PRELIMINARY

Alternate Process Flowsheet For WAROX Production

Introduction

Development has continued at Giant Yellowknife Mines on a process for production of a marketable white arsenious oxide (WAROX). Pilot plant work at Research and Productivity Council (RPC) in New Brunswick identified the major parameters of the process for a separate WAROX plant. Preliminary engineering was completed at Fenco Engineers Inc, including a capital cost estimate for the production of 7000 tonnes/yr of WAROX.

The process involved feeding current and underground crude As_2O_3 to a fluosolids reactor operating at 450° C to sublime the arsenic. Inert impurities and gold were collected on a high temperature filter. Cold air was added to to cool the gas stream to 110° C and condense a purified arsenic. This final WAROX product was collected in a cold baghouse and compacted for shipment.

Final tests at RPC used sintered metal stainless steel filters for hot gas filtration at 450° C. Additional tests were required, and a pilot plant is currently under construction to further test hot gas filtration. Concepts regarding antimony elimination and As_2O_3 particle size growth are also being evaluated.

Consideration is also being given to the purification of arsenic within the existing gas cleaning plant. Replacement of the existing cottrell with sintered metal filters would result in a marketable WAROX product. The addition of crude As_2O_3 from underground would give the projected 7000 tonnes per year of WAROX. A process is described in this report incorporating WAROX production into the existing plant. Pilot plant tests are required to demonstrate that a pure product can be produced and to obtain engineering data for sizing and costing a full scale plant, modifying the existing roaster off-gas system.

General Process Description

The attached flowsheet shows major equipment and flows for the process which is based on the production of 7000 tonnes/yr of WAROX product. This is derived from two sources, (1) current roaster off-gas arsenious oxide (As_4O_6) and (2) arsenic from underground stockpile material.

The crude As_2O_3 is fed into the hot roaster off-gas in a fluosolids sublimator. Available heat in the gas stream is used to sublime arsenic with a resultant temperature drop from 430° C to 370° C. The gas stream, enriched in As_4O_6 and reduced in volume flow is passed through a hot filter to remove Fe_2O_3 and inert solids. The filter off-gas is mixed with ambient air to obtain condensation of the arsenic at 110° C. High purity As_2O_3 is collected in a baghouse (existing) and discharged to a briquetting and flaking process. Final WAROX product is drummed for shipment.

Features of the proposed process include:

1. Utilization of roaster off-gas heat to sublime the crude As_2O_3.

2. Reduced volumetric flows in the off-gas system as follows:

	Current ACFM	Proposed ACFM
Hot filtration (ESP)	8,700	7,970
Cooling Air (20° C)	26,160	10,514
Baghouse/stack (110° C)	35,000	18,446

3. Utilization of existing fan, condenser and baghouse for WAROX production.

4. Flexibility in that treatment of crude As_2O_3 can be shut off and downstream cooling air adjusted to accommodate the higher temperature.

5. Increased concentration oof As_4O_6 and SO_2 in the gas streams. The effect of this in terms of As_2O_3 crystal size and SO_2 emissions requires evaluation.

6. An expected decrease in arsenic emissions by about 50%.

Detailed Process Description

Vaporization of Arsenic Trioxide From Stockpile Dust

The crude As_2O_3 from a surface storage bin is dried and fed to a reactor along with roaster off-gas. The fluosolids reactor/sublimator utilizes heat in the roaster off-gas to heat and sublimate the arsenic in the crude dust. Gas cooling occurs (430° C to 370° C) with a net decrease in volume and increase in As_4O_6 concentration. The heat balance is given in Appendix I.

The requirements of the reactor are twofold, namely (1) to obtain good gas/solid mixing and (2) to provide the necessary residence time for the vaporization of As_2O_3. Conceptually, the reactor size is determined by the vaporization kinetics which in turn is dependent on dust particle size and heat transfer. Data on this is lacking. The dust is known to be extremely fine (<2 microns) and is expected to vaporize readily at 370° C. The data needed for reactor sizing will have to be obtained from pilot plant tests. A coarse bed material would be required to maintain fluidity and provide a constant bed temperature. Inert solids from the roaster and from crude dust would be carried through the reactor.

The vapor pressure/temperature relationship of As_4O_6 is given in table I. A temperature of 370° C can contain over 8000 g/m^3 As_4O_6. Condensation of As_4O_6 from a gas stream containing 59.0 g/m^3 will begin at about 230° C.

reclaim product and/or producing a product having a higher bulk density.

With respect to reclaim of dust from underground, many possible schemes have been discussed. One idea, an overhead monorail hoist and clamshell bucket that could be used to pick up the dust and drop it onto a screen where the undersize would be transferred to surface using a tubular drag conveyor, may have merit.

Processing Alternatives

1. Sintered Metal Filter Only

Installing a sintered metal filter assembly is the simplest of the alternatives. The process has been thoroughly tested, the equipment can be installed in an existing building, the major piece of equipment is installed as a complete assembly, and there are no major changes to manpower or operating routine. The disadvantage is that, unless it is installed as part of a future reclaim and purification plant, it does nothing to recover the gold and arsenic stored underground.

The more obvious benefits of the installation are listed below.

recover an additional 665 oz/yr Au	\$310,000
produce and sell approx 3,000 tons/yr of purified As_2O_3	\$570,000
no need for underground storage	\$250,000
no need for cottrell overhauls	\$50,000
reduce costs for water treatment	\$100,000
total	\$1,280,000

The filter assembly and necessary booster fan would be installed in the cottrell building following removal of two of the four cottrell sections. The estimated capital cost for this installation is \$2,950,000. There would be no increase in operating cost.

2. Fuming Plant

A full scale fuming plant would be capable of treating a high tonnage of crude feed from underground. It could also operate as a stand alone entity, totally independent of conventional mine or mill operations.

In normal operation, the plant would treat all of the current production As_2O_3 , using the excess heat in the roaster exhaust to vaporize As_2O_3 from underground reclaim. The benefits of this procedure are twofold; it saves on fuel costs, and it reduces the volume of stack gas by performing some of the cooling function normally done by the addition of cooling air. The plant would be capable of receiving all types of material from underground, dusty or sloppy. If necessary, the material would be dried before feeding into the fuming reactor. The purified As_2O_3 would be compacted and stored in the existing arsenic silo for shipping.

Gold recovery from underground, especially from the early high grade stopes, is an important consideration, and it may be desirable to increase the plant throughput to increase gold production. Excess As_2O_3 could be returned underground (or to TRP storage) and sold later.

Alternative Technologies

Asarco, Beatty, Anaconda, and likely several other As_2O_3 producers have, until recently used a relatively low tech process for purification of arsenic trioxide. Low grade flue dust from roasting operations is reroasted and the resulting fume is condensed in long brick flues equipped with collecting chambers called kitchens . As the fume progresses down the length of the flue, contaminants drop out until relatively pure product is collected on the floor and walls of the kitchens near the end of the flue. The low grade dust collected in the first kitchens is recycled while the higher grade dust is marketed. It is likely that the high grade product will also have a high bulk density as crystals will have had time to grow. Some of the fume also condenses out on the relatively cool brick surface of the kitchens and this material will definitely have a high bulk density.

The Ashio plant in Japan used a very similar process in that crude baghouse dust from the first stage roaster was reroasted in a reverberatory furnace. The exhaust gas was passed through a large secondary condenser equipped with a number of air cooled baffles. The product from this condenser normally graded 99.3% As_2O_3 and had a bulk density of 94 to 120 lb/ft^3. No detailed information about this condenser is available, however in 1988 Furukawa, the company that owns the Ashio plant, offered to transfer their technology to Giant for $206,000. The offer may still be open.

High temperature leaching followed by crystallization was tested at Giant in the late 1970's. The process showed promise and it was used by Cominco's Con mine to treat several thousand tons of crude baghouse dust stored as a sludge in surface ponds. The plant was very expensive to build and operate, and metallurgical difficulties were a constant problem. The process did have the advantages that it could handle wet feed, it produced a very high purity product, and bulk density of the crystalline product was very high.

Underground Reclaim

During the past fifteen years several ideas for reclamation of baghouse dust from underground storage have been proposed. Many were totally impractical and others were discarded for environmental reasons. In an attempt to clearly define the kinds of materials that would have to be dealt with, Geocon Inc was contracted in 1981 to collect samples from the stopes and to determine the physical characteristics of the dust. As the samples were recovered, they were analysed for gold and arsenic content.

Following the borehole sampling, a sample of dust from stope B2-35 was tested by Jenike & Johanson to determine flow properties of the material. This information was required for designing bins, chutes and hoppers that would be used for storage and handling of the reclaimed material. Critical rathole diameters were also determined, and it was found that if a reclaim system could cut a slot exceeding 12 feet in length and 2.9 feet in width, the rathole would collapse, allowing a large amount of material to be withdrawn.

Results of the borehole sampling indicated a wide range of material in storage, eg. moisture content ranging from less than 1% to greater than 6%. Since vacuum recovery was being given a lot of consideration at the time, moisture content and general flowability was of particular importance in designing a reclaim system. When the results of the Geocon and Jenike & Johanson reports became available, H.G. Engineering was consulted for their ideas on a reclaim system. They discussed five possible methods, none of which seemed to be appropriate.

In 1984, a vacuum test was conducted on dry (0.45% moisture) dust from stope C9. Though a reasonably high rate of recovery was accomplished (4,253 lbs/hr), the high compaction of the dust caused problems in that the lumps had to be broken up before they could be picked up in the vacuum hose. A second vacuum test was done in 1988 on material in stope B2-36. Moisture content was less than 1.0%, but even this small amount of moisture caused blockages in the vacuum hose. Because of the lack of fluidity of this material, the test was unsuccessful. The results of these tests indicated that vacuuming was not likely to work on compacted or moist material. If vacuuming was to be used for reclaim of dry, loose material, a second method of recovery would still be required for moist and/or compacted material.

Slurrying of the material using high pressure water jets to liquefy a small amount of dust, combined with pumping of the slurry as it was formed, was considered for a time. This would probably work for a high percentage of the dust stored in the arsenic chambers, but it was felt that there would also be a fair degree of risk. It is possible that water dispersion might proceed at a higher rate than the pumping, which would lead to water saturation of some of the stored dust.

An endless bucket chain suspended in the stope, with links and buckets added as the chain is lowered, was also considered. This may be technically feasible, but there would be quite a bit of difficulty in making the initial linkup of the chain inside the chamber. The problem would be in bringing the two ends of the chain together from where they enter the stope.

Accessing the stopes from the lower bulkheads, and mechanically reclaiming the dust was briefly considered. The need to isolate the recovery drift from the rest of the mine while reclamation was being done, and the need to prevent contamination of the mine while transporting the material to surface, was felt to be too difficult. There was also the potential for labour unrest because of the contamination risk.

Reclamation from the top seemed to be the most likely approach, and a clamshell bucket suspended from a monorail attached to the top of the stope was considered. The clamshell bucket would be hoisted up to dump into a vibrating screen. The screen undersize would gravity feed onto a live bottom feeder (several short side by side screw conveyors) which would convey the material into a tubular drag conveyor, and thence to surface storage. Tubular drag conveyors can handle a variety of materials, including peanut butter for example, and it was felt that this idea would work.

There was still a problem with worker exposure, and the idea was further refined. The new layout would use the same equipment, but instead of being located in the arsenic chamber above the dust, it would be located in a new drift driven several feet above the arsenic chamber. A number of slots would be sunk from the drift into the chamber, and the clamshell would retrieve the dust through the slots. The operator would be located on surface, monitoring his equipment via closed circuit TV.

Perhaps 90% of the dust can be reclaimed using the clamshell. The remaining dust on the floor of the chamber could possibly be picked up by a remote controlled scooptram and moved to where the clam could acess it. The dust on the walls could be washed down using a water cannon mounted on the scooptram, the resulting water and arsenic slurry being pumped to surface for treatment. A thickener and press filter would be required for dewatering on surface, and the arsenic saturated water would be recycled back to the water cannon.

A second clamshell recovery system and U/G development would be required to ensure no interruption in production. Additional equipment for final cleanup would also be needed, ie. remote scooptram, pumps and piping, thickener, filter press, etc. The additional capital expenditure for this equipment and U/G development would not be required until three years and four years after startup.

Densification of As_2O_3

There are several ways in which the bulk density of As_2O_3 can be increased. Controlled sublimation from a gas, cold surface condensation, crystalliztion from a mother liquor, extrusion of a paste, roll compaction, disc or drum pelletizing, and shaker tables have all been examined for use at Giant at one time or another. For example, there are 2 machines in the boneyard at Giant, a paste extruder and a pan pelletizer. It is likely that these were once used to test densification of baghouse dust for underground storage but no documentation has been found to show the results of testwork.

In 1975 Falconbridge Metallurgical Lab tested crude baghouse dust in a flat roll compactor with addition of 3% water. Bulk density was increased from 26 lb/ft^3 to 109 lb/ft^3. They also examined the use of a hydraulic plunger compactor and a paste extruder. The roll compactor was determined to be the best alternative.

Larry Connell and Bryan Cross conducted crystallization testwork in 1979 on dissolved baghouse dust. Outside testing was done at Struthers-Wells and the crystallized product had a bulk density of about 125 lb/ft^3.

Shipments of crude baghouse dust in drums from Giant were densified by vibrating the drums on shaker tables as they were being filled. As the entrained air escaped and the material compacted in the drum, the density increased from about 30 lb/ft^3 to about 50 lb/ft^3.

Samples of purified As_2O_3 from pilot plant studies was sent to Ferro-Tec and Ludman machine in 1988 for compaction testing. Both companies produced high quality button compacts on a laboratory press. Only Ferro-Tec was willing to test the material on a full size compactor in their shop however, and their tests confirmed that a bulk density of at least 106 lb/ft^3 could be achieved in a roll compactor with the addition of 3% water and 30 tons of roll pressure. Ferro-Tec also tested densification of the purified dust using pin agglomeration followed by pan pelletizing. The experiment was only partially successful in that lignin rather than water was required as a binder, and the pellet density achieved was only 77 lb/ft^3 .

Furukawa, a Japanese company offered to sell their As_2O_3 sublimation technology to Giant for a fee of approximately $206,000 in 1988. The key to their ability of producing dense crystal from direct sublimation was in the design of a second stage condenser, with which they could apparently control the rate of sublimation and crystal formation. The fee was felt to be too high at the time. Given the high costs of installing and operating an alternative system, this may be the way to go.

Cold surface condensation can be used to plate a film of arsenic trioxide directly from the gas phase onto a cold surface, from which it can be scraped off as a dense, high purity flake. Patent and literature searches done by consultant Ron Hatch turned up only small scale apparatus not suitable for an industrial application. Current investigations indicate that the equipment is available, but is inefficient and very expensive. More information is being sought but it seems more and more likely that technology from an earlier age might be more suitable. Two examples are shown below.

Anaconda used a primitive type of cold surface condensation in their arsenic trioxide plant, which was built at Anaconda, Montana in 1904. Essentially crude arsenic trioxide was fumed from a wood fired furnace and carried through brick flues to the condensing chamber. The chamber was 8 ft high, 16 ft wide, and 240 ft long, divided into small kitchens by partitions spaced every 7 feet. The fume took a zig-zag course through the kitchens, causing the fume to come in contact with the cold walls and ceiling, condensing out the arsenic. There was a small door into each kitchen from the outside, which permitted periodic removal of the deposited arsenic. The dust might have to be reprocessed to bring the product quality to minimum standard, 95 to 99% pure. Unfortunately the paper from which the above information was taken did not include any reference to bulk density of the product.

Asarco used a similar idea until quite recently. Their process used four Godfrey roasters connected to three kitchens having multiple stalls (15 stalls, 5 ft wide, 51 ft long) .To quote from Asarco's description "Generally speaking, saleable As_2O_3 is deposited in the back half of the kitchens, dust deposited in the front half is rerouted. All arsenic is pulled from the kitchens using a double drum hoist and scraper. A heavy crystalline deposit of As_2O_3 forms on the walls and arches of kitchens and must be dug out every 8-12 months." Again there is no mention of bulk density, but a 'heavy crystalline deposit' indicates that this portion of the condensate at least, will have a high bulk density.

CAPITAL AND OPERATING COSTS

The estimated capital cost of installing sintered metal filters to replace the cottrells is $2,950,000. For the basic plant, there will be no increase in operating costs. If a dense, dust free product is desired to make the product more attractive to clients, and to reduce shipping costs, a compaction circuit will cost an additional $1,554,000 and operating costs will increase by about $200,000/yr.

A full scale fuming plant complete with compaction equipment will be capable of treating both reclaimed and current production material at a rate of about 7,500 tpy. The capital cost of the fuming plant, not including underground reclaim, is estimated at an initial $8,362,000 plus $1,116,000 in the third year of operation for dewatering equipment associated with washing down the underground storage chambers. The operating cost of the fuming plant is estimated at $1,342,000 per year, not including transportation or underground reclaim. In 1990, bulk trucking costs to Conley, Ga. were quoted at $410/ton. Underground reclaim operating costs are currently estimated at $291,000/yr.

Sintered Metal Filters
Capital Cost

Quotations have been received from suppliers of the major items of equipment, as shown below. US prices have been converted to Canadian at a rate of 1.36:1.

Sintered metal filter assembly, including filter elements and housing, blowback valves, and control system	$872,700
Booster fan capable of 11,000 ACFM, 400° C, 40" static pressure. includes 350 hp motor	$73,000
Ferro-Tec 30 ton roll compactor	$254,300
Used 10" X 6" Denver roll crusher	$11,935
20 ton compactor feed bin	$15,000
bin aerator	$10,000
rotary valve 6"	$5,000
compactor feed screw	$4,000
compactor feed hopper	$3,000
roll crusher feed hopper	$3,000
roll crusher discharge hopper	$3,000
product screen	$27,900
recycle conveyors	$25,000
bucket elevator	$74,000
equipment cost	$1,381,835
GST	$96,728
total	$1,478,563
Installed cost (eqpt cost X 3.05)	$4,509,618
Demolition of cottrell sections #3 & #4	$96,000

Installed cost of the sintered metal filter and booster fan only, including cost of demolishing one cottrell section, is estimated at $2,950,000.

Installation of the compactor, because of the potential for arsenic dust contamination, should be done in a separate building dedicated to operation of the compactor, roll crusher, and product screens. Auxiliary equipment includes dust collection apparatus, bucket elevator, day bin, etc. All up capital cost is estimated at about $1,560,000.

Total capital cost of the sintered metal filter and compaction plant, $4,510,000.

Operating Cost

There would be no incremental cost of operation of the sintered metal filter. The cottrell operators would operate the filters rather than the cottrells. The annual cost of operating the booster fan under normal conditions (110 bhp) would be $69,000. This would be more than offset by eliminating the cottrell electrical requirements. There would be costs involved in occasional acid treatment of the filter elements, but these are expected to be less than cottrell maintenance costs would be.

Operation of the compactor and the As_2O_3 loadout facility would cost about $200,000/yr. A full time operator would be required and arsenic pay would undoubtedly be an issue. Safety gear, plant heating and lighting, maintenance, air quality control, etc. would make up the remainder of the operating cost.

Fuming Plant
Capital Cost

The 1988 Fenco/Lavalin feasibility study has been used as a basis for estimating current capital cost for the fuming plant. The 1988 estimate has been adjusted upward by 17% based on a comparison of the current plant cost index with the index of 1988. Some current quotes have also been used.

The current cost of equipment in the fuming plant is estimated at $2,697,000. Using the plant cost ratio method (equipment cost X 3.10) The cost estimate for the complete plant is $8,361,000. A detailed equipment list is attached.

Operating Cost

The Fenco/Lavalin study indicated a plant operating cost of$1,544,200 per year, about $0.10/lb of As_2O_3 produced. Under the current scheme, there are two areas where cost savings could be made, as shown below.

	Current	Fenco
Electric power	155,000	155,000
Propane @ $0.21/liter (plant heating and drying)	30,000	30,000
Propane @ $0.21/liter (process)	102,000	25,000
operating labour	431,000	431,000
supervision, 15% of labour	65,000	5,000
maintenance labour	43,000	143,000
supervision, 20% of mtce labour	28,600	5,000

materials	143,000	143,000
payroll overhead 35% of above payroll	241,000	204,400
operating supplies 20% of plant maintenance	62,800	58,200
taxes	71,400	71,400
insurance	71,400	71,400
Total processing plant operating cost	1,544,200	1,342,400

Savings could be made in the following areas.

- Propane used in process will be minimized by utilizing excess heat from roaster exhaust gas.
- No dedicated operating or maintenance supervision.

Alternative to Compaction System

The capital and operating costs for the compaction system represent a big part of the costs for either flowsheet. Compactors are expensive, dusty, high maintenance machines, and they need close operator attention. Provided it could be done cost effectively, it would be preferable if a dense As_2O_3 product could be produced directly from condensation of the fume. Using long brick flues and kitchens to do this, as was frequently done in the past, would undoubtedly be very expensive, and handling of the bulk product in the old way, using slushers and wheelbarrows, would be considered an unacceptable exposure hazard these days.

Furukawa's Ashio arsenic smelter in Japan used a specially designed condenser following their secondary roast, that was reportedly able to produce a dense (94 to 119 lb/ft^3) particulate directly from condensation of the fume. This product was collected in a hopper below the condenser and drawn off with a screw conveyor. Several years ago Furukawa was willing to sell the technology to Giant and the opportunity may still be available.

Use of this technology would likely result in an operating cost savings of about $290,000/yr. Instead of two plant operators around the clock, only one would be required. An accurate estimate of the capital cost of the condenser is not possible without having more detail. From the brief description that is available, "The second condenser was a single rectangular unit equipped with a few air cooled baffles. The dimensions, number of baffles, etc. are undoubtedly dependent upon furnace gas volume, arsenic loading, ambient temperature, etc., and this appears to be the area of knowhow which Furukawa is not willing, understandably, to divulge at this stage." From the description, and from a sketch of the plant and flowsheet, it seems unlikely that the condenser would cost as much as the compaction circuit.

Underground Reclaim
Capital Cost

From testwork done on vacuuming dust from underground storage, it seems unlikely that this method would be successful for reclamation of most of the stored material. Even a small amount of contained moisture causes severe blockages in the vacuum hose, which are very difficult to clear. A clamshell bucket capable of reclaiming 3 tons/hr over a single eight hour shift per day would provide enough feed for the fuming plant to produce 7,500 tons/yr of purified As_2O_3.

The hoisting apparatus for the clamshell would be located in an oversized drift above the arsenic chamber. The clam would be raised and lowered through slots in the floor, dumping its load onto a vibrating screen to remove rocks and other debris. The screen undersize would be conveyed to a tubular drag conveyor for transportation of the material to surface storage.

Capital cost of the installation, from 1988 equipment quotations and u/g development estimates, is now estimated at $1,046,000. A second apparatus would have to be prepared in advance, so that when one stope is nearing depletion, the next is ready to go. This would be required in year four. Additional underground development, estimated at $250,000 would be required in year five.

Final cleanout of the stopes might be done using a remote controlled 3/4 cy scooptram, which would bring the inaccessible (to the clamshell) material to a point where it could be picked up by the clam. A capital estimate of $225,000 for the scooptram has been used in the economic study. Cleanout with the scooptram might be followed by washing the walls with a water cannon mounted on the scooptram. The material would be sluiced to a sump to be pumped to surface for processing. $175,000 for pumps and pipelines has been used in the capital estimate. An additional $1,116,000 for surface dewatering equipment (thickener and filter press) would be required to handle this material.

Total capital cost for underground reclaim:

Year one	Year four	Year five
$1,046,000	$1,046,000	$250,000
	$225,000	
	$175,000	
	<u>$1,116,000</u>	
total year four	$2,562,000	

Operating Cost

The reclaim equipment would be operated from surface using closed circuit TV and other monitoring equipment. One operator per day, seven days per week, would be required, to recover up to 8,000 tpy of crude dust. This is a reclaim rate of about 2 tons per operating hour. Fenco's annual operating cost estimate in 1988 was $249,000/yr. An updated estimate would be $291,000.

Perhaps 90% of the dust could be reclaimed by the clamshell at an operating cost of $291,000/yr. Assuming that 8% of the total can then be recovered by scoop tram and the remaining 2% must be recovered by water cannon and pumping, additional operating costs will apply. No real operating cost estimates have been made, but a guess of $200/ton reclaimed by the scooptram and $400/ton reclaimed by the water cannon may be close. This would add $319,000 in year four and $303,000 in year five.

Stope	B2–34	B2–33	B2–35&36
Tons dust	13,281	12,595	36,500
Tons As2O3	6,330	6,141	25,860
% As2O3	47.67	48.76	70.85
Oz/t Au	2.38	1.325	0.767
Oz Au	31,609	16,688	27,980

Royal Oak Mines Inc, Giant Mine
Arsenic Reclaim and Purification
Economic study (5000 – 7500 tpy)
Cash flow projection

gold price = $460/oz 90% Au recovery
As2O3 price = $0.33/lb 100% As2O3 recovery

year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
U/G source		B2–34	B2–34	B2–33 & 34	B2–33 & 35	B2–35 – 36	B2–35 – 36	B2–35 – 36	B2–35 – 36	B2–35 – 36
PRODUCTION										
Tons feed from mill	0	3,625	3,625	3,625	3,625	3,625	3,625	3,625	3,625	3,625
Tons feed from U/G	0	4,293	6,390	8,357	8,548	6,417	6,417	6,417	6,417	6,417
Tons feed processed	0	7,918	10,015	11,982	12,173	10,042	10,042	10,042	10,042	10,042
Tons As2O3 from mill		2954	2954	2954	2954	2954	2954	2954	2954	2954
Tons As2O3 from U/G		2046	3046	4047	4546	4546	4546	4546	4546	4546
Tons As2O3 processed	0	5,000	6,000	7,015	7,954	7,476	7,476	7,476	7,476	7,500
Tons As2O3 sold	0	5,000	6,000	7,000	7,500	7,500	7,500	7,500	7,500	7,500
Ounces gold produced	0	9,784	14,276	13,021	9,923	5,084	5,084	5,084	5,084	5,084
REVENUES										
Revenue Arsenic (X1000)	0	$3,300	$3,960	$4,620	$4,950	$4,950	$4,950	$4,950	$4,950	$4,950
Revenue Gold (X1000)	0	$4,501	$6,567	$5,990	$4,565	$2,338	$2,338	$2,338	$2,338	$2,339
Revenues/ton feed	0	$985	$1,051	$885	$782	$726	$726	$726	$726	$726
Revenues/ton As2O3	0	$1,560	$1,755	$1,512	$1,196	$975	$975	$975	$975	$972
Total revenue (X1000)	0	$7,801	$10,527	$10,610	$9,515	$7,288	$7,288	$7,288	$7,288	$7,289
Total operating (X1000)	0	$3,683	$4,093	$4,955	$5,136	$4,708	$4,708	$4,708	$4,708	$4,708
Operating/ton feed	0	$465	$409	$413	$422	$469	$469	$469	$469	$469
Operating/ton sold	0	$737	$682	$708	$685	$628	$628	$628	$628	$628
CAPITAL (X1000)	$9,407	0	0	$2,562	250	0	0	0	0	0
Cash flow (X1000)	($9,407)	$4,118	$6,434	$3,093	$4,128	$2,580	$2,580	$2,580	$2,580	$2,581
Cash flow using rail freight	(12,332)	4,584	7,120	3,999	5,144	3,596	3,596	3,596	3,596	3,597

Stope	B2-34	B2-33	B2-35&36
Tons dust	13,281	12,595	36,500
Tons As2O3	6,330	6,141	25,860
% As2O3	47.67	48.76	70.85
Oz/t Au	2.38	1.325	0.767
Oz Au	31,609	16,688	27,980

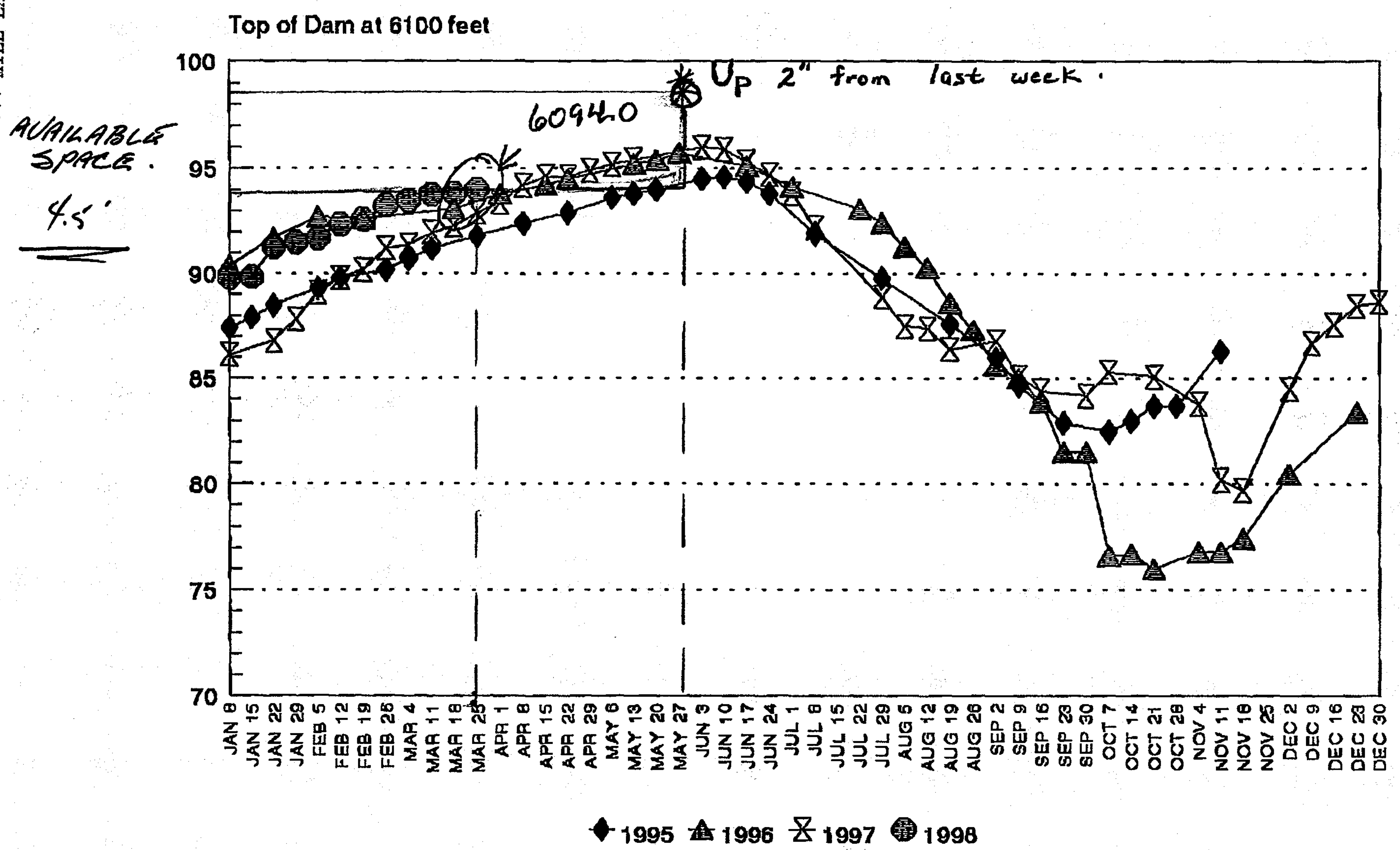
Royal Oak Mines Inc, Giant Mine
Arsenic Reclaim and Purification
Economic study (5000 – 7500 tpy)
Capital and operating costs

year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
U/G source		B2-34	B2-34	B2-33 & 34	B2-33 & 35	B2-35 – 36	B2-35 – 36	B2-35 – 36	B2-35 – 36	B2-35 – 36
U/G OPERATING (X1000)										
clamshell (90% recovery)	0	291	291	291	291	291	291	291	291	291
scoop (8% @ $200/t)	0	0	0	212	202	0	0	0	0	0
pump (2% @ $400/t)	0	0	0	106	101	0	0	0	0	0
subtotal	0	291	291	610	593	291	291	291	291	291
PLANT OPERATING (X1000)										
conventional (98%)	0	1,342	1,342	1,342	1,342	1,342	1,342	1,342	1,342	1,342
slurry (2% @ $500/t)	0	0	0	133	126	0	0	0	0	0
subtotal		1,342	1,342	1,475	1,468	1,342	1,342	1,342	1,342	1,342
FREIGHT, $410/t (X1000)	0	2,050	2,460	2,870	3,075	3,075	3,075	3,075	3,075	3,075
total U/G, plant, and freight	0	3,683	4,093	4,955	5,136	4,708	4,708	4,708	4,708	4,708
CAPITAL (X1000)										
U/G clamshell	1,046			1,046	250					
U/G scoop				225						
U/G pump				175						
plant conventional	8,361									
plant slurry				1,116						
Total capital	9,407			2,562	250					
Total costs	9,407	3,683	4,093	7,517	5,386	4,708	4,708	4,708	4,708	4,708

TRANSFER FACILITY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
capital	2,925									
operating		634	634	634	634	634	634	634	634	634
truck freight to transfer		300	360	420	450	450	450	450	450	450
rail freight		650	780	910	975	975	975	975	975	975
total freight		1,584	1,774	1,964	2,059	2,059	2,059	2,059	2,059	2,059
difference truck vs rail		466	686	906	1,016	1,016	1,016	1,016	1,016	1,016

Royal Oak Mines Inc. - Giant Mine

Northwest Pond Water Elevations



Top of Dam = 6100 ft. (less 1.5 ft. freeboard)

Att: John Stard Denis Gratton Kent Morton Bryan Cross Stephen Schultz

Mar 26.