Royal Oak Mines Inc

To: Larry Connell
CC: Bryan Cross
From: Kent Morton
Date: March 7, 1997

Subject: The Use of Mill Tailings to Scrub Sulphur Dioxide From Roaster Off Gas

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I just have a few comments and/or queries

From the September 1995 stack test

arsenic conc. 3.15 mg/m^3, 0.134 kg/h (1,115 kg/yr @ 95% roaster availability)
sulphur dioxide conc. 30.81 g/m^3, 1287.5 kg/h (29,355 kg/d @ 95% roaster availability)
average gas temperature, 77.8°C
total gas flow rate, 12.52 m^3/s (26,528 cfm)
dry gas flow rate, 11.62 m^3/s (24,621 cfm)
water concentration, 7.3%

Re: short term action to reduce ground concentrations. What about increasing dilution air at the stack? Even if the cooling effect of the dilution air results in an initial lower volume of gas, just continue to increase the dilution air until the desired SO_2 concentration is achieved.

Re: scrubbing with mill tailings. Should consider what effect scrubbing will have on lime requirement in the ETP?

Treatment of a high volume of dilute gas would require large equipment. A lower volume of a concentrated gas would be easier to handle. If As_2O_3 purification is done using refuming, the gas volume would be about ½ the present volume.

Maybe this is a good time to reconsider recycling gas from the cottrell exhaust back into the first stage roaster (remember the inert gas generator discussions?). We would have a bleed stream of concentrated SO_2 to deal with and perhaps better roaster performance. Combining this with a long brick flue (*a la* Anaconda and Asarco) or similar heat exchanger for cooling the gas and condensing the arsenic would dispense with the need for adding quench air ahead of the baghouse.

Assuming the results of the bench testwork are encouraging, is there an advantage to running a small scale pilot test using actual tailings and gas streams? A few small pumps and 1" flexible polyethylene pipelines could be used for the slurry and liquid streams. Gas could be drawn off the flue at the point where the opacity meter was once located. A couple of small agitated reaction tanks could be set up fairly quickly. Should the budget be adjusted to include this?

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Background

The NWT Government has proposed new regulations under the NWT Environmental Protection Act that would require Royal Oak to reduce the mass emission rate of sulphur dioxide from the Giant Mine roaster stack from 50 to 5 tonnes per day by June 30, 2006. While we have no firm date for the passage of this regulation into law, we have been advised by the GNWT that this regulation will be put in place sometime in 1997.

The proposed regulation would also require that Royal Oak propose and take un-specified action within the next one to two year time frame to reduce ground level concentrations of sulphur dioxide in the Yellowknife area. The type of remedial action that has been considered to meet this short term requirement includes:

i) Replacement of the existing 150 feet high roaster stack with a new 300 feet high stack at an estimated cost of $1.25 to $1.5 million. Dispersion modeling of the Giant roaster stack showed that doubling the stack height to 300 feet would result in a 40 to 45 percent reduction in SO_2 ground level concentrations.

ii) Installing a propane fired heater in the roaster duct work to raise the exhaust gas temperature from 230° F to 430° F at an estimated capital cost of $525,000 plus an additional annual operating cost of $525,000. Dispersion modeling of the Giant roaster stack showed that increasing the exhaust gas temperature to 430° F would result in a 50 to 60 percent reduction in SO_2 ground level concentrations during the summer months.

Proposal to Scrub Roaster Off Gas with Mill Tailings

The tailings slurry from the Giant mill contains significant alkalinity originating from the carbonate content of the tailings solids and from the residual lime left in the slurry after processing. Initial indications are that the tailings slurry has a buffering capacity of as much as 100 Kg of sulphuric acid per ton of solid tailing. The objective of this proposal is to evaluate the technical and economic feasibility of utilizing as much of this residual alkalinity as possible to scrub some of the sulphur dioxide from the roaster off gas. To the best of our knowledge this type of approach is not being used any where else in the mining industry. Two side benefits anticipated from this scrubbing process would be:

1) the reduction of arsenic trioxide in the roaster stack exhaust gas resulting from the removal of some water soluble arsenic in the gas scrubbing process; and

2) the oxidation of some of the cyanide contained in the mill tailings slurry through contact with SO_2 in the scrubber.

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On a conceptual basis, an undetermined portion of the roaster off gas would be removed from the duct work downstream of the current baghouse and scrubbed through the mill tailings slurry in a mechanically agitated tank. The rate of gas withdrawal from the roaster off gas would be matched with the scrubbing capacity of the mill tailings slurry so that no sulphur dioxide gas would exit the scrubbing tank thereby eliminating the capital cost of additional gas handling equipment downstream of the proposed scrubber tank. A copy of the conceptual flowsheet for this scrubbing circuit is attached.

The questions that must be answered by the proposed technical and economic evaluation are as follows:

3) What reduction in ground level concentrations of sulphur dioxide can be expected as a result of the removal of 5%,10%, 20% or 30% of the mass emission rate of sulphur dioxide from the Giant roaster stack?

4) What is the scrubbing capacity of the individual components of the Giant mill tailings slurry? Can the scrubbing efficiency of the slurry be increased by removing one of the streams making up the combined mill tailings slurry, ie. the mine water stream for example?

5) How much sulphur dioxide can be neutralized by the mill tailings slurry in a retention time of 5, 10, 15, 30, 45 and 60 minutes?

6) What volume of roaster off gas can be scrubbed with the mill tailings slurry in a retention time of 5, 10, 15, 30, 45 and 60 minutes while leaving no residual SO_2 in the gas exiting the scrubber?

7) What is the impact of scrubbing a partial gas stream on the emission rates of arsenic trioxide from the Giant roaster? Will this additional arsenic increase the operating costs at the existing effluent treatment plant?

8) What is the impact of scrubbing a partial gas stream on the cyanide concentration in the mill tailings slurry discharged into the tailings impoundment? Will there be any resulting savings in operating cost at the existing effluent treatment plant?

9) What are the design parameters for a full scale scrubber installation?

10) What is the estimated capital and operating cost of a full scale scrubber installation?

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The proposed program to evaluate the technical and economic feasibility of scrubbing SO_2 from the Giant roaster off gas using mill tailings slurry has been sub-divided into three distinct areas of study:

A) Stack Dispersion Modeling

In 1995 and again in 1996 Royal Oak Mines and the GNWT jointly funded the development of a numeric model to simulate the dispersion pattern of the exhaust gas from the Giant roaster stack. The work was done by HUM Scientific of Halifax under sub-contract to M.M. Dillon Engineering of Yellowknife. HUM Scientific are recognized by Environment Canada as one of the more competent air dispersion model builders in Canada. The model was successfully verified against actual ground level concentrations of sulphur dioxide that were measured by the GNWT in previous routine monitoring in the Yellowknife area. The model was subsequently used to predict the impact on ground level concentrations of SO_2 that would result from installing a higher stack, raising the temperature of the exhaust gas or by increasing the exit velocity of the exhaust gas from the stack. As part of this technical investigation it is proposed that HUM Scientific be contracted to determine what impact a reduction of 5, 10, 20 and 30% in the mas emission rate of sulphur dioxide from the existing Giant roaster stack would have on the ground level concentrations of sulphur dioxide in the Yellowknife area. We have invested a significant amount of money in the existing dispersion model so it makes economic sense to go back to the model builder to have this new work carried out. The cost of this task has been estimated at $2,500 following consultation with HUM Scientific. The information derived from this modeling would be used to predict the benefits that would be attained by investing in gas scrubbing equipment at the Giant mine.

B) Laboratory Investigations & Determination of Design Parameters

The laboratory investigations would be carried out by Royal Oak personnel in the mill lab at the Giant Mine. A laboratory flotation cell would be converted for use as a test apparatus for the scrubbing tests. The laboratory investigations would be sub-divided as follows:

i) Determination of scrubbing capacity of the individual components of the Mill Tailings

The final tailings stream from the Giant mine is made up from at least six waste streams which include the flotation circuit tailings, the cyanide leach residue, the barren bleed solution from the Merril Crowe process, cyanide leach residue from the hot cottrell dust leach circuit, wash water from the roaster calcine wash thickener and groundwater pumped to surface from the underground mine. Each of these materials will have a separate capacity to neutralize SO_2. It may be possible to maximize the amount of SO_2 neutralized in a fixed scrubber capacity by excluding one or two of the streams that have much lower neutralizing capacity. To test this it will be necessary to understand the capacity of each stream to neutralize SO_2 individually. Two techniques are proposed to determine this capacity:

A mechanically agitated 1,000 ml sample of each material will be titrated against a weak sulphuric acid solution (10% sulphuric acid by weight) to determine the amount of sulphuric acid in grams required to bring the buffered pH of each material down to 7.0.

The individual capacity of each of these stream to neutralize sulphur dioxide will be determined by contacting a known concentration of SO_2 with the material utilizing the laboratory test apparatus constructed for that purpose. A compressed gas bottle containing a known, verified concentration of sulphur dioxide will be purchased for use in this test procedure. The bottle will be equipped with a pressure reducing valve and a gas rotameter so that the quantity of gas used can be accurately measured. The gas bottle will be piped through the pressure reducing valve and rotameter to the air inlet on the shaft of the laboratory flotation cell. A plexiglass housing will be constructed to go over the top of the flotation cell to contain any gas released from the surface of the flotation cell during the scrubbing test. Four liters of material will be placed in the flotation cell and agitated with the standard flotation cell mechanism. A pH probe will be set up in the cell to provide a continuous read out on an attached meter of the pH of the solution or slurry being tested. A drager tester will be used to monitor for SO_2 gas inside the plexiglass housing via a sampling port equipped with a rubber diaphragm which has been slitted to allow the tip of the glass drager tube to penetrate inside the plexiglass housing. Once the pH has settled a small volume of SO_2 will be added on a continuous basis through the rotameter into the flotation cell where it will be dispersed by the agitator. The pH and SO_2 concentration inside the plexiglass housing would be measured at 30 second intervals and recorded. The test would be terminated once an appreciable SO_2 concentration had been detected inside the housing. The total length of time that SO_2 has been added will be recorded so that the quantity of SO_2 added can be calculated from the known gas concentration used and the rate of gas addition to the cell. It will require some field trials to ascertain the initial set point for the rate of SO_2 gas addition and to determine when the test should be terminated.

ii) Determination of the Scrubbing Capacity of the Combined Mill Tailings Stream

The results from the first phase of this test program will be analyzed to determine whether there is any predicted benefit in removing one or more of these waste streams from the combined tailings stream to be used for scrubbing the roaster off gas. The capital cost of the scrubbing system will be a function of the required size of the scrubbing tank which in turn is dependent upon the retention time for efficient neutralization of the SO_2. The retention time can be increased by either building a large scrubbing tank or reducing the volume of scrubbing slurry per unit of time. The latter can be achieved by eliminating those streams from the combined tailings stream that have a low neutralizing capacity. These streams can be added back into the tailings downstream of the scrubber installation. Based on the analysis the test program described above would be repeated utilizing the combined tailings slurry stream less those individual streams consciously removed as a result of their low neutralizing potential. The results would be repeated over a number of test cycles using fresh tailings material to verify the neutralizing capacity of the mill tailings and to determine the var iability in neutralizing capacity that occurs between samples of mill tailings taken at different times.

iii) Determination of the Scrubbing Circuit Parameters

The circuit parameters to be defined in this phase of test work include;

i) the required scrubbing circuit retention time,

ii) the required volume in the scrubbing circuit,

iii) the impact of scrubbing on total arsenic levels in the mill final tailings slurry,

iv) the impact of scrubbing on total, weak acid dissociable and free cyanide concentrations in the final mill tailings slurry.

The test procedure described above would be used at varying scrubber retention times of 5, 10, 15, 30, 45 and 60 minutes to enable a curve of retention time versus SO_2 neutralization efficiency to be developed.

The average volumetric flow rate would be measured for each of the tailings streams to be used in the scrubbing circuit. The measurements will include the maximum, minimum and average flow for each stream.

Once the optimum scrubbing circuit retention time has been established, the test procedure would be repeated over several cycles at the optimum retention time. The concentration of total arsenic, total cyanide, weak acid dissociable cyanide and free cyanide in solution would be measured before and after contact with the roaster off gas to enable the impact on each parameter from scrubbing to be determined.

The total estimated cost of this laboratory investigation is estimated at $5,000 which is solely to cover the purchase of the necessary equipment and supplies. No labor component has been included as the work will be carried out by Royal Oak personnel.

C) Economic Assessment

Using the data obtained from the laboratory investigations a preliminary flowsheet and a set of process design parameters for a gas scrubbing circuit will be drafted by Royal Oak (Larry Connell). A consultant, Ron Hatch (who has extensive experience both in gas handling equipment at various smelters and with the Giant gold roaster when it was owned and operated by Falconbridge), would be retained to review the results of the laboratory investigations , the proposed flowsheet and the process design parameters. Ron Hatch would be asked to bring his experience to bear in how we have interpreted the results and to suggest modifications to the flowsheet and design parameters before they are passed on for preliminary design engineering and cost estimating. The cost of this work is estimated at $2,500.

A consulting engineering firm with demonstrated experience in the design and construction of gas scrubbing equipment will be retained to carry out a pre-feasibility level design and capital cost estimate (+/- 30%) for a full scale installation at the Giant mine based on the flowsheet and process design parameters provided by Royal Oak. The estimated cost of this portion of the work is estimated at $40,000 Cdn.

A final report summarizing all of the elements of this technical and economic evaluation would be put together by Royal Oak personnel (L. Connell) along with a recommendation regarding the feasibility of implementation.

Schedule

The proposed schedule for this work is presented in Table 1.0. The schedule assumes internal approval to proceed by March 14th with a final report due at the end of June. The laboratory test program would be completed over a two month period.

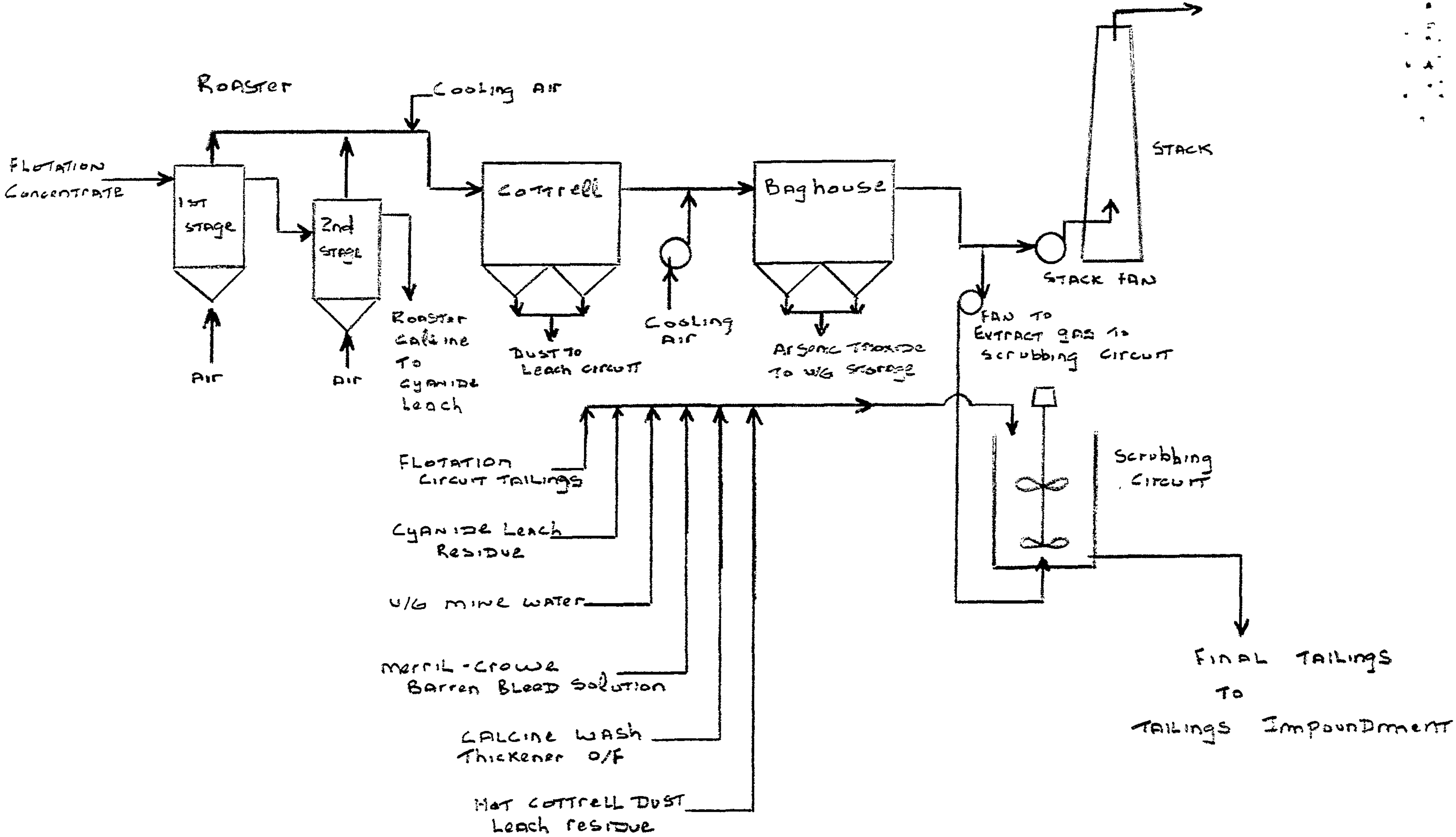
The estimated overall cost of the technical evaluation is estimated at $51,500 as presented in Table 2.0. The majority of this expense ($40,000) is to have a pre-feasibility design and cost estimate prepared by an outside engineering firm from Royal Oak's process design criteria.

Table 1.0 Proposed Project Schedule

Project Activity	March	April	May	June
Internal Approval to Proceed	X			
Dispersion Modeling				
Impact of SO2 removal on ground level concentrations	XX			
Laboratory Investigations				
Initial Set up and Testing of Laboratory Equipment & Procedures	XX	X		
Determination of Scrubbing Capacity on Individual Mill Tailings Streams		XX		
Determination of Scrubbing on Combined Mill Tailings Stream		X		
Determination of Scrubbing Circuit Parameters		X	XX	
Economic Feasibility				
Review of Lab Investigations & Process Design Parameters by R. Hatch			XX	
Pre-feasibility Design and Cost Estimate by Engineering Firm				XXX
Final Report				
Preparation of final report				XXXX

Table 2.0 Proposal to Evaluate the Use of Mill Tailings to Scrub SO2 from Roaster Off Gas - Estimated Cost of Technical & Economic Evaluation

	Estimated Cost $Cdn	Party Carrying out the Work
Dispersion Modeling		
Impact of SO2 removal on ground level concentrations	$2,500	Hum Scientific
Laboratory Investigations		
Equipment & Supplies	$5,000	Local Purchases
Labour	$0	Giant Personnel
Analytical Work	$0	Giant Personnel
Economic Feasibility		
Review of Lab Investigations & Process Design Parameters	$4,000	Ron Hatch
Pre-feasibility Design and Cost Estimate	$40,000	Consulting Engineering firm
Final Report		
Preparation of final report	$0	L. Connell
Total Estimated Cost	$51,500	



Conceptual Flowsheet - SO_2 Scrubbing Circuit - Giant Mine