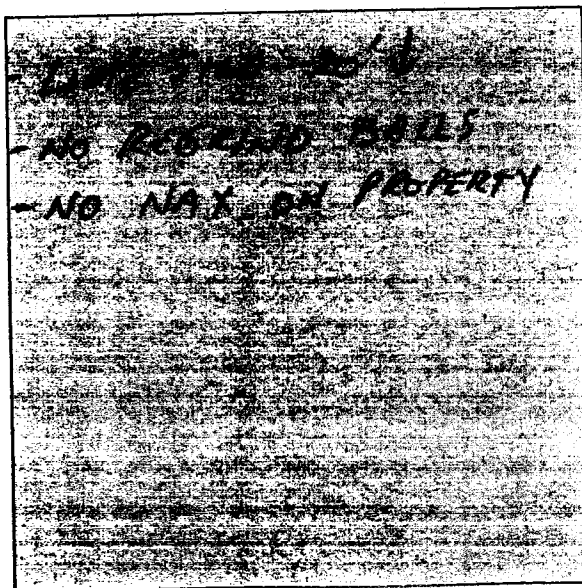


ROYAL OAK MINES Inc.
ARSENIC TRIOXIDE LEACHING AND CRYSTALLIZATION TESTWORK

Progress Report #2



Erica Kresin
ember 1997

Dissolution of As_2O_3 from Giant's baghouse dust

Executive Summary

Testwork was conducted on Giant's baghouse dust to evaluate the effect of the %solids on arsenic, antimony and iron recoveries. All tests were conducted for 30 minutes, at 95°C. The results show that arsenic recovery is very sensitive to the %solids and the process requires dilute slurries to be effective. Additional testwork, at longer residence times, is required in an attempt to achieve a smoother curve, less sensitive to the solids concentration in the slurry.

Preliminary results show that the three purification techniques tested (activated carbon and ion exchange resins) produced crystals of better quality than those obtained without any purification of the pregnant solution. The best results were achieved by batch treating the pregnant solution with 15 g/L of resin A, prior to crystallization. The crystals produced assayed 76.08% As (100.45% As_2O_3), 0.08% Sb and 0.04% Fe. Additional testwork will be conducted using a column arrangement to percolate the pregnant solution through a bed of resin or activated carbon.

This testwork has shown that a dramatic increase in the amount of crystals produced is achieved by reduction of the pregnant solution volume by evaporation. The pregnant solutions produced in this testwork contained only 31 g/L of arsenic (40.9 g/L As_2O_3), on average, considerably less than the reported solubility of As_2O_3 in water, at 95°C (100 g/L).

Feed Material

The testwork presented on this report was conducted on BHD Composite September 97, a composite sample obtained by sampling baghouse dust for a period of four weeks (September 1 to 26, 1997). Average assays for this composite were:

Arsenic	67.50%
Antimony	1.10%
Iron	1.72%
Gold	0.140 oz/ton

Hot Water Leach Tests

The effect of the %solids on the recovery of arsenic, antimony and iron was investigated. Tests were conducted at 95°C, 30 minutes residence time and at the following %solids: 5.3, 6.0, 6.3, 6.6, 6.9, 8.1, 8.2 and 10.1%. It took approximately 30 minutes to heat the slurry from room temperature to 95°C. Time zero was the time when the slurry reached 95°C.

Arsenic recovery as a function of %solids is presented on Table 1 and Graph 1. %solids has a dramatic impact on arsenic recovery. As the %solids increases, arsenic recovery decreases. The highest arsenic recovery was achieved at 5.3% solids (86.6% on average). At 8.2% solids, the arsenic recovery drops to 71.0% and at 10.1% solids to 59.3%. These results show that arsenic recovery is very sensitive to the %solids and the process requires dilute slurries to be effective.

Additional testwork will be conducted to investigate the effect of %solids on arsenic recovery, at longer residence times. The objective is to obtain a smoother curve, with recoveries that can be sustained over a broader range of solids concentration in the slurry.

Antimony recovery as a function of %solids is presented on Table 2 and Graph 2. Antimony recovery decreases as %solids increases. At 5.3% solids, 19.8% of the antimony was recovered. At 8.2% solids, antimony recovery drops to 12.4% and at 10.1% solids to 9.2%. Antimony recovery increases with an increase in arsenic recovery, as shown on Graph 3.

Iron recovery is not a function of %solids, as shown on Table 3 and Graph 3. Average iron recovery for all tests was 0.34%.

Residues from four tests conducted at 5.3% solids, 95°C and 30 minutes contained, on average, 21% of the initial weight assaying 40.76% arsenic.

Crystallization

Preliminary crystallization tests were conducted on pregnant solutions obtained in hot water leach tests. As_2O_3 crystals were produced by evaporating pregnant solution to dryness, in a beaker covered with a watch glass. Crystals produced using this procedure provide the 'worst case scenario' as all impurities collect in the solid phase.

- Test # As-97-024

Leach test conditions: 5.3% solids, 30 minutes at 95°C

500 mL of pregnant solution were evaporated to dryness. 34.5 g of crystal were produced assaying: 53.43% arsenic (70.55% As_2O_3 equivalent), 0.09% antimony and 0.04% iron.

- Test # As-97-025

Leach test conditions: 5.3% solids, 4 hours at 95°C

500 mL of pregnant solution were evaporated to dryness. 28.9 g of crystal were produced assaying: 58.05% arsenic (76.65% As_2O_3 equivalent), 0.19% antimony and 0.04% iron.

- Test # As-97-028

Leach test conditions: 5.3% solids, 3 hours at 95°C

500 mL of pregnant solution were evaporated to dryness. 18.5 g of crystal were produced assaying: 56.36% arsenic (74.42% As_2O_3 equivalent), 0.09% antimony and 0.04% iron.

A series of crystallization tests was then conducted, using different techniques to purify the pregnant solution obtained by a hot water leach of BHD, at 5.3% solids, 95°C and 30 minutes. Results for the hot water leach tests are presented on Table 4. Average recoveries for seven tests were: 91.6% arsenic, 16.4% antimony and 0.4% iron. These results are better than those presented above, with a higher arsenic recovery and a lower antimony recovery. Average pregnant solution assay was: 31.30 g/L arsenic, 74 ppm antimony and 3 ppm iron.

A summary of test conditions and results for eleven crystallization tests are presented on Tables 5 and 6 respectively. In all tests, initial pregnant volume was approximately 700 mL. Metallurgical balances for iron were poor, in all crystallization tests. This may be due to experimental and assay errors. An effort will be made to increase the accuracy of the iron assays at the low concentrations that occur in the crystallization testwork.

Three crystallization tests were conducted with no pre-treatment of the pregnant solution and at different levels of agitation: test 97-065 at strong agitation for 8 hours, final temperature 25°C; test 97-067B at mild agitation for 8 hours, no agitation for 11 hours, final temperature 15°C; test 97-069B at no agitation for 20 hours, final temperature 12°C. No crystals were produced in any of these tests.

In test 97-078, the volume of pregnant solution was reduced by evaporation to approximately 300 mL. The crystallization test was then conducted for 13 hours, with no agitation, final temperature 9°C. 17.7 g of crystals were produced assaying 76.30% As (100.75% As_2O_3), 0.33% Sb and 0.08% Fe. The filtrate assayed 22.33 g/L As, 7 ppm Sb and 1.6 ppm Fe.

In tests 97-073B and 97-079B, 5 g of reagent grade arsenic trioxide (76.04% As, 0.61% Sb and 0.25% Fe) were added prior to the crystallization test. In the first test the pregnant solution was submitted to crystallization directly. In the second test, the volume of pregnant solution was reduced to approximately 300 mL prior to crystallization. Reducing the volume of pregnant solution has a dramatic impact on the amount of crystals produced. The first test produced only 6 g of crystals. The second test produced 24.6 g.

Three tests were conducted including a pre-treatment step with 15 g/L of activated carbon (tests 97-069A, 073A and 079A). The activated carbon was introduced into the kettle containing pregnant solution and stirred for 30 minutes, at 95°C. The activated carbon was removed by filtering the solution. In test 97-079A, the volume of pregnant solution was reduced to approximately 300 mL, after removal of the activated carbon. In this test, 17.1 g of crystals were produced, assaying 76.04% As (100.41% As_2O_3), 0.10% Sb and 0.04% Fe. This product is cleaner than the one obtained without any pre-treatment (test 97-078). The filtrate assayed 19.3 g/L As, 15.3 ppm Sb and 1.2 ppm Fe. Tests 69A and 73A were conducted without

reduction in pregnant solution volume. The first test produced only a small amount of crystals: 0.6 g. The second test produced 5.5 g of crystals.

Activated carbon assays will be reported when available.

Two tests were conducted using ion exchange resins (test 97-076A, 15 g/L of resin A; test 97-076B, 15 g/L of resin B). The resin was introduced into the kettle containing pregnant solution and stirred for 30 minutes, at 30°C. The resin was removed by filtering the solution. In both tests, the pregnant solution volume was reduced to approximately 300 mL prior to crystallization. The first test produced 16.2 g/L of crystals assaying 76.08% As ($100.45\% \text{As}_2\text{O}_3$), 0.08% Sb and 0.04% Fe. The filtrate assayed 22.76 g/L of As, 6.8 ppm Sb and 1.1 ppm Fe. The second test produced 16.6 g of crystals assaying 76.46% As ($100.95\% \text{As}_2\text{O}_3$), 0.16% Sb and 0.05% Fe. The filtrate assayed 17.28 g/L As, 0.5 ppm Sb and 0.4 ppm Fe. The products of these two tests contain lower levels of impurities than the one obtained without any pre-treatment (test 97-078)

Resin assays are not available.

The preliminary results presented above show that the three purification techniques tested (activated carbon and ion exchange resins) produced crystals of better quality than those obtained without any purification of the pregnant solution. These results will be verified by additional testwork using a column arrangement to percolate the pregnant solution through a bed of resin or activated carbon.

This testwork has shown that a dramatic increase in the amount of crystals produced is achieved by reduction of the pregnant solution volume by evaporation. The pregnant solutions produced in these tests contained only 31 g/L of arsenic ($40.9 \text{ g/L } \text{As}_2\text{O}_3$), considerably less than the reported solubility of As_2O_3 in water, at 95°C (100 g/L).

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ARSENIC TRIOXIDE LEACHING AND CRYSTALLIZATION TESTWORK

Table 1

Hot Water Leach Tests

Test conditions: 30 min, distilled water, 95 C

Test #	%solids	Arsenic			Head	
		Recovery (%)	Av. Rec. (%)	Concentration (g/L)	Backcalc (%)	Assayed (%)
97-026	5.3	92.7	86.6	31.53	66.5	66.10
97-024	5.3	92.5		32.69	66.3	67.85
97-059	5.3	84.9		25.53	68.88	67.36
97-049	5.3	76.3		29.21	70.62	63.23
97-048	6.0	93.3	83.8	30.79	67.14	63.23
97-053	6.0	79.9		30.27	66.02	67.51
97-061	6.0	78.3		26.88	65.81	67.71
97-050	6.3	79.1		30.12	67.69	67.36
97-057	6.3	88.5	84.1	34.15	67.70	67.46
97-062	6.3	84.6		31.52	64.41	67.63
97-060	6.6	83.3		31.90	67.36	68.15
97-063	6.6	67.2		27.70	68.40	66.75
97-051	6.6	70.4	73.6	29.21	65.80	67.36
97-064	6.9	81.2		31.90	67.04	65.86
97-054	6.9	80.0		31.60	66.42	67.63
97-047	6.9	75.3		29.81	65.34	65.68
97-055	8.1	76.4	76.4	31.45	66.24	67.74
97-046	8.2	66.5		32.22	64.12	68.12
97-072	8.2	75.4		33.70	65.84	69.33
97-056	10.1	61.2		37.74	66.46	67.65
97-071	10.1	59.3	59.3	34.97	67.23	69.33
97-045	10.1	57.3		34.93	67.60	67.92
Average					66.81	67.15

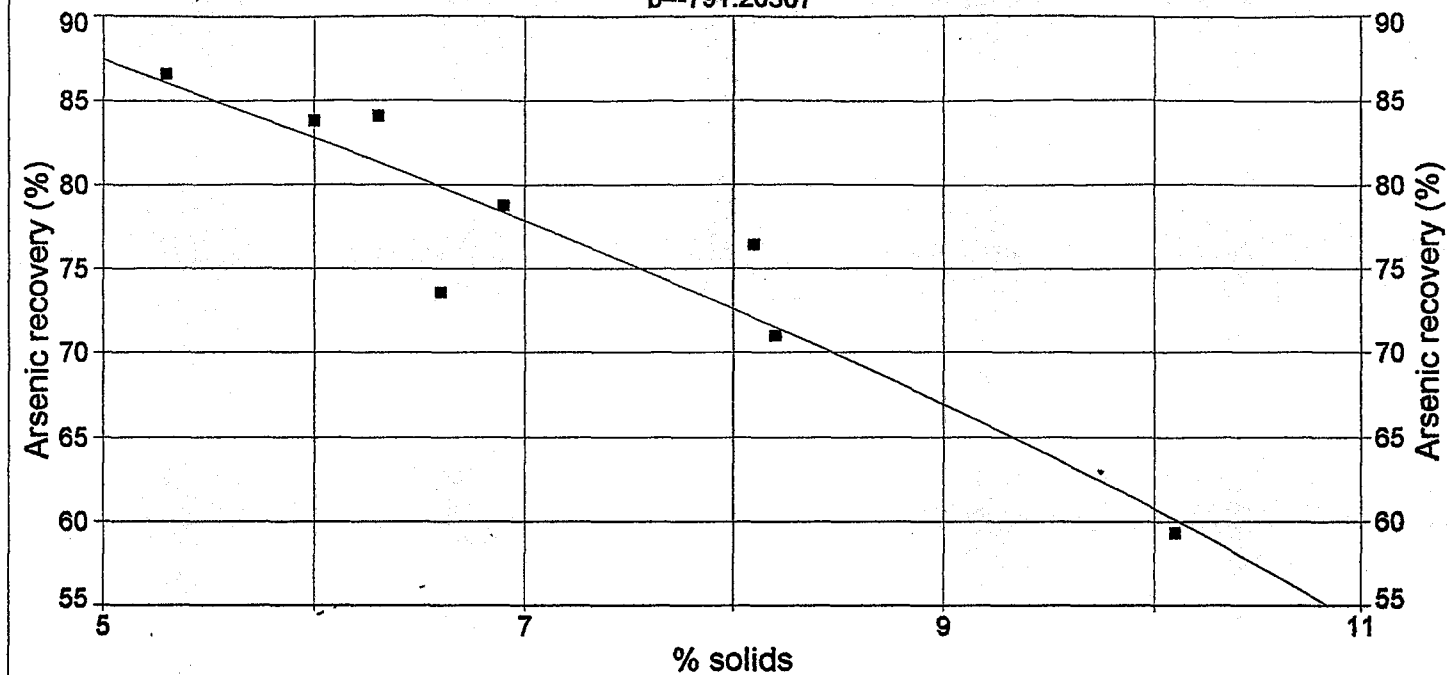
Graph 1 - Arsenic recovery vs %solids

Rank 3 Eqn 85 $y^2=a+bx$

$r^2=0.87678163$ DF Adj $r^2=0.82749428$ FitStdErr=3.3685576 Fstat=42.694037

a=11603.625

b=-791.20507



Rank 3 Eqn 85 $y^2=a+bx$

r^2 Coef Det	DF Adj r^2	Fit Std Err	F-value
0.8767816267	0.8274942774	3.3685575543	42.694036772

Parm	Value	Std Error	t-value	95% Confidence Limits	
a	11603.62472	440.5651082	26.33804744	10525.60074	12681.64870
b	-791.205072	57.29284854	-13.8098400	-931.395622	-651.014522

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Table 2

Hot Water Leach Tests

Test conditions: 30 min, distilled water, 95 C

Test #	%solids	Antimony			Head	
		Recovery (%)	Av. Rec. (%)	Concentration (ppm)	Backcalc (%)	Assayed (%)
97-026	5.3	24.4	19.8	93	1.01	1.1
97-024	5.3					
97-059	5.3	18.2		69	1.01	1.00
97-049	5.3	16.9		94	1.21	1.05
97-048	6.0	29.4	22.0	99	0.87	1.05
97-053	6.0	18.3		82	0.93	0.96
97-061	6.0	18.3		80	1.00	0.99
97-050	6.3	20.1	17.1	88	0.96	1.00
97-057	6.3	20.1		102	1.06	0.98
97-062	6.3	11.0		54	1.05	1.01
97-060	6.6	14.0	15.3	70	1.05	0.95
97-063	6.6	14.1		78	1.07	1.06
97-051	6.6	17.7		93	0.98	1.00
97-054	6.9	14.9	15.8	81	1.06	0.98
97-064	6.9	13.9		68	0.96	1.10
97-047	6.9	18.5		95	0.97	1.04
97-055	8.1	11.8	11.8	75	1.11	1.00
97-072	8.2	10.4	12.4	63	1.03	1.05
97-046	8.2	14.3		92	0.98	1.03
97-056	10.1	7.5	9.2	63	1.07	0.98
97-071	10.1	8.1		70	1.08	1.05
97-045	10.1	11.9		108	1.05	1.04
Average					1.03	1.02

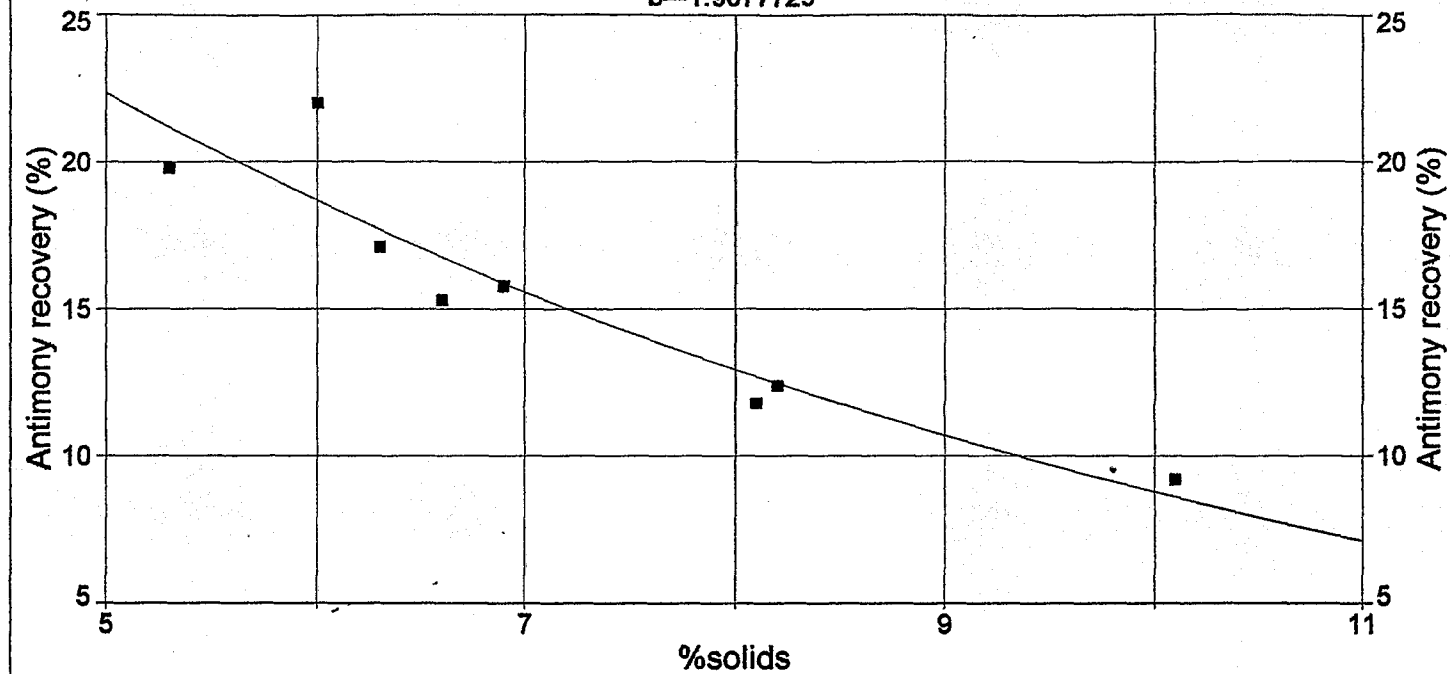
Graph 2 - Antimony recovery vs %solids

Rank 5 Eqn 75 $y^{0.5}=a+bx^{0.5}$

$r^2=0.86816859$ DF Adj $r^2=0.81543602$ FitStdErr=1.666343 Fstat=39.512673

a=8.9965113

b=-1.9077729



Rank 5 Eqn 75 $y^{0.5}=a+bx^{0.5}$

r^2	Coef Det	DF Adj r^2	Fit Std Err	F-value
0.8681685868		0.8154360216	1.6663430438	39.512673016

Parm	Value	Std Error	t-value	95% Confidence Limits	
a	8.996511312	1.640341850	5.484534405	4.982739402	13.01028322
b	-1.90777288	0.626905588	-3.04315820	-3.44175559	-0.37379017

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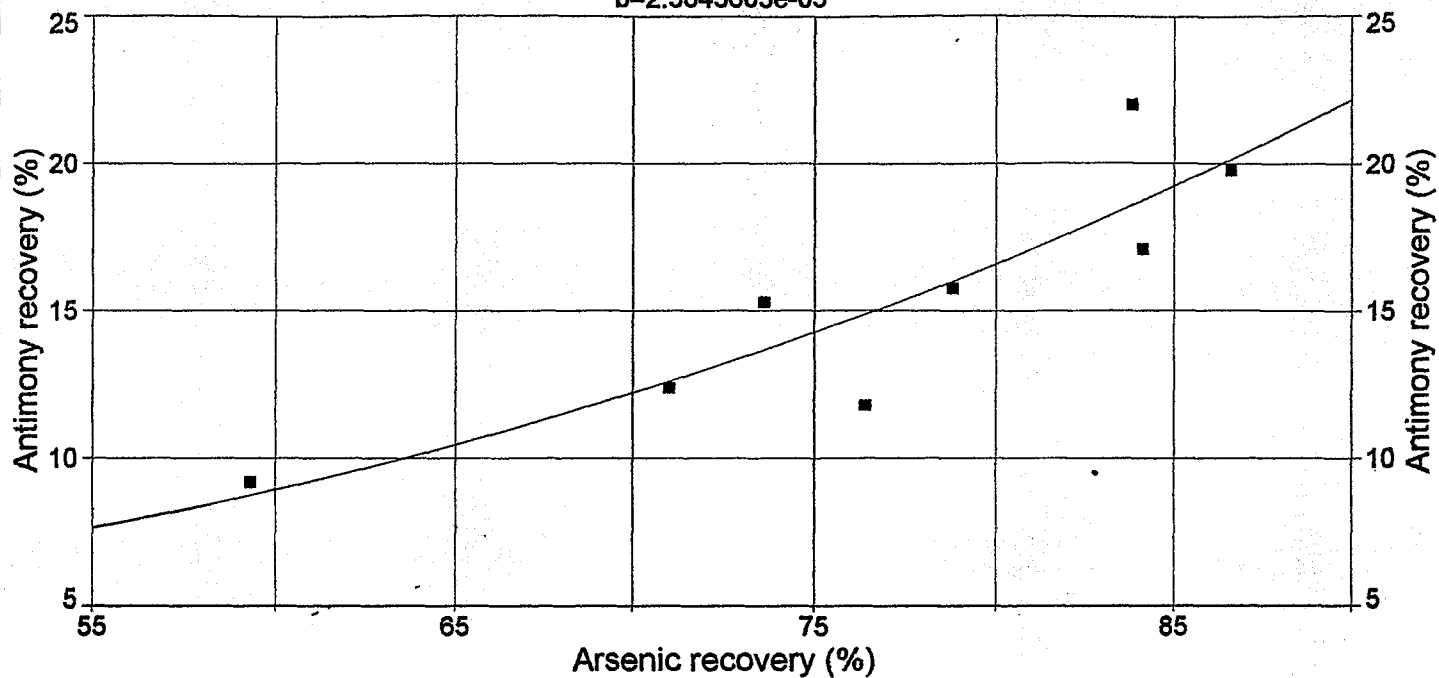
Graph 3 - Antimony recovery vs Arsenic recovery

Rank 7 Eqn 7 $y=a+bx^3$

$r^2=0.78601804$ DF Adj $r^2=0.70042526$ FitStdErr=2.1229685 Fstat=22.039747

$a=3.3643418$

$b=2.5845603e-05$



Rank 7 Eqn 7 $y=a+bx^3$

r^2	Coef Det	DF Adj r^2	Fit Std Err	F-value
0.7860180395	0.7004252552	2.1229684510	22.039746831	

Parm	Value	Std Error	t-value	95% Confidence Limits	
a	3.364341825	2.676423904	1.257028762	-3.18463154	9.913315190
b	2.58456e-05	5.50533e-06	4.694650874	1.23745e-05	3.93167e-05

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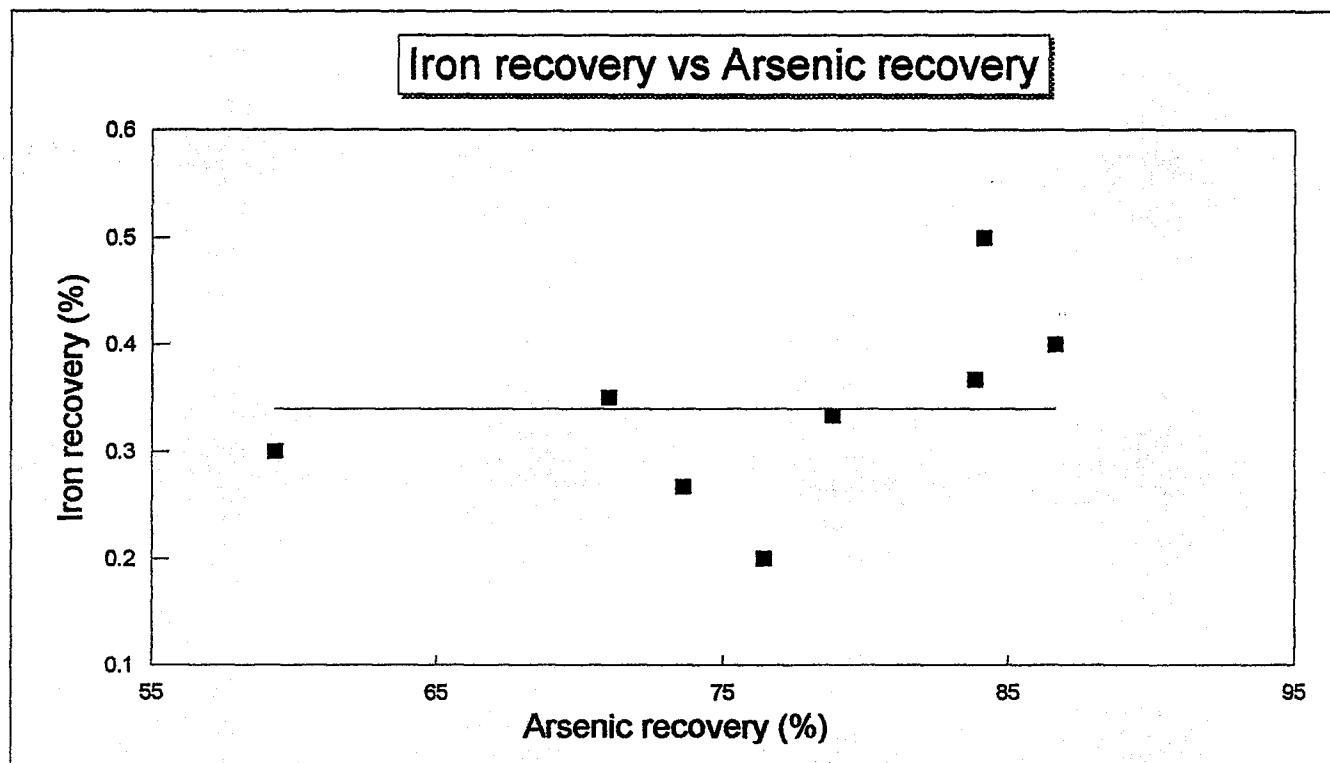
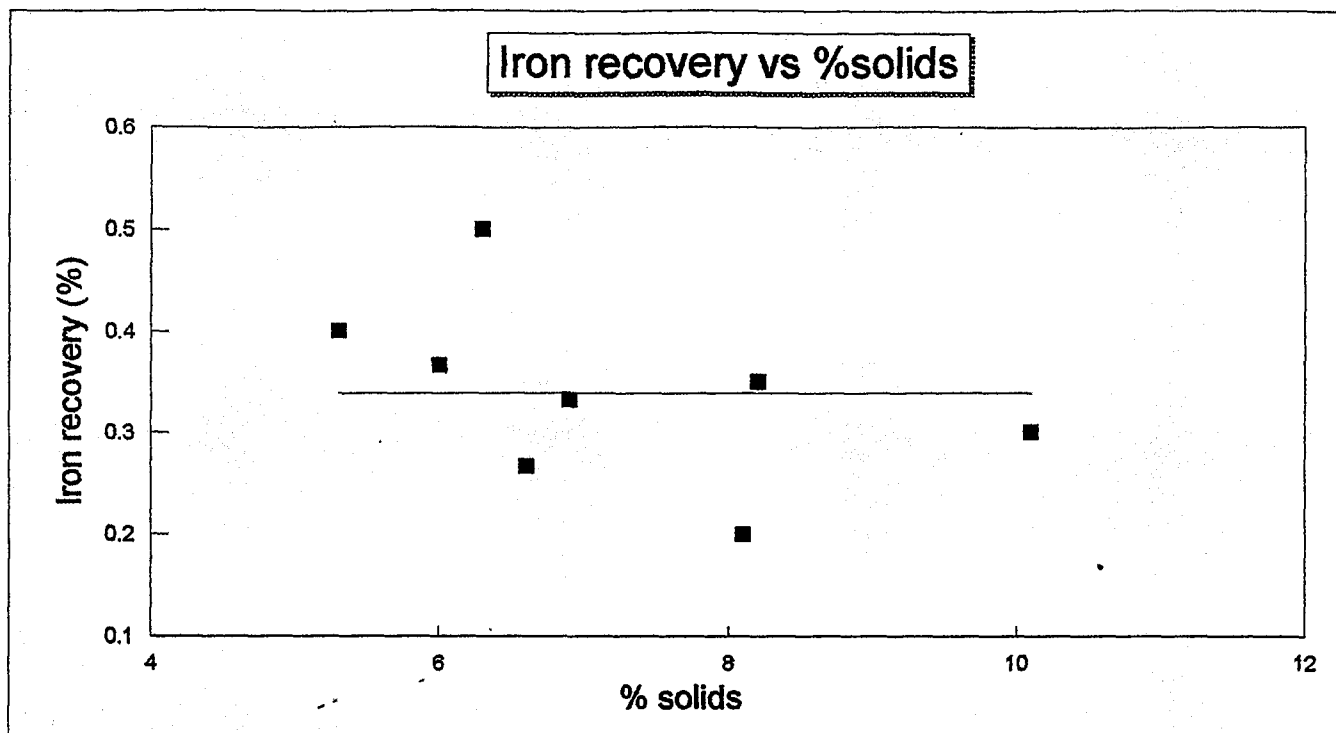
Table 3

Hot Water Leach Tests

Test conditions: 30 min, distilled water, 95 C

Test #	%solids	Iron			Head	
		Recovery (%)	Av. Rec (%)	Concentration (ppm)	Backcalc (%)	Assayed (%)
97-026	5.3	0.4	0.4	4	1.94	1.69
97-024	5.3	0.8		7	1.73	1.69
97-059	5.3	0.2		1	1.48	1.31
97-049	5.3	0.2		2	1.84	1.88
97-048	6.0	0.3	0.4	3	1.99	1.88
97-053	6.0	0.4		4	1.48	1.65
97-061	6.0	0.4		3	1.39	1.47
97-050	6.3	0.4	0.5	3	1.39	1.59
97-057	6.3	0.6		5	1.58	1.45
97-062	6.3	5.0		56	1.83	1.68
97-060	6.6	0.1	0.3	1	1.45	1.41
97-063	6.6	0.3		3	1.59	1.53
97-051	6.6	0.4		3	1.33	1.59
97-054	6.9	0.4	0.3	3	1.55	1.69
97-064	6.9	0.2		2	1.57	1.38
97-047	6.9	0.4		4	1.52	1.88
97-055	8.1	0.2	0.2	2	1.63	1.72
97-072	8.2	0.4	0.4	5	1.63	1.50
97-046	8.2	0.3		3	1.57	1.88
97-056	10.1	0.4	0.3	6	1.61	1.66
97-071	10.1	0.2		3	1.62	1.50
97-045	10.1	0.3		4	1.60	2.04
Average			0.3		1.59	1.65

Graph 4



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Table 4

Hot water leach test conditions: 5.3% solids, 30 min, 95 C

Test #	Arsenic		Head	
	Recovery (%)	Concentration (g/L)	Backcalc (%)	Assayed (%)
97-065	92.2	31.82	66.09	65.86
97-067	93.3	31.45	68.95	69.41
97-069	90.6	31.90	70.12	69.35
97-073	91.1	30.40	67.39	69.11
97-076	91.4	30.25	68.89	68.88
97-078	89.3	30.10	66.13	68.76
97-079	94.9	33.17	71.69	68.76
Average	91.8	31.30	68.47	68.59

Test #	Antimony		Head	
	Recovery (%)	Concentration (ppm)	Backcalc (%)	Assayed (%)
97-065	17.8	72	0.98	1.10
97-067	17.9	79	1.10	1.06
97-069	17.1	81	1.12	1.07
97-073	17.8	77	1.04	1.07
97-076	13.1	65	1.27	1.09
97-078	15.9	73	1.09	1.09
97-079	15.5	72	1.19	1.09
Average	16.4	74	1.11	1.08

Test #	Iron		Head	
	Recovery (%)	Concentration (ppm)	Backcalc (%)	Assayed (%)
97-065	0.4	3	1.66	1.38
97-067	0.4	3	1.54	1.50
97-069				
97-073	0.1	1	1.76	1.57
97-076	0.4	3	1.47	1.63
97-078	0.4	3	1.40	1.50
97-079	0.4	3	1.52	1.50
Average	0.4	3	1.56	1.51

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Table 5

Crystallization tests

Test #	Pre-treatment	Volume reduced	Crystallization			
			Initial temp. (C)	Final temp. (C)	Agitation	Time (hours)
97-065	none	no	94	25	mechanical, 8	8
97-067B	none	no	94	15	mechanical, 1	19
97-069B	none	no	95	12	none	20
97-078	none	yes	100	9	none	13
97-073B	5 g of reagent grade As ₂ O ₃ , 30 min, 95 C	no	95	12	none	20
97-079B	5 g of reagent grade As ₂ O ₃ , 30 min, 95 C	yes	100	11	none	20
97-069A	10.5 g activated carbon for 30 min, 95 C	no	95	12	none	20
97-073A	10.5 g activated carbon for 30 min, 95 C	no	94	13	none	19.5
97-079A	10.5 g activated carbon for 30 min, 93 C	yes	100	11	none	20.5
97-076A	10.5 g Resin A, 30 min, 30 C	yes	100	7.5	none	18
97-076B	10.5 g Resin B, 30 min, 30 C	yes	100	6	none	18

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Table 6

Crystallization tests

Test #	Crystal					Filtrate		
	Weight (g)	%As	%As ₂ O ₃	%Sb	%Fe	As (g/L)	Sb (ppm)	Fe (ppm)
97-065	0.0	n/a	n/a	n/a	n/a	29.73	51	1
97-067B	0.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
97-069B	0.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
97-078	17.7	76.30	100.75	0.33	0.08	22.33	7	1.6
97-073B	6.0	76.42	100.90	0.93	0.05	25.43	8	0
97-079B	24.6	76.00	100.35	0.26	0.04	18.42	25.4	1.2
97-069A	0.6	n/a	n/a	n/a	n/a	26.44	17	0.7
97-073A	5.5	76.57	101.10	0.24	0.05	19.02	8	1
97-079A	17.1	76.04	100.41	0.10	0.04	19.33	15.3	1.2
97-076A	16.2	76.08	100.45	0.08	0.04	22.76	6.8	1.1
97-076B	16.6	76.46	100.95	0.16	0.05	17.28	0.5	0.4