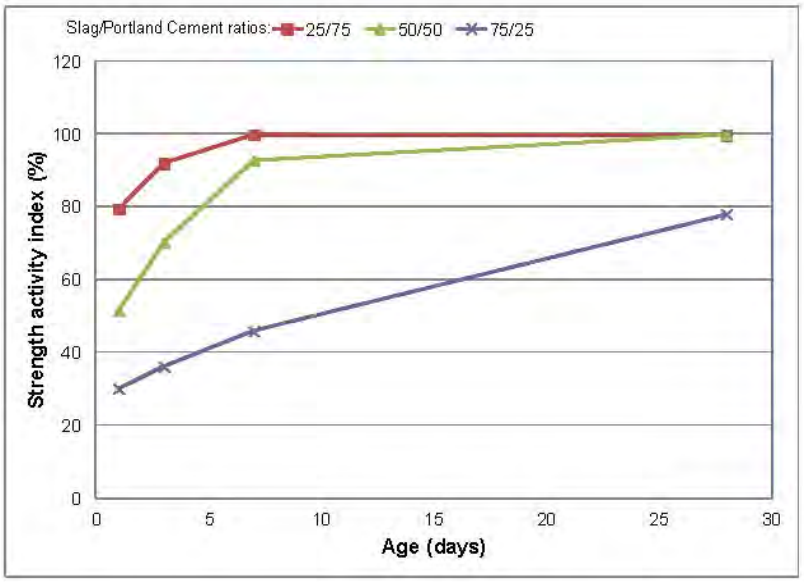


Figure 5.2. Compressive Strength of Mortar Cubes Using Various Blend Ratios of Slag and Cement Type I/II (Slag/PC) from Lafarge.

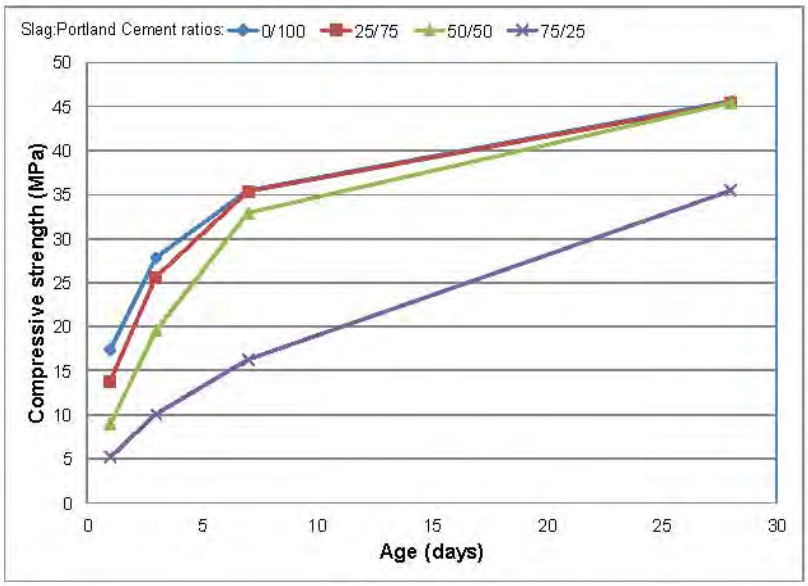


Table 5-4. Chemical Composition of Binders.

Binder sample	**Lafarge Portland Cement Type I/II**	**Lafarge Fly Ash Type F**	**Lafarge Slag**	**Holcim Portland Cement Type I/II**	**Holcim Envirocore™**
Sample Number	**S122-15**	**S123-15**	**S124-15**	**S134-15**	**S135-15**
Element Oxide (%)	(%)	(%)	(%)	(%)	(%)
SiO_2	32.0	46.7	20.4	20.2	18.6
Al_2O_3	13.4	18.1	4.83	4.11	4.14
Fe_2O_3	0.99	5.97	3.45	3.29	2.80
MgO	5.08	5.89	0.70	2.37	1.78
CaO	42.3	15.2	63.4	64.6	63.8
Na_2O	0.23	3.11	0.37	0.17	0.12
K_2O	0.41	1.46	0.31	0.49	0.34
TiO_2	0.50	0.95	0.28	0.21	0.22
P_2O_5	0.03	0.41	0.06	0.05	0.05
MnO	0.23	0.10	0.07	0.04	0.04
Cr_2O_3	<0.01	0.02	0.01	0.02	0.02
V_2O_5	<0.01	0.03	0.01	0.01	0.01
C(t)	0.53	0.07	0.58	0.57	1.49
LOI	1.54	0.55	3.13	2.82	6.22
S	1.50	0.35	1.21	1.10	0.91
SO_3	3.75	0.87	3.02	2.76	2.25
Sum	96.7	98.5	97.0	98.4	98.1

Note: Data from Amec Foster Wheeler Laboratory in Hamilton, Ontario, Canada

Tables 5-5 and 5-6 show the geochemistry of the Lafarge Portland Cement (Type I/II) and the Lafarge slag, respectively.

Table 5-5. Geochemistry of the Lafarge Portland Cement (Type I/II).

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SAMPLE ANALYTE COUNT

Project: Testing
Pace Project No.: 10349606

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
10349606003	Lafarge Type 1 Portland Cement (Type I/II)	EPA 6010C	DM	26	PASI-M
		EPA 7471B	LMW	1	PASI-M
		ASTM D2974	JDL	1	PASI-M

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ANALYTICAL RESULTS

Project: Testing
Pace Project No.: 10349606

SAMPLE ID: Lafarge Type 1 Lab ID #10349606003

SAMPLE DETAILS: Portland Cement (Type I/II)

Sample: Lafarge Type 1 **Lab ID: 10349606003** Collected: 05/23/16 09:00 Received: 05/24/16 12:45 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010C MET ICP	Analytical Method: EPA 6010C Preparation Method: EPA 3050								
Aluminum	**27600**	mg/kg	41.8	1.4	5	05/26/16 10:45	05/31/16 10:27	7429-90-5	
Antimony	**3.9J**	mg/kg	4.2	0.84	5	05/26/16 10:45	05/31/16 10:27	7440-36-0	D3
Arsenic	**28.1**	mg/kg	4.2	0.84	5	05/26/16 10:45	05/31/16 10:27	7440-38-2	
Barium	**987**	mg/kg	2.1	0.067	5	05/26/16 10:45	05/31/16 10:27	7440-39-3	
Beryllium	**0.13J**	mg/kg	1.0	0.11	5	05/26/16 10:45	05/31/16 10:27	7440-41-7	D3
Boron	**23.4J**	mg/kg	31.4	2.7	5	05/26/16 10:45	05/31/16 10:27	7440-42-8	D3
Cadmium	**0.87**	mg/kg	0.63	0.040	5	05/26/16 10:45	05/31/16 10:27	7440-43-9	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: Testing
Pace Project No.: 10349606

Sample: Lafarge Type 1 **Lab ID: 10349606003** Collected: 05/23/16 09:00 Received: 05/24/16 12:45 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010C MET ICP	Analytical Method: EPA 6010C Preparation Method: EPA 3050								
Calcium	**431000**	mg/kg	105	4.8	5	05/26/16 10:45	05/31/16 10:27	7440-70-2	
Chromium	**59.5**	mg/kg	2.1	0.43	5	05/26/16 10:45	05/31/16 10:27	7440-47-3	
Cobalt	**20.1**	mg/kg	2.1	0.11	5	05/26/16 10:45	05/31/16 10:27	7440-48-4	
Copper	**253**	mg/kg	2.1	0.17	5	05/26/16 10:45	05/31/16 10:27	7440-50-8	
Iron	**21700**	mg/kg	10.5	2.7	5	05/26/16 10:45	05/31/16 10:27	7439-89-6	
Lead	**34.7**	mg/kg	2.1	0.42	5	05/26/16 10:45	05/31/16 10:27	7439-92-1	
Magnesium	**4390**	mg/kg	105	1.1	5	05/26/16 10:45	05/31/16 10:27	7439-95-4	
Manganese	**659**	mg/kg	1.0	0.071	5	05/26/16 10:45	05/31/16 10:27	7439-96-5	
Molybdenum	**7.7**	mg/kg	3.1	0.21	5	05/26/16 10:45	05/31/16 10:27	7439-98-7	
Nickel	**17.9**	mg/kg	4.2	1.1	5	05/26/16 10:45	05/31/16 10:27	7440-02-0	
Potassium	**3490**	mg/kg	523	9.1	5	05/26/16 10:45	05/31/16 10:27	7440-09-7	
Selenium	**4.7**	mg/kg	4.2	1.2	5	05/26/16 10:45	05/31/16 10:27	7782-49-2	B
Silver	**1.6J**	mg/kg	2.1	0.33	5	05/26/16 10:45	05/31/16 10:27	7440-22-4	D3
Sodium	**3220**	mg/kg	209	3.5	5	05/26/16 10:45	05/31/16 10:27	7440-23-5	
Thallium	**2.6J**	mg/kg	4.2	0.71	5	05/26/16 10:45	05/31/16 10:27	7440-28-0	D3
Tin	**39.2**	mg/kg	15.7	0.79	5	05/26/16 10:45	05/31/16 10:27	7440-31-5	
Titanium	**1320**	mg/kg	5.2	0.029	5	05/26/16 10:45	05/31/16 10:27	7440-32-6	
Vanadium	**49.2**	mg/kg	3.1	0.056	5	05/26/16 10:45	05/31/16 10:27	7440-62-2	
Zinc	**1010**	mg/kg	4.2	1.2	5	05/26/16 10:45	05/31/16 10:27	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**<0.0043**	mg/kg	0.017	0.0043	1	05/25/16 11:15	05/25/16 21:20	7439-97-6	
Dry Weight	Analytical Method: ASTM D2974								
Percent Moisture	**0.35**	%	0.10	0.10	1		06/02/16 09:56		

REPORT OF LABORATORY ANALYSIS

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QUALIFIERS

Project: Testing
Pace Project No.: 10349606

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

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TNI - The NELAC Institute.

LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis

ANALYTE QUALIFIERS

B	Analyte was detected in the associated method blank.
D3	Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
M6	Matrix spike and Matrix spike duplicate recovery not evaluated against control limits due to sample dilution.
R1	RPD value was outside control limits.

Table 5-6. Geochemistry of the Lafarge 100Grade NewCem Slag.

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(612)607-1700

June 03, 2016

Rob Shogren
Lafarge
5400 W. Marginal Way
Seattle, WA 98106

RE: Project: Testing
Pace Project No.: 10349606

Dear Rob Shogren:
Enclosed are the analytical results for sample(s) received by the laboratory on May 24, 2016. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jenni Gross

Jennifer Gross
jennifer.gross@pacelabs.com
Project Manager

Enclosures

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Minneapolis, MN 55414
(612)607-1700

CERTIFICATIONS

Project: Testing
Pace Project No.: 10349606

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
525 N 8th Street, Salina, KS 67401
A2LA Certification #: 2926.01
Alaska Certification #: UST-078
Alaska Certification #MN00064
Alabama Certification #40770
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
Colorado Certification #Pace
Connecticut Certification #: PH-0256
EPA Region 8 Certification #: 8TMS-L
Florida/NELAP Certification #: E87605
Guam Certification #:14-008r
Georgia Certification #: 959
Georgia EPD #: Pace
Idaho Certification #: MN00064
Hawaii Certification #MN00064
Illinois Certification #: 200011
Indiana Certification#C-MN-01
Iowa Certification #: 368
Kansas Certification #: E-10167
Kentucky Dept of Envi. Protection - DW #90062
Kentucky Dept of Envi. Protection - WW #:90062
Louisiana DEQ Certification #: 3086
Louisiana DHH #: LA140001
Maine Certification #: 2013011
Maryland Certification #: 322
Michigan DEPH Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT0092
Nevada Certification #: MN_00064
Nebraska Certification #: Pace
New Jersey Certification #: MN-002
New York Certification #: 11647
North Carolina Certification #: 530
North Carolina State Public Health #: 27700
North Dakota Certification #: R-036
Ohio EPA #: 4150
Ohio VAP Certification #: CL101
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Oregon Certification #: MN300001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Saipan (CNMI) #:MP0003
South Carolina #:74003001
Texas Certification #: T104704192
Tennessee Certification #: 02818
Utah Certification #: MN000642013-4
Virginia DGS Certification #: 251
Virginia/VELAP Certification #: Pace
Washington Certification #: C486
West Virginia Certification #: 382
West Virginia DHHR #:9952C
Wisconsin Certification #: 999407970

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SAMPLE SUMMARY

Project: Testing
Pace Project No.: 10349606

Lab ID	Sample ID	Matrix	Date Collected	Date Received
10349606004	Lafarge New Cem (Grade 100 Slag)	Solid	05/23/16 09:00	05/24/16 12:45

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SAMPLE ANALYTE COUNT

Project: Fly Ash Testing
Pace Project No.: 10349606

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
10349606004	Lafarge New Cem (Grade 100 Slag)	EPA 6010C	DM	26	PASI-M
		EPA 7471B	LMW	1	PASI-M
		ASTM D2974	JDL	1	PASI-M

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ANALYTICAL RESULTS

Project: Testing
Pace Project No.: 10349606

Sample: Lafarge New Cem **Lab ID: 10349606004** Collected: 05/23/16 09:00 Received: 05/24/16 12:45 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010C MET ICP	Analytical Method: EPA 6010C Preparation Method: EPA 3050								
Aluminum	**49300**	mg/kg	42.7	1.4	5	05/26/16 10:45	05/31/16 10:30	7429-90-5	
Antimony	**<0.85**	mg/kg	4.3	0.85	5	05/26/16 10:45	05/31/16 10:30	7440-36-0	D3
Arsenic	**1.5J**	mg/kg	4.3	0.85	5	05/26/16 10:45	05/31/16 10:30	7440-38-2	D3
Barium	**336**	mg/kg	2.1	0.068	5	05/26/16 10:45	05/31/16 10:30	7440-39-3	
Beryllium	**5.0**	mg/kg	1.1	0.12	5	05/26/16 10:45	05/31/16 10:30	7440-41-7	
Boron	**56.0**	mg/kg	32.0	2.8	5	05/26/16 10:45	05/31/16 10:30	7440-42-8	
Cadmium	**0.16J**	mg/kg	0.64	0.041	5	05/26/16 10:45	05/31/16 10:30	7440-43-9	B,D3
Calcium	**183000**	mg/kg	107	4.9	5	05/26/16 10:45	05/31/16 10:30	7440-70-2	
Chromium	**33.0**	mg/kg	2.1	0.44	5	05/26/16 10:45	05/31/16 10:30	7440-47-3	
Cobalt	**0.48J**	mg/kg	2.1	0.11	5	05/26/16 10:45	05/31/16 10:30	7440-48-4	D3
Copper	**5.1**	mg/kg	2.1	0.17	5	05/26/16 10:45	05/31/16 10:30	7440-50-8	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: Testing
Pace Project No.: 10349606

Sample: Lafarge New Cem **Lab ID: 10349606004** Collected: 05/23/16 09:00 Received: 05/24/16 12:45 Matrix: Solid

Results reported on a "dry weight" basis and are adjusted for percent moisture, sample size and any dilutions.

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010C MET ICP	Analytical Method: EPA 6010C Preparation Method: EPA 3050								
Iron	**2370**	mg/kg	10.7	2.8	5	05/26/16 10:45	05/31/16 10:30	7439-89-6	
Lead	**1.4J**	mg/kg	2.1	0.43	5	05/26/16 10:45	05/31/16 10:30	7439-92-1	D3
Magnesium	**21800**	mg/kg	107	1.1	5	05/26/16 10:45	05/31/16 10:30	7439-95-4	
Manganese	**1150**	mg/kg	1.1	0.073	5	05/26/16 10:45	05/31/16 10:30	7439-96-5	
Molybdenum	**0.38J**	mg/kg	3.2	0.21	5	05/26/16 10:45	05/31/16 10:30	7439-98-7	D3
Nickel	**<1.2**	mg/kg	4.3	1.2	5	05/26/16 10:45	05/31/16 10:30	7440-02-0	D3
Potassium	**2700**	mg/kg	533	9.3	5	05/26/16 10:45	05/31/16 10:30	7440-09-7	
Selenium	**<1.2**	mg/kg	4.3	1.2	5	05/26/16 10:45	05/31/16 10:30	7782-49-2	D3
Silver	**0.39J**	mg/kg	2.1	0.34	5	05/26/16 10:45	05/31/16 10:30	7440-22-4	D3
Sodium	**1170**	mg/kg	213	3.5	5	05/26/16 10:45	05/31/16 10:30	7440-23-5	
Thallium	**2.0J**	mg/kg	4.3	0.73	5	05/26/16 10:45	05/31/16 10:30	7440-28-0	D3
Tin	**1.2J**	mg/kg	16.0	0.81	5	05/26/16 10:45	05/31/16 10:30	7440-31-5	B,D3
Titanium	**1820**	mg/kg	5.3	0.030	5	05/26/16 10:45	05/31/16 10:30	7440-32-6	
Vanadium	**16.1**	mg/kg	3.2	0.057	5	05/26/16 10:45	05/31/16 10:30	7440-62-2	
Zinc	**12.9**	mg/kg	4.3	1.2	5	05/26/16 10:45	05/31/16 10:30	7440-66-6	
7471B Mercury	Analytical Method: EPA 7471B Preparation Method: EPA 7471B								
Mercury	**<0.0045**	mg/kg	0.017	0.0045	1	05/25/16 11:15	05/25/16 21:22	7439-97-6	
Dry Weight	Analytical Method: ASTM D2974								
Percent Moisture	**0.70**	%	0.10	0.10	1		06/02/16 09:56		

REPORT OF LABORATORY ANALYSIS

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(612)607-1700

QUALIFIERS

Project: Testing
Pace Project No.: 10349606

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis

ANALYTE QUALIFIERS

B	Analyte was detected in the associated method blank.
D3	Sample was diluted due to the presence of high levels of non-target analytes or other matrix interference.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
M6	Matrix spike and Matrix spike duplicate recovery not evaluated against control limits due to sample dilution.
R1	RPD value was outside control limits.

The chemistry of the tailings water (decant water from the filter cake) is shown in Table 5-7 below.

Table 5-7. Chemical Composition of the Mine Water.

Parameters	Units	S153-15	RDL
pH	-	6.98	N/A
Dissolved sulphate (SO_4)	mg/L	1200	1
Dissolved chloride (Cl)	mg/L	340	1
Metals			
Total Aluminum (Al)	mg/L	0.020	0.005
Total Arsenic (As)	mg/L	0.240	0.001
Total Calcium (Ca)	mg/L	570	0.2
Total Copper (Cu)	mg/L	0.520	0.001
Total Iron (Fe)	mg/L	<0.1	0.1
Total Lead (Pb)	mg/L	<0.0005	0.0005
Total Magnesium (Mg)	mg/L	12	0.05
Total Nickel (Ni)	mg/L	0.057	0.001
Total Potassium (K)	mg/L	27	0.2
Total Silicon (Si)	mg/L	3.30	0.05
Total Sodium (Na)	mg/L	25	0.1

Note: RDL = reporting detection limit; Data from MAXXAM Analytics Laboratory

K5-C. Paste Characterization, Mixing Procedures, and Laboratory Test Results

1.0 INTRODUCTION

This section describes the cement paste (CP) mix designs tested to date for use in cemented paste for surface deposition (into the CTF) and for cemented paste backfill (CPB) (into the underground workings).

The following sections will:

- Define the physical targets of the paste mix designs for surface deposition and for cemented paste backfill,
- List the standardized testing methods for the paste, and
- Report the laboratory test results for the binders, tailings water, and two paste mix designs (one containing 2% binder and another containing 4% binder).

The Black Butte Copper Tailings will make up a high proportion of the paste designs and the characteristics and index tests have been previously presented in Appendix K5-A.

2.0 CEMENT PASTE MIX DESIGN PHYSICAL TARGETS

Two CP mix design physical targets were established early to guide the BBC experimental paste program:

- The first cemented paste (CP) mix design is for surface deposition with the following targeted physical paste properties:
    - slump for the paste mixes is 7 to 9 inches (~178 - 229 mm) for paste pumpability.
    - No target for unconfined compressive strength (UCS) is available; however UCS and potential strength reduction over time are important for this application.

- The second cemented paste design is for backfill (CPB) with the following targeted physical paste properties:
    - slump for the paste mixes is 6 to 8 inches (~152 - 203 mm) for paste pumpability, and
    - UCS at 14 days for the Johnny Lee Lower and Upper Copper Zones is 150 kPa (0.21 MPa).

3.0 PASTE MIXING PROCEDURES, TESTING PROTOCOLS, AND TEST METHODS

Filter cake Black Butte Copper tailings samples, and binders sourced from Montana cement plants were shipped to Amec Foster Wheeler in Hamilton, Ontario, Canada in 2015. The filter cake tailings samples were prepared and shipped by International Metallurgical and Environmental Inc. in two shipments (sample ID numbers S153-15 and S173-15).

Index tests were first completed on the tailings paste without binder as discussed in Section 3.1 below. CSP mixes were designed later and are described in Section 3.2 below.

3.1 Paste Index Tests

Due to the limited availability of tailings for the project, index tests were conducted on the tailings paste without binder to gain a preliminary understanding of the material behavior in terms of physical properties and rheology (Table 3-1). Small samples were prepared in a Hobart mixer for the following solids concentrations ranging between 75% and 85% by weight. The solids concentrations used were: 75%, 77.50%, 80%, 82.50%, and 85% by adding solids to the mix.

Cylinder slump measurements were taken for each solids concentration. Cylinder, or Boger slump uses an open-ended cylinder having an aspect ratio of 1:1. The cylinder used is typically 3" (75 mm) diameter by 3" (75 mm) tall. Cylinder slump measurement is used and accepted in the mining industry to predict with reasonably accuracy the yield stress values when compared with the vane rheometer results, as described in Pashias et al. (1996). When the mix became very stiff the solids content was not increased any further and the index testing was stopped.

Table 3-1. Trial Batches Paste No Binder.

No.	Cw	Cylinder slump		Cone slump	
	(%)	mm	inches	mm	inches
1	84.00	10	0.39	85	3.35
2	83.00	15	0.59	170	6.69
3	82.50	20	0.79	210	8.27
4	82.00	24	0.94	230	9.06

3.2 Paste Mix Design

CSP mixes were designed to be workable and to meet the project cone slump requirements. The batches used for fresh and hardened paste mix properties had a total batch mass of approximately 51 pounds (23 kg). The amount of water for each batch was determined based on slump measurements conducted in trial batches. The term "Cw" used in the data tables represents the total solids content of the mix, accounting for all water (both mix water and absorbed water on the aggregate). For example, a mix with 165 pounds (75 kg) of dry aggregate, 11 pounds (5 kg) of dry binder, and 44 pounds (20 kg) of water would have a Cw of 80.0%.

3.3 Paste Mixing Procedures

The mixing procedure for the two paste dosages (2% binder content and 4% binder content) is described below. The sample preparation and curing was done in accordance with ASTM C192 / C192M – Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory. The CSP mixes were batched in a 66 pound (30 kg) capacity rheometer mixer according to a general mixing procedure described below:

- Tailings were placed in the mixer.
- The cementitious materials were added.
- Mixing water (Ontario tap water) was added.
- The ingredients were mixed for 3 to 4 minutes.
- Cylinder slump was measured as described in Section 3.1 above.
- Cone slump was measured following ASTM C143 Standard Test Method for Slump of Hydraulic Cement Concrete.
- The mix was further mixed for 1 minute.
- The mix was tamped into the molds while filling the molds for the density and USC samples.

Twelve 2" x 4" (51 mm x 102 mm) and eight 3" x 6" (76 mm and 152 mm) cylinder specimens were prepared for each mix for density and UCS measurements, as well as specimens for geochemistry and triaxial tests. All of the specimens were cured in the curing room at 20°C (70° F) and 100% relative humidity and demolded prior to the density and UCS tests.

3.4 Paste Test Work Steps

The cemented paste test work was conducted in three sequential steps:

1. Index tests were conducted as detailed in Section 3.1 above.
2. Trial batches were conducted to develop mix designs to meet the target properties, including slump, while maximizing the tailings content for a given binder and binder dosage rate. Upon completion of the trial batches the fill and water content for CSP mixes with different binder dosage rates was defined for the full size batches tested in the test program.
3. CSP test program was conducted assuming the following variables (factors):
    - Slump: mixes with one nominal slump value of 8 inches (203 mm) were designed and evaluated in this program.
    - Binder type: one blend of Portland cement Type I/II and slag from Lafarge based on the certificates presented in Appendix K5.
    - Binder dosage rate: mixes with two binder dosage rates were evaluated in the test program: 2% and 4%.

Table 3-2 lists the paste standardized test methods for the fresh mix properties that have been completed for the two different binder dosages: one with 2% total binder (1% Lafarge Portland Cement Type I/II and 1% Lafarge slag), and the other with 4% total binder (2% Lafarge Portland Cement Type I/II and 2% Lafarge slag). Table 3-3 lists the standardized test methods for the hardened properties for the two different binder dosages noted above.

Table 3-2. List of Paste Tests: Fresh Mix Properties

Mix Property	Method (ASTM or Other)	ASTM Description
Cylinder Slump (or Boger slump)	Defined in Pashias et al. (1996)(1)	Used to predict yield stress values (Standard Industry best practice) and is compared to vane rheometer results
Cone Slump	ASTM C143	Standard Test Method for Slump of Hydraulic Cement Concrete
Set Time	ASTM C191	Standard Test Methods Time and Setting of Hydraulic Cement by Vicat Needle
	ASTM C192/C192M	Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
	ASTM C150/C150M	Standard Specification for Portland Cement
Rheology	Used Haake Viscotester 550 instrument (the configuration used in the testing is the standard used in the Paste backfill Industry)(2)	Data collected includes: (1) calculated yield stress (based on the cylinder slump measurement and accepted as a reasonably accurate yield stress value when compared with the vane rheometer results, (2) rheometer yield stress (determined as the peak shear stress), and (3) the Bingham yield stress (defined as the yield stress above which the material becomes fluid)

Notes: (1) Pashias, N, Boger D.V., Summers, J. and Glenister, D.J., A fifty cents rheometer for yield stress measurement, Journal of Rheology, vol. 40, issue 6, 1996, pp. 1179-1189.
(2) The Haake Viscotester configuration used an immersion sensor system FL100 (radius 0.43-inches (11 mm) and height of 0.63 inches (16 mm) and/or FL10 (radius 20 mm (0.79 inches (20 mm) and height of 2.36 inches (60 mm) with star shaped rotor was used for rheology property measurements. The rotor size was selected based on sample consistency for maximum machine resolution. The shear rate ranged from 0 s^{-1} to 40 s^{-1} and back to 0 s^{-1}. For each solids concentration information including shear rate, shear stress, and viscocity were recorded using a computer program.

Table 3-3. Paste Tests: Hardened Properties

Mix Property	Method (ASTM or Other)	ASTM Description
Hardened Density	ASTM C642	Standard Test Method for Density , Absorption, and Voids in Hardened Concrete
Unconfined Compressive Strength	ASTM C39/C39M	Standard Test Method for Compressive Strength of Cylinderical Concrete Specimens

3.5 Cemented Tailings Paste Test Results Using 2% and 4% Total Binders

The laboratory test results for the two cemented tailings paste mix designs using 2% and 4% total binder dosage rates are presented in Tables 3-4, 3-5, 3-6, 3-7, 3-8, and 3-9. Each paste sample tested used 50% Lafarge Grade 100 NewCem slag and 50% Lafarge Portland Cement (Type I/II) sourced from the Missoula, Montana cement plant.

Table 3-4. Surface paste Mix Designs

No.	Mix Label	Binder type (%)		Binder dosage rate	Cw	Cylinder slump	
		PC	S	(%)	(%)	(mm)	(inches)
1	LCT-S50-2	50	50	2	79.50	16	0.63
2	LCT-S50-4	50	50	4	79.00	15	0.59

No.	Mix Label	Cone slump		Testing age	Cylinder specimen
		(mm)	(inches)	(days)	
1	LCT-S50-2	210	8.27	7, 14, 28, 56	2”x4”, 3”x6”
2	LCT-S50-4	205	8.07	7, 14, 28, 56	2”x4”, 3”x6”

Table 3-5. Hydraulic Conductivity of Paste With 2% and 4% Total Binders.

Sample Tested		Surface paste 2% binder, 50%S-50% PC	Surface Paste 4% binder, 50%S-50% PC
Sample Number		LCT-550- 2	LCT-550-4
Test Method	Results	(cm/s)	(cm/s)
Hydraulic conductivity (k)	Average inflow (run #1	1.69×10^{-06}	9.50×10^{-09}
	Average outflow (run #1)	1.64×10^{-06}	1.09×10^{-08}
	Average of inflow and outflow (run #1)	1.66×10^{-06}	1.02×10^{-08}
	Average inflow (run #2)	-	-
	Average outflow (run #2)	-	-
	Average of inflow and outflow (run #2)	-	-
	Overall Average	1.6×10^{-06}	1.0×10^{-8}

Table 3-6. Trial Batches Paste 2% Binder.

No.	Cw	Cylinder slump		Cone slump	
	(%)	mm	inches	mm	inches
1	80.00	14	0.55	155	6.1
2	79.50	16	0.63	210	8.3

Table 3-7. Trial Batches Paste 4% Binder.

No.	Cw	Cylinder slump		Cone slump	
	(%)	mm	inches	mm	inches
1	82.00	0	0.00	0	0
2	81.50	6	0.24	65	2.6
3	81.00	10	0.39	80	3.1
4	80.00	10	0.39	115	4.5
5	79.00	15	0.59	205	8.1

Table 3-8. Surface Paste Density Results up to 28 Days Using 2% and 4% Binder Contents and Different Cylinder Sizes

Batch #	Mix label	Binder dosage rate	Cone slump		Density results, 3" x 6" cylinders											
					Age (days)											
					7				14				28			
					Average		St. Dev.		Average		St. Dev.		Average		St. Dev.	
		(%)	(mm)	(inches)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)
1	LCT-S50-	2	210	8.27	-	-	-	-	-	-	-	-	2260	3810	-	-
2	LCT-S50-	4	205	8.07	2270	3826	-	-	2258	3805	-	-	2294	3867	-	-

Batch #	Mix label	Binder dosage rate	Cone slump		Density results, 2" x 4" cylinders											
					Age (days)											
					7				14				28			
					Average		St. Dev.		Average		St. Dev.		Average		St. Dev.	
		(%)	(mm)	(inches)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)	(kg/m^3)	(lb/yd^3)
1	LCT-S50-	2	210	8.27	-	-	-	-	-	-	-	-	-	-	-	-
2	LCT-S50-	4	205	8.07	2366	3988	14.5	24.4	2365	3987	8.2	13.9	2370	3995	10.9	18.4

Table 3-9. Surface Paste UCS Test Results up to 28 Days Using 2% and 4% Binder Contents and Different Cylinder Sizes

Batch #	Mix label	Binder dosage rate	Cone slump		UCS results, 3" x 6" cylinders											
					Age (days)											
					7				14				28			
					Average		St. Dev.		Average		St. Dev.		Average		St. Dev.	
		(%)	(mm)	(in)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)
1	LCT-S50-2	2	210	8.27	0.00	0.00	-	-	0.00	0.00	-	-	0.09	12.85	-	-
2	LCT-S50-4	4	205	8.07	0.50	73.15	-	-	0.85	123.08	-	-	1.12	162.20	-	-

Batch #	Mix label	Binder dosage rate	Cone slump		UCS results, 2" x 4" cylinders											
					Age (days)											
					7				14				28			
					Average		St. Dev.		Average		St. Dev.		Average		St. Dev.	
		(%)	(mm)	(in)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)
1	LCT-S50-2	2	210	8.27		-	-	-		-	-	-		-	-	-
2	LCT-S50-4	4	205	8.07	0.50	71.80	0.012	-	0.94	136.68	0.007	1.01	1.14	164.8	0.12	18.12

4.0 CONCLUSIONS

The results of the cement tailings paste testing include:

- The optimum C_w for the 2% binder mix is 79.5% at a cone slump of 8.3".
- The optimum C_w for the 4% binder mix is 79% at a cone slump of 8.1".
- The 2% binder mix does not achieve final set until approximately 28 days age.
- The 4% binder mix achieves final set after approximately 96 hours (4 days).
- All the 28 day UCS test results for the 4% binder mix show a continued increase in strength when compared to 7-day results.
- The 4% binder mix achieves 0.85 MPa at 7 days, 1.12 MPa at 28 days.

K5-D. Photograph Log Trial Batches 2% Binder

PHOTOGRAPHIC RECORD

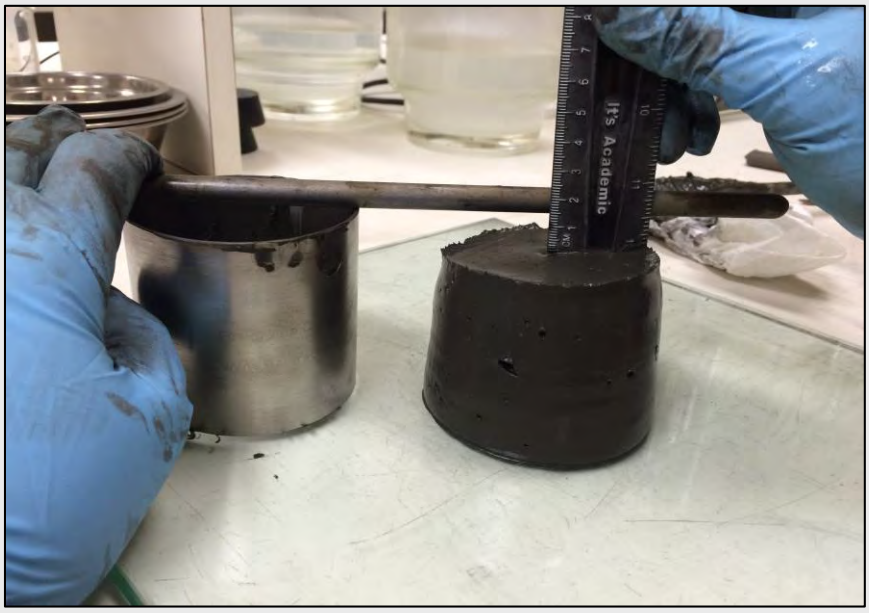
PHOTOGRAPH	1

Description
LST tailings (#S153-15), Cw=80%, 2%, cylinder slump 14mm

PHOTOGRAPH	2

Description
LST tailings (#S153-15), Cw=80%, 2%, cone slump 155mm

PHOTOGRAPHIC RECORD



PHOTOGRAPH	3

Description
LST tailings (#S153-15), Cw=79.5%, 2%, cylinder slump 16mm

PHOTOGRAPH	4

Description
LST tailings (#S153-15), Cw=79.5%, 2%, cone slump 210mm

K5-E. Photograph Log Trial Batches 4% Binder

PHOTOGRAPHIC RECORD

PHOTOGRAPH	1

Description
LST tailings (#S153-15), Cw=81.5%, 4% binder, cylinder slump 6mm

PHOTOGRAPH	2

Description
LST tailings (#S153-15), Cw=81.5%, 4% binder, cone slump 65mm

PHOTOGRAPHIC RECORD

PHOTOGRAPH	3

Description
LST tailings (#S153-15), Cw=81%, 4% binder, cylinder slump 10mm

PHOTOGRAPH	4

Description
LST tailings (#S153-15), Cw=81%, 4% binder, cone slump 80mm

PHOTOGRAPHIC RECORD

PHOTOGRAPH	5

Description
LST tailings (#S153-15), Cw=80%, 4% binder, cylinder slump 10mm

PHOTOGRAPH	6

Description
LST tailings (#S153-15), Cw=80%, 4% binder, cone slump 115mm

PHOTOGRAPHIC RECORD

PHOTOGRAPH	7

Description
LST tailings (#S153-15), Cw=79%, 4% binder, cylinder slump 15mm

PHOTOGRAPH	8

Description
LST tailings (#S153-15), Cw=79%, 4% binder, cone slump 205mm