SUPPORTING DOCUMENT 5

GIANT MINE ARSENIC TRIOXIDE DUST PROPERTIES

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Prepared for:

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

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GIANT MINE STABILIZATION OF ARSENIC TRIOXIDE DUST

1. INTRODUCTION

Over the past twenty years there have been several studies to measure the physical and chemical properties of the Giant Mine arsenic trioxide dust:

- Geocon Inc. (1981) sampling & geotechnical properties
- Jenike & Johanson (1982) flow properties
- Royal Oak Mines Inc. (1998) chemical analysis
- CANMET (2000) chemical properties
- Lakefield Research (2002) physical and thermal properties

Sections 2 to 6 of this report provide a summary of the relevant test results, including a brief description of the methods used.

An overall summary of the dust properties is presented in Section 7.

2. MINE BACKFILL SAMPLING PROGRAMME, GIANT MINE GEOCON INC, (1981)

Geocon collected and tested arsenic trioxide dust from seven of the arsenic stopes (B208, B230, B233, B234, B235, B236 and C9) during the summer of 1981. Samples collected from these stopes represent dust that was placed from 1951 to 1980. Boreholes were completed using a reverse circulation drill, with one borehole installed in each of the stopes. A complete list of samples is provided in Table 1. Most of the samples were collected using a split spoon sampler. Some of the samples from B233, B234 and C9 were collected using a Shelby tube sampler. Bulk dust samples were also collected from each stope.

The samples were submitted for physical tests, including Atterberg Limits, grain size, density, specific gravity, angle of repose and angle of internal friction. All of the laboratory tests were done using ASTM Standard Methods. The results are provided in Tables 2 through 7.

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In 1982, the Giant Mine Laboratory completed arsenic and gold analyses on the Geocon dust samples. Results from these tests are provided in Table 8.

TABLE 1Dust Sample Locations(Feet below ground surface)

				Stope Number			
Sample	B208	B230	B233	B234	B235	B236	С9
No.	(1962–1964)	(1951–1952)	(1952–1956)	(1956–1958)	(1958–1962)	(1958–1962)	(1976–1980)
Split Spoons							
1	138'4'' –		145'3'' –		123'0''-	144'0''-	109'0''-
1	148'4"		167'4"		149'10"	157'9"	110'6"
2	147'7''-		178'10''-	125'0''-	176' –	162'6''-	122'6''-
2	149'6"		182'3"	126'6"	177'6"	168'8"	128'
2	152'4''-		189'2''-		194'2''-	192'6''-	134'6'' –
5	154'4"		190'8"		195'8"	199'4"	138'6"
1	167'10'' –		218'10''-	144'8''-	213'6" –	222'6''-	142'3''-
4	169'4"		221'6"	146'8"	215'0"	227'8"	158'9"
5	188'10'' –			172'8''-	217'9''-		162'9" –
5	190'10"			176'6"	219'3"		167'9"
6				178'8''-			174'1''-
0				192'8"			178'7"
7				188'8''-			170'11'' –
/				207'0"			242'3"
Shelby T	ubes						
1		225' - 251'					
2		253'6''-					
2		265'					
2				132'8''-			
3				135'2"			
1							140' –
4							142'6"
5			230' -				158'7'' –
3			232'6"				161'5"
6			222'1''-				170'11'' –
0			224'7"				173'5"

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TABLE 2 Atterberg Limits (Geocon, 1981)

Stope	B230	B234	B236
Liquid Limit	inconclusive	inconclusive	inconclusive
Plastic Limit	24%	20%	19%

Note: tests completed on bulk dust samples.

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TABLE 3

Grain Size

(Geocon, 1981)

Stope	B208	B208	B230	B233	B234	B235	B236
Sample	1	4	1	4	3	2	Bulk
% <0.045mm	98.2%	100%	100%	100%	100%	90.8%	100%

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TABLE 4

Dry Density

(Geocon, 1981)

Stope	B208	B230	B230	B233	B234	B235	B236	С9	С9	C9
Sample	Bulk	Bulk	1	Bulk	Bulk	Bulk	Bulk	Bulk	2	5
Max* (p.c.f)	69.1	77.3		82.3	85.3	84.2	74.6	91.1		
Min* (p.c.f)	39.7	48.3		50.7	55.6	53.3	41.6	55.1		
In-situ**			101.3						96.2	83.7
(p.c.f)										
% moisture			10.1						1.6	0.6

* ASTM STP No.523 (1973) Relative density involving cohesionless soils.

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** Determined from weight and volume of recovered samples in Shelby tubes. Due to sampling conditions, values are not considered representative by Geocon, with the possible exception of Stope C9 sample 5.

TABLE 5Specific Gravity(Geocon, 1981)

Stope	B208	B230	B233	B234	B235	B236	C9
Sample	1	1	3	3	2	Bulk	3
Sp.	3.22	3.17	3.15	3.23	2.59	3.79	3.06
gravity							

Note: Standard procedure was performed using alcohol instead of water.

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TABLE 6

Angle of Repose

(Geocon, 1981)

Stope	B208	B230	B233	B234	B235	B236	С9
Sample	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk
Board	-	-	58.0°	55.5°	52°	57°	49°
Cone $4 \frac{1}{4}$ "	-	-	49.4°	55.5°	48°	52°	50°
Base							
Cone 10" base	46.4°	47.7°	46.7°	46.1°	46.7°	48.7°	48°

Note: Tests by 10" base cone were found to be more consistent. Therefore, testing by the other two methods was not completed for all samples.

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TABLE 7

Angle of Internal Friction (Geocon, 1981)

Stope	B230	B236	С9
Sample	Bulk	Bulk	Bulk
Cohesion	0	0	0
intercept			
Angle of friction	35°	33°	34°

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Stope	Sample	Arsenic	Gold	Comment
		(%)	(opt)	
B 230	1	35.08%	0.67	Shelby Tube
	2	46.77%	0.63	
	3	47.40%	0.85	Shelby Tube
		43.08%	0.72	Average of discrete samples
		50.56%	0.76	Bulk sample - vacuum
B 233	1	48.03%	1.23	
	2	40.76%	1.27	
	3	31.28%	1.40	
	4	31.92%	1.49	Average of 2 samples
	5	30.02%	1.50	Shelby Tube
	6	34.44%	1.35	Shelby Tube
		36.08%	1.37	Average of discrete samples
		47.08%	0.88	Bulk sample - vacuum
B 234	1			
	2			
	3	27.81%	2.66	Shelby Tube
	4	29.0%	2.46	
	5	42.0%	2.18	
	6	38.2%	2.34	
	7	38.8%	2.18	
		35.16%	2.36	Average of discrete samples
		35.70%	2.44	Bulk sample - vacuum
B 235	1	56.5%	0.74	
	2	52.8%	0.75	Average of 2 samples
	3	59.2%	0.90	
	4	49.9%	0.86	
	5	57.2%	0.83	
		55.12%	0.82	Average of discrete samples
		58.00%	0.60	Bulk sample - vacuum

 TABLE 8

 Chemical Analyses (Giant Mine Laboratory, June 1982)

Stope	Sample	Arsenic	Gold	Comment
		(%)	(opt)	
B 236	1	38.8%	0.76	
	2	49.6%	0.88	
	3			
	4	53.4%	0.80	
		47.27%	0.81	Average of discrete samples
		60.67%	0.27	Bulk sample - vacuum
B 208	1	45.98%	0.28	Average of 2 samples
	2	56.25%	0.30	
	3	67.31%	0.41	Average of 2 samples
	4	65.73%	0.35	
	5	57.83%	0.38	
		58.62%	0.34	Average of discrete samples
		51.51%	0.19	Bulk sample - vacuum
C 9	1	40.76%	0.20	
	1A	66.13%	0.17	
	2			
	2A	73.06%	0.09	
	3			
	3A	74.21%	0.08	
	4	50.50%	0.06	Shelby Tube
	4A	68.44%	0.06	
	5	70.01%	0.05	Shelby Tube
	5A	68.44%	0.07	
	6	56.20%	0.06	Shelby Tube
	6A	71.52%	0.09	
	7	70.36%	0.14	
		64.51%	0.10	Average of discrete samples
		59.60%	0.16	Bulk sample - vacuum

 TABLE 8

 Chemical Analyses (Giant Mine Laboratory, June 1982) (cont'd)

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3. FLOW TEST RESULTS FOR ARSENIC SAMPLE. JENIKE & JOHANSON LTD. (1982)

Jenike & Johanson tested the flow properties of two of Geocon's bulk samples (from stopes B235 and C9). A limited set of tests was completed on both samples to determine which sample had the worst flow characteristics, and that sample (B235) was subjected to a complete set of tests. Testing was conducted at the as-received moisture content of 0.7%.

Flow properties were expressed in terms of bin dimensions and maximum hopper angles at three residence times. Bulk density was also determined. Test results and diagrams of the three bin types with key parameters identified are provided in Appendix A. The bulk density data is provided below.

TABLE 9Consolidation vs. Bulk Density (Stope B235 Sample)(Jenike & Johanson, 1982)

Major consolidating pressure (lbs/ft ²)	29	62	172	372	806	1746	3780	8187
Bulk density (lbs/ft ³)	57.2	61.9	68.7	74.4	80.6	87.3	94.5	102.3

Prepared by: DDS Checked by: CK

4. ARSENIC TRIOXIDE MANAGEMENT, GIANT MINE NT ROYAL OAK MINES INC. (1998)

Royal Oak Mines prepared a report outlining arsenic trioxide management practices and options for permanent disposal, as per the Giant Mine's Water License. This report included results of chemical analyses on a composite sample of arsenic trioxide dust that was collected in September, 1997 from the baghouse. The results are provided in Table 10.

TABLE 10

Analysis of Baghouse Dust (Composite Sample September 1997)

Parameter	Unit	Giant Lab	Lakefield	Maxxam
As	%	66.09	68.5	58.10
Sb	%	1.05	1.16	1.39
Fe	%	2.50	1.50	1.61
Al	ppm		5500	2540
Ba	ppm		15	2
Be	ppm		<1.0	< 0.1
Cd	ppm		<5.0	1.1
Ca	ppm		3900	3540
Cr	ppm		14	11.3
Со	ppm		20	17.1
Cu	ppm		350	143
La	ppm		<50	1.61
Pb	ppm		490	453
Li	ppm			2.9
Mg	ppm		2600	2270
Mn	ppm		80	94.1
Hg	ppm			14.3
Мо	ppm		<10	1.9
Ni	ppm		44	41.3
Р	ppm		62	41
K	ppm		1600	178
Se	ppm		<50	<1
Si	ppm			429
Ag	ppm			3.1
Na	ppm		390	185
Те	ppm		<10	
T1	ppm			0.13
Sn	ppm		<20	
Ti	ppm			12.7
U	ppm			<50
V	ppm			10.9
Y	ppm		<5.0	
Zn	ppm		170	137
Zr	ppm			1.27

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5. RECOVERY AND PURIFICATION OF ARSENIC OXIDE – GIANT MINE. CANMET (2000)

CANMET was contracted by DIAND to investigate options for producing a purified arsenic oxide product suitable for sale. The options investigated were hot water leaching of arsenic trioxide dust and resublimation of the dust. During the course of these investigations, the solubility of arsenic trioxide dust at various temperatures was determined. Mineralogical examinations were completed to evaluate the nature of the feed and products. Testing was completed on four samples, including composite samples of dust collected in April, 1997 and January, 1998, and dust from Chamber 212 and 236. Dust was placed in these chambers from 1965 to 1971 and from 1958 to 1962, respectively. The two chamber samples were retrieved by Giant Mine staff. The two composite samples were probably collected from the baghouse. The mineralogical examination consisted of X-ray diffraction and scanning electron microscopy (SEM) with energy dispersive X-ray analysis (EDX). Quantitative analyses of particles were determined by electron microprobe. Chemical analysis results of the four samples are presented in Table 11.

TABLE 11Chemical Analysis of Arsenic Trioxide Dust(CANMET, 2000)

	Com					
	Com	posite	Composite		Chamber	Chamber
As (%)	68.2	68.7	66.7	69.6	56.2	58
Sb (%)	0.87	0.84	1.48	1.49	2.13	0.3
Fe (%)	1.23	1.17	0.78	0.81	2.62	1.66
Al (%)	0.64	0.64	0.33	0.33	1.06	0.92
Ca (%)	0.4	46	0.	37	0.65	0.57
Mg (%)	0.24	0.26	0.13	0.13	0.37	0.36
Si (%)	1.05	1.09	0.61	0.61	2.07	1.81
Au (ppm)	2.2		2	.4	11.0	5.1

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The X-ray diffraction (XRD) results are summarized in Table 12. The results indicate that the four samples were mineralogically very similar. Each of the samples contained a major amount of As_2O_3 of the arsenolite structure, minor amounts of iron arsenate, minor to trace amounts of an antimony/arsenic trioxide phase, trace amounts of calcium iron arsenate, minor chlorite((Fe,Al,Mg)₆(Si,Al)₄O₁₀(OH)₈), and trace

amounts of muscovite and quartz. Arsenolite was consistently the dominant phase; although, the amounts of chlorite, muscovite and quartz, relative to arsenolite, varied somewhat from sample to sample.

TABLE 12 XRD Results of Four Samples of Arsenic Trioxide Dust (CANMET, 2000)

Species	January 98	April 97	212 Chamber	236 Chamber
	Composite	Composite		
As ₂ O ₃	major	major	major	major
Fe arsenate	minor	minor	minor	minor
(Sb,As) ₂ O ₃	minor	minor	minor	trace
Ca-Fe arsenate	trace	trace	minor	trace
Fe arsenate-sulphate	trace	trace	trace	very rare
Iron oxide	trace	trace	trace	trace
Ca-Fe oxide	very rare	trace	trace	very rare
Ca sulphate	very rare	very rare	trace	very rare
Chlorite	minor	minor	minor	minor
Quartz	trace	trace	trace	trace
Muscovite	minor	minor	minor	minor
	•	1		Prepared by: DDS

Checked by: CK

The composition of the various mineral phases, as determined by electron microprobe, is summarized in Tables 13 to 16. The two more recent samples, January 98 Composite and April 97 Composite, had higher As_2O_3 contents and contained less of the impurity silicate phases. The antimony content of the dusts varied from 0.3 to 2.13%, with antimony occurring as an impurity in the As_2O_3 phase and as a distinct $(Sb,As)_2O_3$ phase. Most of the antimony in the samples was present as a solid solution in the As_2O_3 crystals. The dominant arsenic carrier is the As_2O_3 phase. A minor amount of the arsenic was present as an iron oxide or iron arsenate phase, in which the arsenic content varied from 1.9 to 38%. The calcium arsenate or calcium-iron arsenate phases were only minor arsenic carriers in any of the dust samples. Most of the iron in the samples occurred in silicate form (chlorite) and as iron oxide.

	(CANMET, 2000)									
Element	January 98 Composite		April	97 Composite	21	12 Chamber	23	6 Chamber		
	Avg	Range	Avg	Range	Avg	Range	Avg	Range		
As	75.03	63.04 - 82.11	76.29	71.45 - 82.70	76.01	70.24 - 82.42	76.78	71.43 - 79.87		
Sb	1.31	0.00 - 5.38	0.23	0.00 - 0.54	1.19	0.08 - 3.52	0.19	0.00 - 0.99		
Fe	0.18	0.00 - 2.01	0.18	0.02 - 0.52	0.56	0.25 - 1.72	0.27	0.08 - 1.13		
Pb	0.07	0.00 - 1.88	0.04	0.00 - 0.52	0.03	0.00 - 0.22	0.02	0.00 - 0.13		
Ca			0.04	0.00 - 0.19	0.05	0.00 - 0.30	0.01	0.00 - 0.09		
S			0.03	0.00 - 0.18	0.04	0.00 - 0.15	0.01	0.00 - 0.11		
Si					0.05	0.00 - 0.52	0.05	0.00 - 0.62		
# particles	39		24		31		60			

TABLE 13Composition of the As2O3 Phase (wt%)(CANMET, 2000)

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TABLE 14

Composition of the (Sb,As)₂O₃ Phase (wt%) (CANMET, 2000)

Element	January 98 Composite		April 97 Composite		21	2 Chamber	236 Chamber	
	Avg	Range	Avg	Range	Avg	Range	Avg	Range
As	35.16	28.94 - 38.95	35.94	30.71 - 42.45	50.46	42.57 - 56.72		
Sb	44.65	40.50 - 47.77	44.55	42.43 - 46.72	24.44	20.93 - 31.10		
Fe	0.05	0.01 - 0.09	0.14	0.00 - 0.84	0.33	0.12 - 1.49		
Pb	0.01	0.00 - 0.07	0.06	0.00 - 0.34	0.03	0.00 - 0.11		
Са			0.01	0.00 - 0.11				
S			0.84	0.50 - 1.23	0.01	0.00 - 0.02		
# particles	39		32		?		-	

Prepared by: DDS

Checked by: CK

TABLE 15
Composition of the As-bearing Iron Oxide Phase (wt%)
(CANMET, 2000)

Element	Element January 98 Composite		Ар	ril 97	212 Chamber		236 Chamber	
				Composite				
	Avg	Range	Avg	Range	Avg	Range	Avg	Range
As	4.68	3.15 - 5.87			8.54	3.51 - 14.88	7.67	1.97 – 14.90
Sb	1.67	1.15 - 2.10			3.09	0.77 - 9.89	0.56	0.18 - 0.90
Fe	59.11	57.51 - 61.11			52.41	44.90 - 57.53	53.24	40.88 - 66.34
Pb	0.10	0.05 - 0.17			0.38	0.16 - 0.78	0.22	0.02 - 0.57
S	0.04	0.00 - 0.08			0.33	0.02 - 3.02	0.01	0.00 - 0.04
Ca					0.26	0.00 - 0.99	0.15	0.00 - 0.49
Cr							0.36	0.00 - 6.18
# particles	9		-		16		17	

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TABLE 16

Composition of the Iron Arsenate Phase (wt%) (CANMET, 2000)

Element	January 98		April 97 Composite		212 Chamber		236 Chamber	
	С	omposite						
	Avg	Range	Avg	Range	Avg	Range	Avg	Range
As	15.95	7.92 - 21.63	9.04	6.69 - 11.48	31.67	26.19 - 37.33		
Sb	0.27	0.06 - 0.87	5.20	0.58 - 9.28	0.49	0.38 - 0.73		
Fe	10.15	1.78 - 38.33	38.17	18.35 - 55.31	12.60	11.34 - 13.21		
Pb	0.10	0.04 - 0.19	0.12	0.00 - 0.25	0.72	0.50 - 1.10		
S	3.57	0.23 - 7.41	0.85	0.04 - 1.55	1.58	1.12 - 2.21		
Ca	0.73	0.04 - 4.39	0.82	0.00 - 2.40	0.86	0.64 - 3.46		
Bi	0.03	0.00 - 0.07	0.00	-				
# particles	16		4		21		-	

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Solubility curves were determined for reagent grade As_2O_3 , Sb_2O_3 and each of the four Giant Mine dust samples. Tests were conducted in a reaction vessel contained in a temperature controlled circulating oil bath. Approximately 1.5 L of solution with an excess of dust was stirred with a magnetic stirrer. The slurry was stirred for approximately three days to attain equilibrium. Samples of the solution were withdrawn and analyzed for arsenic, antimony and iron. After the samples were taken, the solution temperature was increased to 100°C in 10°C increments, with samples

collected at each incremental temperature. The solution was then cooled to approximately 95°C and then to room temperature in 10°C steps. A detailed discussion of the sampling methodology is provided in CANMET (2000).

The solubility curves generated by CANMET (2000) are provided in Appendix B. Measured solubility values for reagent grade As_2O_3 and Sb_2O_3 were in general agreement with values published by Linke and Seidell (1965). The solubility of Sb_2O_3 was significantly less than As_2O_3 .

The solubility of arsenic trioxide dust was approximately half that of reagent grade As_2O_3 for all four dust samples (8.3 to 10.8 g/L at 25°C), except for the 236 Chamber sample (15 g/L at 25°C) which was slightly less than the reagent grade material. CANMET (2000) concluded that the low solubility is an inherent property of the dust resulting from the solid solution of antimony in arsenic trioxide crystals. The higher the antimony content the lower the solubility. This effect appears to be most apparent when antimony is in the range of 0 - 0.5%.

Typical temperatures in the underground at Giant Mine are 5°C in the upper levels and 10°C in the deeper levels (Supporting Document 3, Appendix A). The arsenic trioxide dust solubility expected at these temperatures is summarized in Table 17.

TABLE 17Solubility of Arsenic Trioxide Dust

	5°C	10°C
g As ₂ O ₃ /L	6.2 - 11.9	7.4 - 12.7
g As/L	4.7 – 9.0	5.6 - 9.6
	P	repared by: DDS

Checked by: CK

6. AN INVESTIGATION IN THE CEMENT AND BITUMEN STABILIZATION OF GIANT YELLOWKNIFE ARSENIC TRIOXIDE DUST SAMPLES – MEASUREMENT OF PHYSICAL PROPERTIES LAKEFIELD RESEARCH (2002)

Lakefield Research was contracted by DIAND to measure a select number of physical properties as part of a broader program on dust stabilization. Five barrels of dust were retrieved from the Giant Mine warehouse, and submitted for thermal conductivity, permeability and freezing point of saturated solutions. These samples represent dust collected from the baghouse in 1998 and 1999. The test methodology and results are provided in Appendix C. Chemical analyses on the dust are reported in Supporting Document 14, Appendix A. The results are summarized in Tables 18 to 20.

WICCA		(Lakefield, 2002)	C THORIGE Dust
Metal	Unit	Arsenic Trioxide Dust-1	Arsenic Trioxide Dust-2
Ag	g/t	18	19
Al	g/t	15000	15000
Ва	g/t	46	47
Be	g/t	<1	<1
Bi	g/t	<20	<20
Ca	g/t	11000	11000
Cd	g/t	9.3	9.4
Co	g/t	54	57
Cr	g/t	59	59
Cu	g/t	340	360
Fe	g/t	55000	55000
Κ	g/t	5000	5100
Li	g/t	<20	<20
Mg	g/t	7600	7900
Mn	g/t	260	260
Мо	g/t	<20	<20
Na	g/t	1000	1000
Ni	g/t	92	99
Р	g/t	<100	<100
Pb	g/t	1200	1300
Sb	g/t	8600	8300
Se	g/t	<100	<100
Sn	g/t	<100	<100
Sr	g/t	16	16
Ti	g/t	340	300
Tl	g/t	<100	<100
V	g/t	69	70
Y	g/t	<2	<2
Zn	g/t	510	520
As_2O_3	%	66.9	67.9

TABLE 18 Metal Concentrations in Arsenic Trioxide Dust

Prepared by: DDS Checked by: CK

TABLE 19Hydraulic Conductivity(Lakefield, 2002)

Test No.	Compaction	Hydraulic Conductivity
	(g/cm ³)	k (cm/sec)
1	0.83	2.24 x 10 ⁻⁴
2	1.05	0.73 x 10 ⁻⁴
3	1.15	0.67 x 10 ⁻⁴

Prepared by: DDS

Checked by: CK

TABLE 20

Thermal Properties (Lakefield, 2002)

Property	Value
Thermal Conductivity (0% H2O)	0.093 W/m-k
Thermal Conductivity (1% H2O)	0.100 W/m-k
Freezing pt. of saturated solution	-0.7°C
	Prepared by: DDS

Checked by: CK

7. SUMMARY OF ARSENIC TRIOXIDE DUST PROPERTIES

The chemical properties of the arsenic trioxide dust have changed over time as a result of changes to the processing and dust collection systems. These changes are discussed in Section 2 of the main report. The most significant change occurred in 1964, which was the year the final dust collection system was implemented.

Samples from chambers B230, B233, B234, B235, B236 and B208 are categorized as "old" dust (deposited before 1964), while samples from chamber C9 and bulk samples collected from the baghouse in the last few years of mining are categorized as "new" dust (produced since 1964). This age distinction is evident in the chemical analyses and solubility data. Tables 21 and 22 summarize typical values for these properties that can be expected in the underground environment.

Parameter	Unit	"Old" Dust	"New" Dust
As	%	46.42	65.31
Au	opt	1.07	0.094
Sb*	ppm	12200	11078
Fe*	ppm	21400	22889
Al*	ppm	9900	7180
Ca*	ppm	6100	4718
Mg	ppm	3600	2078
Si	ppm	19400	6806
Ва	ppm	-	8.5
Be	ppm	-	<0.5
Cd	ppm	-	1.1
Cr	ppm	-	12.6
Со	ppm	-	18.6
Cu	ppm	-	246
Pb	ppm	-	472
Mn	ppm	-	87
Hg	ppm	-	14
Мо	ppm	-	1.9
Ni	ppm	-	43
Р	ppm	-	52
K	ppm	-	889
Se	ppm	-	<1
Ag	ppm	-	3.1
Na	ppm	-	288
Sn	ppm	-	<20
Zn	ppm	-	154

TABLE 21 Chemical Composition of "Old" and "New" Arsenic Trioxide Dust

* Includes Lakefield (2002) results

Prepared by: DDS Checked by:CK

TABLE 22
Solubility of "Old" and "New" Dust

	5°C	10°C
"Old" dust (g As ₂ O ₃ /L)	11.9	12.7
(g As/L)	9.0	9.6
"New" dust (g As ₂ O ₃ /L)	6.2	7.4
(g As/L)	4.7	5.6
	Prep	oared by: DD
	C	Leeleed benCI

Checked by:CK

The physical properties appear to be consistent between "old" and "new" dust samples, where such comparisons could be made. A summary of the physical properties is provided in Table 23.

TABLE 23Physical Properties of Arsenic Trioxide Dust

Parameter	Unit	Range
Atterberg Limits		
liquid limit		inconclusive
plastic limit	%	19 - 24
Grain Size	% <0.045mm	90.8 - 100
Dry Density		
Maximum	lbs/ft ³	69.1 – 91.1
Minimum	lbs/ft ³	39.7 - 55.6
In-situ	lbs/ft ³	83.7 - 101.3
Specific Gravity		2.59 - 3.79
Angle of Repose		46.1° - 58°
Angle of Internal Friction		33° - 35°
Hydraulic Conductivity	cm/s	6.7×10^{-5}
(at 71.8 lbs/ft ³)	CIII/S	0.7 x 10
Thermal Conductivity		
at 0% H ₂ O	W/m-k	0.093
at 1% H ₂ O	W/m-k	0.100
Freezing pt. of saturated		-0.7°C
solution		0.7 C

Prepared by: DDS Checked by: CK

8. **RECOMMENDATIONS**

While the information available today characterizes the arsenic trioxide dust properties sufficiently for a comparison of alternatives, additional testing will be required once an alternative has been selected. At that time it could be necessary to understand the relevant properties of the dust on a chamber by chamber and stope by stope basis.

It is recommended that samples be collected initially from each period of dust production, and subsequently where additional variability is apparent, from each distinct horizon in each chamber and stope. The testing required will vary depending on which alternative is selected, but the following properties should be considered in all cases:

- In-situ density
- In-situ moisture content
- Specific gravity
- Compressibility
- Grain size
- Susceptibility to liquefaction
- In-situ temperature
- Solubility, thermal conductivity and heat capacity
- Wettability

A phased approach to the testing would be prudent, with additional testing carried out only until trends become clear.

This report, Giant Mine - Arsenic Trioxide Dust Properties, has been prepared by:

STEFFEN, ROBERTSON AND KIRSTEN (CANADA) INC.

Diana Sollner P.Eng. Environmental Engineer

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APPENDIX A Flow Property Data

Jenike & Johanson (1982)

SUMMARY OF TESTS PERFORMED

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This report presents various flow property test results as indicated for the following material(s):

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BULK MATERIAL		DESCRIPT	ION	PARTICL	E SIZE	MOI CON	STURE TENT
1		ARSENIC		AS RECD	•	AS	RECD.
BULK MATERIAL	TIME hr	TEMPERATURE 'F	BIN DIM	BULK DENSITY	HOPPER ANGLES	CHUTE ANGLES	FLOW RATE
l	0.0	72 to 74	x	x	x		
	24.0	72 to 74	x				
	168.0	72 to 74	x		х		

Usenike & Johanson Ltd.

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PARTICLE SIZE AS RECD. MOISTURE CONTENT AS RECD.

SECTION I. BIN DIMENSIONS FOR DEPENDABLE FLOW (in ft)

STORAGE TIME AT REST 0.0 hr TEMPERATURE 72 deg F to 74 deg F

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PART A. BINS WITH UNLIMITED MAXIMUM SIZE

	MASS	FLOW	FU	N N E	L	FL	O W			
P-FACTOR	BC	BP	BF	- EH=	2.5	5	10	20	24	ft
	ft	ft	ft							
1.00	1.0	0.5	0.6	DF=	2.4	4.6	8	14	15	ſt
1.25	1.2	0.6	0.8	DF =	2.9	5	10	15	17	ft
1.50	1.7	0.8	1.3	DF=	3.4	6	11	17	19	ſt
2.00	4.4	2.0	3.9	DF =	4.3	8	13	19	21	ft

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PARTICLE SIZE AS RECD. MOISTURE CONTENT AS RECD.

STORAGE TIME AT REST 24.0 hr

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TEMPERATURE 72 deg F to 74 deg F

PART A. BINS WITH UNLIMITED MAXIMUM SIZE

	MASS	FLOW	FU	NNE	L	ΓL	. O W			
P-FACTOR	BC	BP	BF	EH=	2.5	5	10	20	24	ft
	ft	ft	ft							
1.00	1.9	1.0	1.0	DF=	2.7	4.3	8	14	17	ft
1.25	2.2	1.1	1.2	DF=	3.0	5	9	17	20	ft
1.50	2.5	1.2	1.4	DF =	3.4	6	10	20	24	ft
2.00	3.5	1.7	2.7	DF=	4.1	7	13	25	30	ft

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PARTICLE SIZE AS RECD. MOISTURE CONTENT AS RECD.

STORAGE TIME AT REST 168.0 hr TEMPERATURE 72 deg F to 74 deg F

.

*

Sec. 1

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PART A. BINS WITH UNLIMITED MAXIMUM SIZE

	MASS	FLOW	F U I	N N E	L	FL	ΟW			
P-FACTOR	BC	BP	BF	EH=	2.5	5	10	20	24	ft
	ft	ft	ft.							
1.00	4.4	2.1	2.9	DF=	4.3	7	12	16	17	ft
1.25	6.7	3.2	4.3	DF =	5.0	8	13	17	18	ft
1.50	9.0	4.3	5.4	DF =	6	9	14	18	19	ft
2.00	12.2	6.0	6.8	DF=	7	11	16	20	20	ft

.....

BULK MATERIAL 1: ARSENIC PARTICLE SIZE AS RECD. MOISTURE CONTENT AS RECD. SECTION II. BULK DENSITY TEMPERATURE 72 deg F 10.0 20.0 40.0 80.0 0.5 1.0 2.5 5.0 EH, ft 806. 1746. 3780. 8187. 29. 62. 172. 372. SIGMA1, psf 87.3 94.5 102.3 57.2 61.9 68.7 74.4 80.6 GAMMA, pcf COMPRESSIBILITY PARAMETERS Bulk density GAMMA, is a function of the principal consolidating pressure SIGMAl as follows: BETA GAMMA = GAMMAO (SIGMA1 / SIGMAO) . For GAMMA between 60.3 and 84.1 pcf GAMMAO = 52.7 pcf

SIGMA0 = 13.0 psf

BETA = 0.10296

Sec. 2

Sec. 1

GAMMA MINIMUM = 48.2 pcf

	BUL	<u>k mater</u>	IAL 1:	ARSENI	<u>c</u>		
1	P	ARTICLE	SIZE A	S RECD.			
	мо	ISTURE	CONTENT	AS RECI	D.		
SECTION III. MAXIMUM H	IOPPER AN	GLES FO	R MASS-	FLOW		• * * •	
WALL MATERIAL: STAINLE	SS STEEL	2B FIN	. SHEET				
STORAGE TIME AT REST Temperature 72 deg b	0.0 hrs 5 to 7	4 deg F					
HOPI	PER ANGLE	S FOR V	ARIOUS	HOPPER	SPANS		
WIDTH OF OVAL, ft DIA OF CONE, ft	0.38 0.76	0.50	1.0 2.0	2.0 4.0	4.0 8.0	4.8 9.6	
Wall Friction Angle PHI-PRIME, deg	27.	27.	27.	27.	27.	27.	
Hopper Angles THETA-P, deg THETA-C, deg	24. 12.	24. 12.	24. 12.	24. 12.	24. 12.	24. 12.	
WALL MATERIAL: AGED MI	LD STEEL		*				
STORAGE TIME AT REST TEMPERATURE 72 deg B	0.0 hrs 5 to 7	4 deg F					
НОРІ	PER ANGLE	S FOR V	ARIOUS	HOPPER	SPANS		
WIDTH OF OVAL, ft DIA OF CONE, ft	0.38 0.76	0.50 1.00	1.0 2.0	2.0 4.0	4.0 8.0	4.8 9.6	
Wall Friction Angle PHI-PRIME, deg	40.	39.	37.	34.	31.	32.	
Hopper Angles THETA-P, deg THETA-C, deg	15. 3.	15. 3.	15. 3.	15. 3.	15. 3.	17. 5.	
Note: Flow along walls and conical diam	s is ques neters le	tionabl ss than	e for o 8.25	val wid ft.	ths les:	s than	4.13 ft

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PARTICLE SIZE AS RECD.

MOISTURE CONTENT AS RECD.

WALL MATERIAL: STAINLESS STEEL 2B FIN. SHEET STORAGE TIME AT REST168.0 hrs TEMPERATURE 72 deg F to 74 deg F

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HOPPER ANGLES FOR VARIOUS HOPPER SPANS

WIDTH OF OVAL, ft DIA OF CONE, ft	0.38 0.76	0.50 1.00	1.0 2.0	2.0 4.0	4.0	4.8 9.6
Wall Friction Angle PHI-PRIME, deg	27.	27.	27.	27.	27.	27.
Hopper Angles THETA-P, deg THETA-C, deg	24. 12.	24. 12.	24.	24. 12.	24. 12.	24. 12.

APPENDIX B Solubility Data

(CANMET, 2000)



Fig. 26 - Experimentally determined solubility of As₂O₃ over the January 98 Composite sample.



PROTECTED BUSINESS INFORMATION



Fig. 27 - Experimentally determined solubility of As₂O₃ over the April 97 Composite sample.



Fig. 28 - Experimentally determined solubility of As_2O_3 over the 212 Chamber sample.



PROTECTED BUSINESS INFORMATION



Fig. 29 - Experimentally determined solubility of As_2O_3 over the 236 Chamber sample.

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Fig. 36 - Comparison of the solubilities of As_2O_3 over the four As_2O_3 -rich dust samples as a function of temperature, as obtained on heating only.



APPENDIX C An Investigation in the Cement and Bitumen Stabilization of Giant Yellowknife Arsenic Trioxide Dust Samples – Measurement of Physical Properties

Lakefield Research (2002)

AN INVESTIGATION INTO THE CEMENT AND BITUMEN STABILIZATION

of

GIANT YELLOWKNIFE ARSENIC TRIOXIDE DUST SAMPLES

submitted by

DIAND

LR Project: 10394-001

Progress Report No. 2

Measurement of Physical Properties

NOTE: This report refers to the samples as received. The practice of this Company in issuing reports of this nature is to require the recipient not to publish the report or any part thereof without the written consent of Lakefield Research.

Lakefield Research

185 Concession Street, Postal Bag 4300 Lakefield, Ontario, K0L 2H0 Tel: (705) 652-2024 Fax: (705) 652-1918 July 5, 2002

ABSTRACT

Stabilization tests were conducted on an arsenic trioxide dust sample from the Giant Yellowknife mine, assaying $\sim 69\%$ As₂O₃. Results to date have been presented in Progress Report #1.

Thermal conductivity and permeability (hydraulic conductivity) of the dust as well as saturated solution freezing point were measured.



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INTRODUCTION

Lakefield Research was contracted by DIAND to conduct cement and bitumen stabilization tests on arsenic trioxide dust samples from the Giant Yellowknife mine, and to measure thermal (conductivity, freezing point) and flow (permeability, thickening, filtration) characteristics of the sample.

This report contains all physical measurement results to date. All results have been forwarded to Ms. Diana Sollner, SRK, as soon as they were available.

LAKEFIELD RESEARCH

C. J. Ferron, Ph. D. V.P. Metallurgical Technology

L. Liu, Ph.D., P. Ag. Senior Environmental Scientist

> Q. Wang, Ph.D. Project Metallurgist

Experimental testwork: I Report preparation:

J. Dirycz, C. Silva, L. Liu, Q. Wang, J. Ferron C. Pilley

05/07/02 Master PR 2 July.doc



SUMMARY AND DISCUSSIONS

1. Measurement of Physical Parameters

1.1. Hydraulic Conductivity (Permeability)

The hydraulic conductivity of the dust sample was measured as-received ($\sim 1\%$ H₂O). Because of the high solubility of the dust in water, a saturated solution was first prepared, and then used for the measurement. All test details are appended.

The hydraulic conductivity was measured at room temperature for 3 compaction values of the dust.

Results are summarized below in Table 1.

Test #	Compaction (g/cm ³)	Hydr. Conductivity k (cm/sec)
1	0.83	2.24 10-4
2	1.05	0.73 10 ⁻⁴
3	1.15	0.67 10 ⁻⁴

Table 1: Hydraulic Conductivity of As₂O₃ Dust

1.2. Thermal Conductivity

The thermal conductivity of the As_2O_3 dust sample was measured using a Modified Hot Wire technique at 10°C.

All test details are appended.

The test was conducted on a dry sample and on the sample as-received (~1% moisture).

Results are summarized below in Table 2.



Test #	% Moisture	Thermal Conductivity (W/m-k)
1	0	0.093
2	1	0.100

Table 2:	Thermal	Conductivity	⁹ Measurements

1.3. Freezing Point of As Saturated Solution

An arsenic saturated solution was used for the test.

250 mL of solution was placed in a glass beaker and maintained under constant agitation. The sample was placed in a refrigerated vessel, and the temperature recorded with time until the solution froze. The temperature was measured using thermometers and calibrated thermocouples.

The saturated solution froze at ~ -0.7° C. It was observed that no As₂O₃ crystals were observed in the solution until it solidified.



APPENDICES

APPENDIX 1: PERMEABILITY TESTS

Test Name:	Procedure for Hydraulic Conductivity Test #1
Sample Name:	Arsenic Trioxide Dust at 0.83 g/cm3
Project:	10394-001
Date:	06-Jun-02
Purpose:	To measure the hydraulic conductivity (k) of the aforementioned sample.
Procedure:	The soil core and caps are cleaned and dried. The weight of the entire apparatus is then weighed. This weight will be used to calculate the bulk density of the material. The material is then mixed to make it homogonous. The material is placed into the column in small portions. The material is placed into the core one inch at a time. After each inch has been added it is compacted using a 2" OD PVC pipe with duct tape on the end. The pipe should be raised 5" above the surface of the material and let it drop under its own weight. The pipe should be dropped 5 times for every inch of material added. The material is added to the top of the core collar. The core cap is then screwed on. The weight of the complete apparatus is then taken and recorded. The core is then placed in the clamps on the retort stand. The headspace is then filled with arsenic dust saturated water. This is accomplished by pushing water through the spigot at the top of the core. The burette is then attached to the soil core. The stopcock is then opened and As saturated water is poured into the burette. The water is allowed to saturate the soil core until the core begins to drip water at it's base. The stopcock is then closed. The base of the core is submerged into a container of water to ensure the system is closed. The overflow spout on the container represents the base head level. The burette is then topped up to the zero marking with arsenic saturated water. The distance between the overflow spout and the zero mark on the burette is now measured and recorded, this is the initial head measurement. The stopcock and the stopwatch is opened and started, respectively, simultaneously. The water level and the associated time should be recorded on the record sheet.

a	burette surface area in cm ⁻	1.54
Α	soil core surface area in cm ²	20.27
L	length of soil in core in cm	29.2
t	total elapsed time for test (hours)	1.73
h _l	initial head in cm	115.8
	dry bulk density (g/cm ³)	0.82
	initial head in (g)	487.20

Data:

	Elapsed Time	2	Total	Volume	Head	log (Head)
hr	min	sec	sec	(mL)	(cm)	(cm)
0	0	0	0	7.0	111.85	2.0486
0	5	0	300	12.8	108.58	2.0358
0	10	0	600	18.0	105.65	2.0239
0	15	0	900	23.0	102.83	2.0121
0	20	0	1200	28.8	99.56	1.9981
0	25	0	1500	33.8	96.74	1.9856
0	30	0	1800	37.6	94.59	1.9759
0	40	0	2400	47.0	89.29	1.9508
0	45	0	2700	52.0	86.47	1.9369
0	50	0	3000	57.2	83.54	1.9219
0	55	0	3300	62.4	80.61	1.9064
0	60	0	3600	65.0	79.14	1.8984
0	65	0	3900	70.2	76.21	1.8820
0	70	0	4200	75.0	73.50	1.8663
0	82	0	4920	82.2	69.44	1.8416
0	91	0	5460	90.4	64.81	1.8117
0	100	0	6000	97.0	61.09	1.7860
0	104	0	6240	100.0	59.40	1.7738

used 100mL burette with 0.564 cm/mL gradations

Hydraulic Conductivity, Hyd Cond#1



Summary:

The slope of the linear equation is:

-4.376E-05

The k value is calculated using the following equation:

$$k = (slope)(a)(L)$$

(0.434)(A)

$$k = 2.24E-04$$
 cm/sec

Hydraulic Conductivity, Hyd Cond#1

Test Name:	Procedure for Hydraulic Conductivity Test #2					
Sample Name:	Arsenic Trioxide Dust at 1.05 g/cm3					
Project:	10394-001					
Date:	06-Jun-02					
Purpose:	To measure the hydraulic conductivity (k) of the aforementioned sample.					
Procedure:	The soil core and caps are cleaned and dried. The weight of the entire					
	apparatus is then weighed. This weight will be used to calculate the bulk					
	density of the material. The material is then mixed to make it homogonous.					
	The material is placed into the column in small portions. The material is					
	placed into the core one inch at a time. After each inch has been added					
	it is compacted using a 2" OD PVC pipe with duct tape on the end. The pipe					
	should be raised 5" above the surface of the material and let it drop under its own					
	weight. The pipe should be dropped 5 times for every inch of material added.					
	The material is added to the top of the core collar. The core cap is then					
	screwed on. The weight of the complete apparatus is then taken and recorded.					
	The core is then placed in the clamps on the retort stand. The headspace is					
	then filled with arsenic dust saturated water. This is accomplished by pushing water					
	through the spigot at the top of the core. The burette is then attached to the					
	soil core. The stopcock is then opened and As saturated water is poured into the burette.					
	The water is allowed to saturate the soil core until the core begins to drip water at					
	it's base. The stopcock is then closed. The base of the core is submerged into					
	a container of water to ensure the system is closed. The overflow spout on the					
	container represents the base head level. The burette is then topped up to the					
	zero marking with arsenic saturated water. The distance between the overflow spout					
	and the zero mark on the burette is now measured and recorded, this is the initial head					
	measurement. The stopcock and the stopwatch is opened and started,					
	respectively, simultaneously. The water level and the associated time should					
	be recorded on the record sheet.					
Data:	a burette surface area in cm^2 1.54					
	$1 \qquad \text{acil across surfaces error in } \operatorname{arr}^2 \qquad 20.27$					

а	burette surface area in cm ⁻	1.54
Α	soil core surface area in cm ²	20.27
L	length of soil in core in cm	32
t	total elapsed time for test (hours)	5
h _l	initial head in cm	116.7
	dry bulk density (g/cm ³)	1.05
	initial head in (g)	681.00

	Elapsed Time	;	Total	Volume	Head	log (Head)
hr	min	sec	sec	(mL)	(cm)	(cm)
0	0	0	0	2.2	115.46	2.0624
0	5	0	300	4.8	113.99	2.0569
0	10	0	600	6.6	112.98	2.0530
0	15	0	900	9.0	111.62	2.0478
0	20	0	1200	10.6	110.72	2.0442
0	25	0	1500	12.6	109.59	2.0398
0	30	0	1800	14.4	108.58	2.0357
0	40	0	2400	18.0	106.55	2.0275
0	45	0	2700	20.0	105.42	2.0229
0	50	0	3000	21.8	104.40	2.0187
0	55	0	3300	23.8	103.28	2.0140
0	60	0	3600	25.0	102.60	2.0111
0	65	0	3900	27.0	101.47	2.0063
0	70	0	4200	28.8	100.46	2.0020
0	82	0	4920	32.8	98.20	1.9921
0	91	0	5460	35.8	96.51	1.9846
0	100	0	6000	38.4	95.04	1.9779
0	104	0	6240	40.0	94.14	1.9738
0	150	0	9000	46.4	90.53	1.9568
0	150	0	9000	53.0	86.81	1.9386
0	173	0	10380	60.0	82.86	1.9183
0	210	0	12600	68.4	78.12	1.8928
0	240	0	14400	76.2	73.72	1.8676
0	273	0	16380	82.6	70.11	1.8458
0	300	0	18000	88	67.07	1.8265

used 100mL burette with 0.564 cm/mL gradations

Hydraulic Conductivity, Hyd Cond#2)



Summary:

The slope of the linear equation is:

-1.308E-05

The k value is calculated using the following equation:

$$k = (slope)(a)(L)$$

(0.434)(A)

k = 7.32E-05 cm/sec

Hydraulic Conductivity, Hyd Cond#2)

Test Name: Sample Name: Project:	Procedure for Hydraulic Conductivity Test #3 Arsenic Trioxide Dust at 1.15 g/cm3 10394-001
Date:	06-Jun-02
Purpose:	To measure the hydraulic conductivity (k) of the aforementioned sample.
Procedure:	The soil core and caps are cleaned and dried. The weight of the entire
	apparatus is then weighed. This weight will be used to calculate the bulk
	density of the material. The material is then mixed to make it homogonous.
	The material is placed into the column in small portions. The material is
	placed into the core one inch at a time. After each inch has been added
	it is compacted using a 2" OD PVC pipe with duct tape on the end. The pipe should be raised 5" above the surface of the material and let it drop under its own weight. The pipe should be dropped 5 times for every inch of material added. The material is added to the top of the core collar. The core cap is then corrected an The weight of the complete apparatus is then taken and recorded.
	The core is then placed in the complete apparatus is then taken and recorded.
	then filled with arganic dust seturated water. This is accomplished by pucking water
	through the enjoy at the ten of the core. The hurst's accomplished by pushing water
	soil core. The stopcock is then opened and As saturated water is poured into the burette. The water is allowed to saturate the soil core until the core begins to drip water at it's base. The stopcock is then closed. The base of the core is submerged into a container of water to ensure the system is closed. The overflow spout on the container represents the base head level. The burette is then topped up to the zero marking with arsenic saturated water. The distance between the overflow spout and the zero mark on the burette is now measured and recorded, this is the initial head measurement. The stopcock and the stopwatch is opened and started, respectively, simultaneously. The water level and the associated time should be recorded on the record sheet.
Data	a burette surface area in cm^2 1.54

a	burette surface area in cm	1.54
A	soil core surface area in cm ²	20.27
L	length of soil in core in cm	34.5
t	total elapsed time for test (hours)	5
\mathbf{h}_1	initial head in cm	116
	dry bulk density (g/cm ³)	1.15
	initial head in (g)	801.69

Data:

	Elapsed Time	e	Total	Volume	Head	log (Head)
hr	min	sec	sec	(mL)	(cm)	(cm)
0	0	0	0	2.2	114.76	2.0598
0	5	0	300	4.2	113.63	2.0555
0	10	0	600	6.4	112.39	2.0507
0	15	0	900	8.4	111.26	2.0463
0	20	0	1200	10.2	110.25	2.0424
0	25	0	1500	12.2	109.12	2.0379
0	30	0	1800	13.8	108.22	2.0343
0	40	0	2400	17.2	106.30	2.0265
0	45	0	2700	19.0	105.28	2.0224
0	50	0	3000	20.2	104.61	2.0196
0	55	0	3300	22.2	103.48	2.0149
0	60	0	3600	23.2	102.92	2.0125
0	65	0	3900	25.4	101.67	2.0072
0	70 ·	0	4200	27.2	100.66	2.0029
0	82	0	4920	30.2	98.97	1.9955
0	91	0	5460	32.8	97.50	1.9890
0	100	0	6000	35.0	96.26	1.9834
0	104	0	6240	36.2	95.58	1.9804
0	126	0	7560	41.6	92.54	1.9663
0	150	0	9000	46.6	89.72	1.9529
0	173	0	10380	53.8	85.66	1.9328
0	210	0	12600	60.6	81.82	1.9129
0	240	0	14400	67.0	78.21	1.8933
0	273	0	16380	73.0	74.83	1.8741
0	300	0	18000	77.6	72.23	1.8587

used 100mL burette with 0.564 cm/mL gradations



Summary:

The slope of the linear equation is:

-1.117E-05

The k value is calculated using the following equation:

$$k = (slope)(a)(L)$$

(0.434)(A)

k = 6.74E-05 cm/sec

Hydraulic Conductivity, Hyd Cond#3

APPENDIX 2: THERMAL CONDUCTIVITY

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Composite Solutions

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Fax

To:	Liar	igxue Liu	From	Peter Steeves	
Fax	(705	5) 6 52 -0743	Pages:	5	
Phone	*	-	Date:	6/21/02	
Rọ:	The	mal Conductivity	;33		
📮 Urg	ent	× For Review	Please Comment	🗆 Please Reply	🗆 Please Recycle

Dear Liangxue,

Attached is the testing report for your Arsenic Trioxide Dust sample.

Sincerely,

1 Peter Steeves

LAKEFIELD RESEARCH LIMITED Environmental Services RECEIVED
JUN 2 1 2002 Project Number: 10399-002 Project Manager: 1 109
Please And Read Forward To: Act Return Approve Discard Review with Me

EBX NO: : 200 423 1220



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Quote#: CSI-200203-002 Date: June 21,2002

Thermal Conductivity Analysis of Arsenic Trioxide Powder

Dr. Llangxue Liu Senior Environmental Scientist Environmental Services SGS Lakefield Research Ltd. 185 Concession Street Lakefield, Ontario, K0L 2H0 Fax: (705) 642-0743

Objective:

To determine the thermal conductivity of an arsenic trioxide powder using a Modified Hot Wire technique. This analysis is to be carried out at 10 degrees Celsius on the sample "as received" and with moisture added.

What is thermal conductivity?

Thermal conductivity is a physical property of a material that characterizes the ability of that substance to transfer heat. The value of thermal conductivity determines the quantity of heat passing per unit of time per unit area at a temperature drop of 1-degree C per unit length. In the limit of infinitesimal thickness and difference in temperature, the fundamental law of heat conduction is:

$$Q = \lambda A dT / dx$$

Where

- Q is a measure of the heat flow
- A is the cross sectional area
- dT / dx is the temperature / thickness gradient

 λ is defined as the thermal conductivity

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Modified Hot Wire Technique

The modified hot wire method is used for determining thermal conductivity of materials such as ceramics, composites, minerals, plastics, liquids, and powders.

The modified hot wire system is based on a principle that involves supplying a known amount of energy in the form of electrical current to an initially isothermal sample via the nickel sensor while monitoring the resulting temperature rise by also using the sensor as a resistance thermometer. Thus the sensor acts as both a heat source and a dynamic temperature sensor for measuring the thermal transport properties of a material.

During a test the dynamic features of the temperature rise, reflected in the resistance increase of the sensor, is precisely recorded and analyzed so that thermal conductivity can be determined from a single transient recording. The solution to the thermal conductivity equation assumes that the sensor is located in an infinite medium, therefore the transient recording must be interrupted when influences from the outer sample boundaries are recorded by the sensor. This method provides the bulk thermal properties of a material. All interfacial contact resistances at the sample boundary (boundary between sensor element and material) are minimized by setting a delay in the data collection. No assumptions are necessary to remove these influences. Thus thermal property results of solid samples are not affected by mounting pressure, surface roughness or even if a small, relatively thin layer such as an oxidation layer, is present at the sample surface. This modified hot wire technique requires a 1-4 K temperature rise in order to accurately determine thermal conductivity.

Instrument Specifications

Thermal Conductivity Range Accuracy Temperature Range Sensor Diameters Sample Size Sample Thickness Calibration 0.001W/m-K to 10W/m-K

± 5% -50 C to 50 C 5 x 25mm to 5 x 50mm > 1.5 times sensor size depending on thermal conductivity of material 3 calibration pieces, laf 15, laf 20, tefton

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Procedure

- 1) The modified hot wire apparatus is calibrated at 10° C using 3 thermal standards, 2 laf foams and 1 teflon. All of the standards are covered with one layer of a containment bag and a 300 g weight is applied. The bag is to account for the interface resistance that results from testing a contained powder, and the weight is to ensure consistent density of material. This calibration range covers materials from 0.05 W/m-K to 0.27 W/m-K.
- A containment bag is weighed out and then approximately half filled with arsenic trioxide powder. The combination is then re-weighed, this result to be used later in the testing.
- 3) The arsenic trioxide powder is placed in the thermal chamber with a 300 g weight applied. The material is tested when it reaches thermal equilibrium at 10 C.
- 4) With the "as received material" tested, 1% by weight of H2O is added to the sample. Note, this had to be worked into the sample. This working can change the density of the sample, for this reason the sample is then shaken to get back to original density.
- The arsenic trioxide with 1% by weight is then placed in the thermal chamber with a 300 g weight applied and tested when it reaches thermal equilibrium.

<u>Results</u>

Chart 1 and Fig. 1 show results that were achieved for arsenic trioxide using the modified hot wire.

Chart	1
-------	---

10 C		rate (Hz)	Data Points (max. 8000)	Thermal Conductivity (W/m-K)
As received	8-20s	300	3600	0.093
1% by weight H2O	8-20s	300	3600	0.100

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Results cont'd





Conclusions

Thermal conductivity properties of atsenic trioxide powder were analyzed of using the modified hot wire technique.

Test parameters for the arsenic were optimized to include:

- 3 point calibration range of 0.05 to 0.27 W/m-K
- 20 second test time
- 8 second start
- 300 Hz sampling rate
- Total of 3600 data points were analyzed for a conductivity

The modified hot wire technique measured a thermal conductivity value of 0.093 W/m-K on the "as received" material at a temperature of 10 C.

The modified hot wire technique measured a thermal conductivity value of 0.100 W/m-K on the 1% by weight sample.

Packing density is a major factor in the conductivity properties of this arsenic trioxide, with an increase in pressure the conductivity values will change dramatically.

Tests performed by Composite Solutions Laboratory.

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