

**SULPHUR DIOXIDE SCRUBBER PERFORMANCE AT THE GOLDEN BEAR MINE**

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submitted by

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## ABSTRACT

North American Metals Corporation (NAMC) operates a sulphur dioxide ( $\text{SO}_2$ ) scrubbing system as part of a gold processing plant at its Golden Bear Mine. The scrubbing system was designed to remove over 99% of  $\text{SO}_2$  generated from the roasting of a sulphide containing ore. The scrubber used slaked lime (calcium hydroxide) to absorb  $\text{SO}_2$ . Unfortunately, with this process, severe scaling was experienced on scrubber internal surfaces. The scale build up caused an increase in absorber pressure drop and eventually forcing a plant shutdown. Clean out of the absorber tower and components was required weekly.

NAMC contracted Radian Corporation to determine the cause of the scaling and find solutions to the problem. This paper discusses scrubber design, operating problems, process chemistry and an economic evaluation of the process since recent successful changes.

## Introduction

The Golden Bear refractory gold ore roasting operation is located in northwestern British Columbia, about 220 kilometres west of Dease Lake. Mine access is by gravel road and charter aircraft. Employees work a two week in/two week out rotating shift schedule.

Project construction was completed in October 1989 and plant commissioning began in November. Plant throughput averages 360 tonne/day; gold production for 1991 was 56,601 ozs at \$US 354/oz and for 1992 58,224 ozs at \$US 301/oz.

The introduction of new technology at the Golden Bear plant (dry grinding/whole ore roast), coupled with the remote location of the mine provided many unique situations during start up. This paper will focus on resolving a problematic sulphur dioxide scrubbing system and economic evaluation of the changes.

## Scrubber Description - Original Configuration

The SO<sub>2</sub> gas scrubber at Golden Bear was a 4 stage baffle and disc, 316L stainless steel tower. The maximum design allowed for 10,800 normal M<sup>3</sup>/hr containing 86,000 ppm SO<sub>2</sub> with 99% absorption efficiency. The maximum permitted 1 hour average outlet SO<sub>2</sub> concentration was 215 ppm.

The roaster induced draft fan drives the roaster off gas through the scrubber. Gas enters a quench chamber via a 71 cm duct. The gas was quenched by 4 tangential sprays and 4 nozzle sprays with a bleed stream of scrubber recirculation slurry. The gas passed through a 48 cm dia by 58 cm long, right angled transition pipe into the scrubber 2.8 meters up the scrubber tower. The tower is 1.37 m in diameter and 11.5 m high. The gas made its way through a series of four baffle/disc arrangements, the first baffle is at 4.1 m and the others at 1.2 m intervals above the first baffle. The baffles were doughnut shaped and extend inward 20 cm from the tower wall while the discs are 96 cm in diameter, 30 cm above each baffle. The exiting scrubbed gas passed through a Chevron type mist eliminator, 96 cm from the top of the scrubber. The chevron was washed intermittently by water sprays. The gas then passed through a bubble tray (make up water was dispersed here), and finally a CHEAF (cloth medium) before exiting the scrubber to the main stack.

At the base of the scrubber tower was an integral recirculation sump (2800 litres) where the scrubbing solution was collected. At the base of the scrubber, there were two 10.16 cm x 7.62 cm pumps; these were the recirculation pump and the hydroclone feed pump. The recirculation pump delivered the scrubber slurry (2500 l/m) to the centre of the upper most disc in the absorber tower. The absorber slurry then cascaded from baffle to baffle down the tower counter current to the rising SO<sub>2</sub> gas. The hydroclone feed pump delivered tower sump slurry to a nest of 15.2 cm hydroclones. The hydroclone overflow returned to the scrubber sump while the underflow containing the solid calcium sulphite was pumped to tailings. The overflow and underflow densities were 5 and 20 percent solids respectively. pH probes were fitted to the scrubber sump side wall. Magnehelic gauges after each scrubbing stage on the tower, indicated differential pressures through out the scrubbing tower.

## Process Control

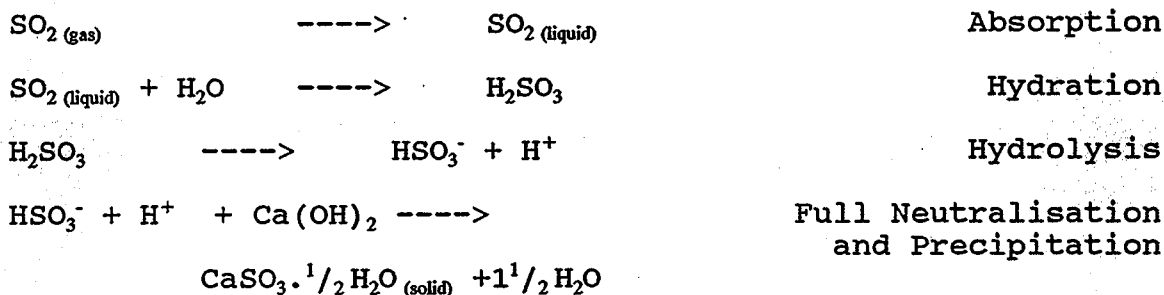
Control of the SO<sub>2</sub> scrubbing process was carried out using separate loops for scrubbing liquor pH and level in the tower sump. Milk of lime was added to the scrubber quench chamber via a 38 mm control valve to maintain the pH setpoint. Scrubber level control was achieved with pressure transducers located on the lower section of the scrubber. Water was added automatically, at the bubble tray, to maintain the level set point. Flow meters were installed on recirculation line and cyclone feed lines. Flow was controlled by manually operated valves.

## Scrubber Operating Problems

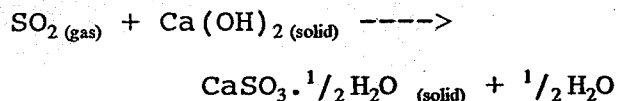
From start up, it was evident that it was not possible to operate the scrubber at a pH of 7 with the milk of lime medium. At pH 10.5 there was no buffer capacity in the scrubbing solution and as the pH fell below 10.5, all the calcium hydroxide was consumed and the scrubbing liquor pH would fall rapidly to pH 3. During these periods of extreme low pH, scrubbing efficiency was severely reduced. Experience established the scrubber operating pH had to be 11.0 - 11.5 to maintain acceptable emissions.

With the scrubber operated at pH 11.0 - 11.5, a large proportion of the alkalinity was solid calcium hydroxide. The solid lime was required due to the extremely high SO<sub>2</sub> concentrations per unit volume in the off gas. The result of the high concentrations of SO<sub>2</sub> and lime was very high super saturation concentrations for calcium sulphite. This in turn made the scale precipitation unavoidable with the design chemistry.

### Scale precipitation Chemistry in the Scrubber



### Overall Reaction inside Scrubber Tower



As a result of these chemical reactions, the scrubber was plagued with scale build up on all internal surfaces. The build up of scale restricted the flow of gas and the operating differential pressure across the scrubber increased. This eventually necessitated process shut down to clean the scrubber. The scale would also blind the chevron, bubble tray and cheaf components. The scale build up within the tower internals would range from 3 cms thick at the upper most baffle to 30 cms in the tower sump. The gap between the lower disc and the wall would be reduced from 20 cms when clean to 5 cms at the time of clean out.

Prior to Radian Corporation's involvement, many operational, mechanical and control changes were made to improve the availability of the scrubber. In order of sequence they were

- a) removed the CHEAF cloth fabric which blinded quickly
- b) removed the quench chamber sprays/nozzles from service to eliminate quench chamber scale
- c) relocated the pH probe from the scrubber sump to the hydroclone over flow stream; this provided a more instantaneous readout of what actually was occurring within the scrubber and allowed for a more accessible area with the probes
- d) installed PLC programming to optimize pH control
- e) installed a 4 m<sup>3</sup> tank in series with the scrubber sump (this tank named the volume tank) to relocate the absorber level control transducers; the outlet from the scrubber to the new volume tank was raised off the scrubber sump floor 1.8 m to have only the hydroclone feed pump drawing off the sump bottom and thus, handling more of the calcium salts to be removed
- f) moved the lime addition point to the volume tank to reduce scrubber inlet scale
- g) installed a continuous emissions monitoring system and further developed process control programs to react to SO<sub>2</sub> emission levels
- h) removed the bubble tray
- i) removed the chevron from its original position and relocated it to the cheaf slot
- j) installed additional wash sprays, below the chevron mist eliminator to wash a larger cross sectional area of this unit

All these changes improved the availability of the scrubber. However, a minimum days production each month was still lost due to required scrubber clean outs. It remained for operations to persist to improve this unit process.

#### Test Work

Upon contracting Radian Corporation, a site visit was organized. Radian's assessment of the problem led to an improvised 4 hour test using sodium hydroxide as source of sodium ion to alter the absorption chemistry in the tower. Initial scrubber operation was promising as the scrubber operated in a steady state condition at pH 6.5.

It was determined that soda ash would be the most cost effective source of sodium ion. A full scale plant test was carried out in December 1992. Results were very positive with no scale prevalent through the test period.

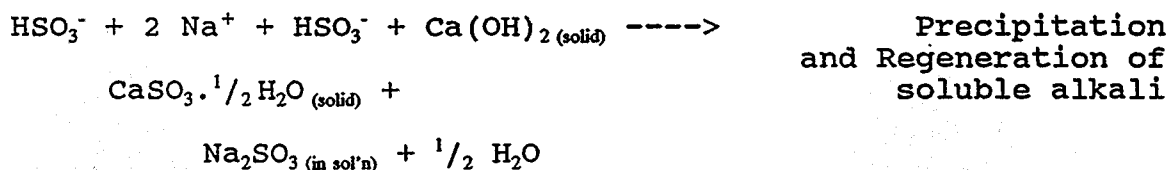
The present chemistry incorporating addition of soda ash allows scrubber operation at an acidic pH as was originally intended while maintaining high absorption of sulphur dioxide. Under these conditions sulphur dioxide gas is absorbed in the tower with a soluble alkali compound replacing the calcium hydroxide. Lime addition at the volume tank allows for calcium sulphite precipitation to occur out side the absorber tower.

#### Reactions in Scrubber Circuit with Soda Ash Added

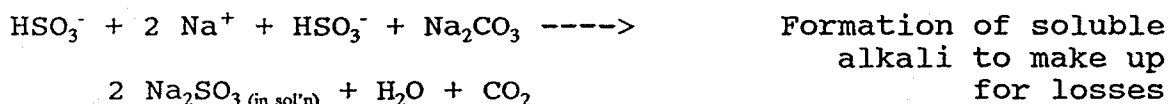
##### In the Scrubber Tower



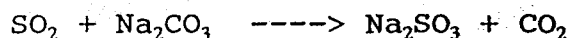
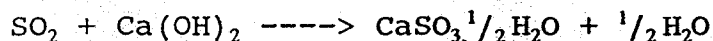
##### Calcium Sulphite precipitation in the volume tank



##### In the soda ash dissolution tank



##### Overall Reactions



To illustrate the buffering capacity of the sodium sulphite versus calcium hydroxide, Figure I shows titration curves of the recirculation liquor with both neutralizing mediums. This analysis is carried out by operations personnel for sulphite content and guides them to adjust the soda ash addition in maintaining soluble alkali levels.

### Equipment Changes/Process Description

The operation was converted over to a dual alkali system at a cost of \$40,000. A bulk soda ash bin and a 0.15 m<sup>3</sup> AccuRate dry solids feeder were added. The hydroclone arrangement, the volume tank and all associated piping to handle the acidic streams were changed out. One new tank with agitator was required for the dissolution of the soda ash.

The soda ash is metered into a mix tank (1 m<sup>3</sup>). The mix solution is a bleed stream from the hydroclone overflow. The bleed stream contains sodium bisulphite which reacts with the soda ash to form sodium sulphite, water and carbon dioxide gas. The soda ash mix tank (sodium sulphite solution) overflows into the volume tank between the scrubber and the recirculation pump. Lime is added and calcium sulphite is precipitated and the sodium sulphite solution is regenerated. The contents of the volume tank are recirculated through the scrubber tower where the sulphur dioxide is removed as sodium bisulphite. This scrubber liquor cascades to the scrubber sump where a portion overflows to the volume tank and a portion is pumped to the hydroclone arrangement. Liquor is pumped to the hydroclone where the precipitated calcium sulphite is removed and the cyclone overflow returns to the scrubber sump or splits to the soda ash mix tank. Circuit control is maintained by measuring the recirculating liquor pH. Soda ash demand is optimized via titrating the recirculating liquor for sulphite species. A single spray of fresh water was reintroduced at the quench chamber.

### Results

Sodium sulphite as a soluble alkali replaced the calcium hydroxide in the neutralizing phase in the SO<sub>2</sub> scrubber tower. The scaling problem was arrested. The net result is less plant down time and a reduction in lime consumption. Operations personnel are no longer subjected to the tedious task of cleaning out the scrubber.

## Economics

The conversion of the lime scrubber to a dual alkali scrubber has accomplished three major gains. Savings in reagents for SO<sub>2</sub> neutralization have been in the order of \$112/tonne sulphur oxidized. This translates into \$400,000/annum at current parameters at Golden Bear. No scale is apparent in the scrubber tower resulting in no requirement for weekly clean out. This incremental gain in plant availability is a minimum 10 days per annum. Given a minimum half of this time would be realized in added production, the ability to produce another 750 ozs gold/annum is achieved. Power savings are realized in keeping a clean absorber tower (ie. the roaster ID fan works less) are assessed at an average instantaneous 20 kw/hr.

Total potential economic impact on a per annum basis

- decrease reagent costs \$ 285,000/annum favourable
- increase production<sup>+</sup> \$ 350,000/annum favourable
- decrease power costs \$ 26,000/annum favourable

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TOTAL            \$ 661,000/annum favourable

+ gold price at \$US 370; exchange rate \$0.80 US = \$1.00 CDN  
- average gold produced/day = 150 ozs

## Conclusions

Use of a soluble alkali in the SO<sub>2</sub> scrubber tower at Golden Bear has resolved a tedious problem

This unit process as described could be considered an option compared to other dual alkali arrangements or absorption tower systems. Capital outlay and square footage required for this system is envisioned less than other systems. This single pass process is a very practical and extremely efficient method of SO<sub>2</sub> neutralization.

## Acknowledgements

The writers wish to thank North American Metals Corporation and Radian Corporation for the opportunity to present this paper.

## REFERENCE

BENSON, L.B., GRAY, S.M. and COLLEY, J.D., SO<sub>2</sub> Scrubber Scaling: Analysis, Evaluation and Recommendations for Solution - Phase 1 Report



# LOCATION MAP

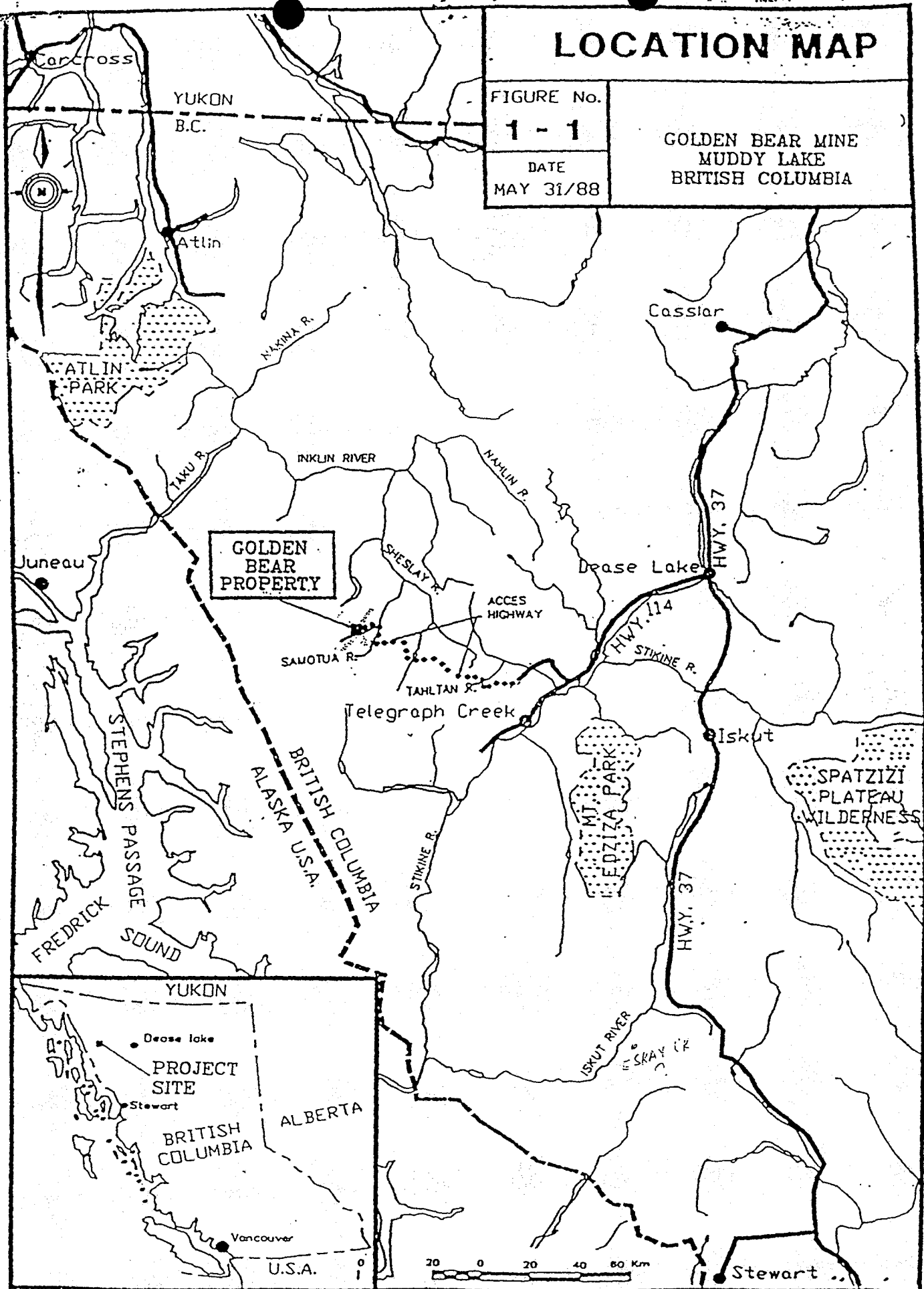
FIGURE No.

1 - 1

DATE

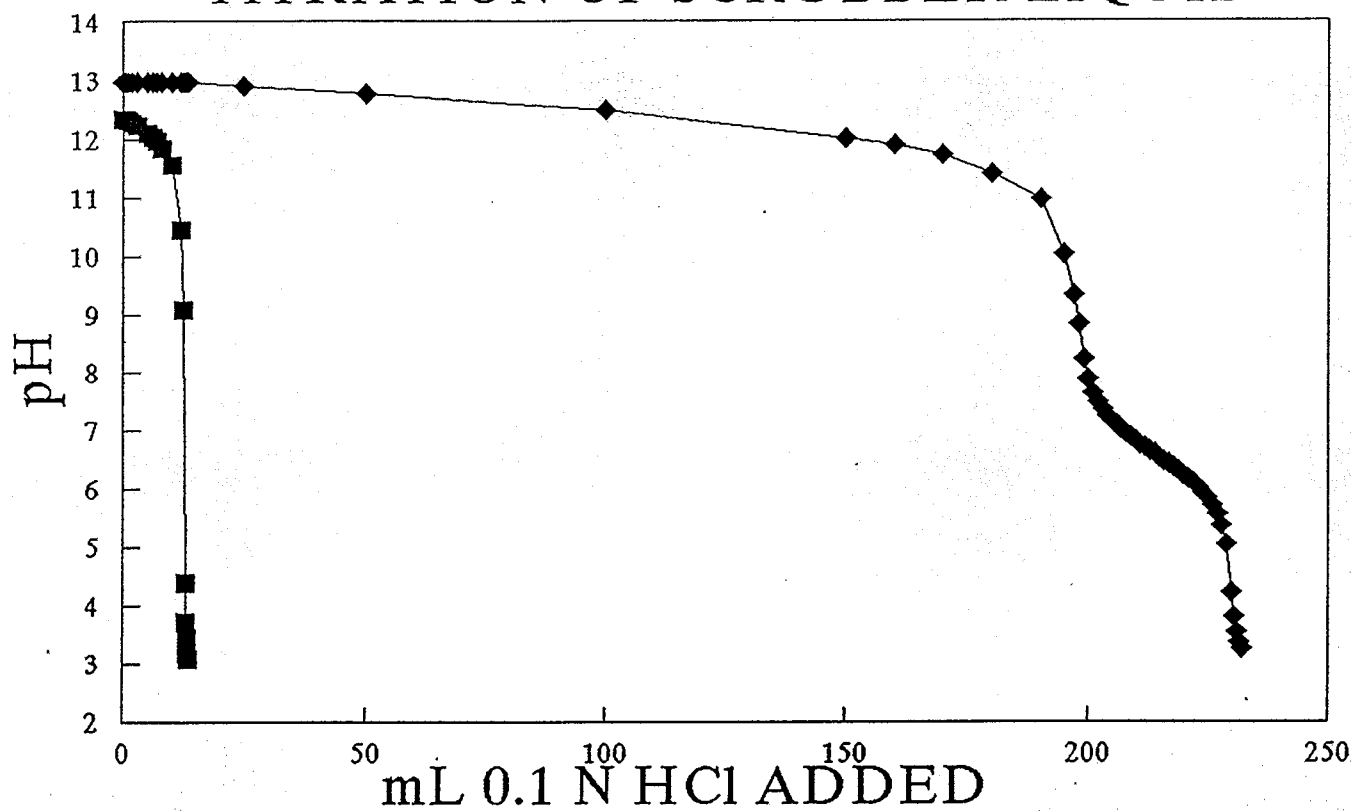
MAY 31/88

GOLDEN BEAR MINE  
MUDDY LAKE  
BRITISH COLUMBIA



# FIGURE 1

## TITRATION OF SCRUBBER LIQUID



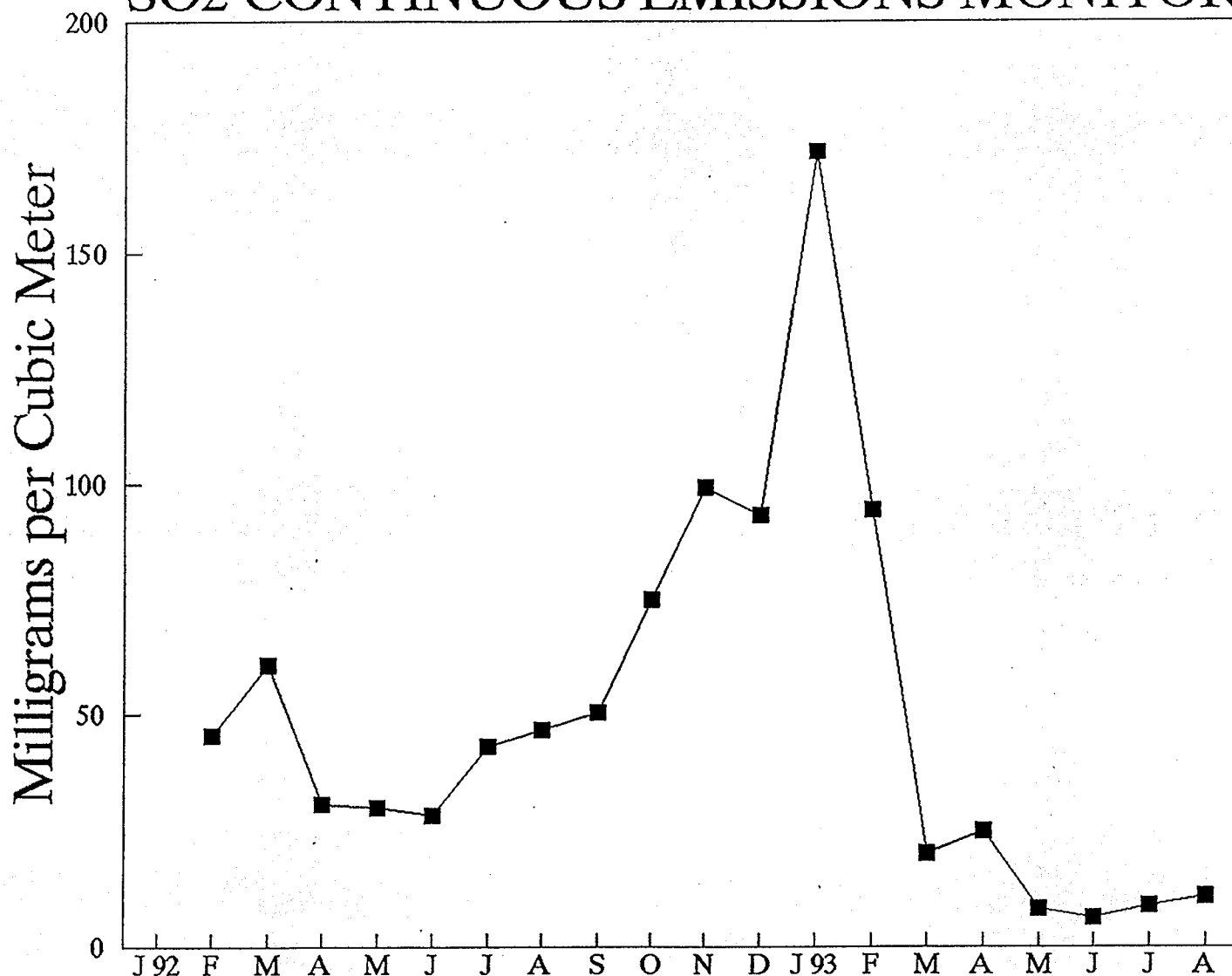
■ NORMAL OPERATION

◆ WITH ~12 000 ppm Na

Normal operation is before soda ash addition.  
Recirc. liquor sample has ~12 000 ppm Na+.

# FIGURE 2

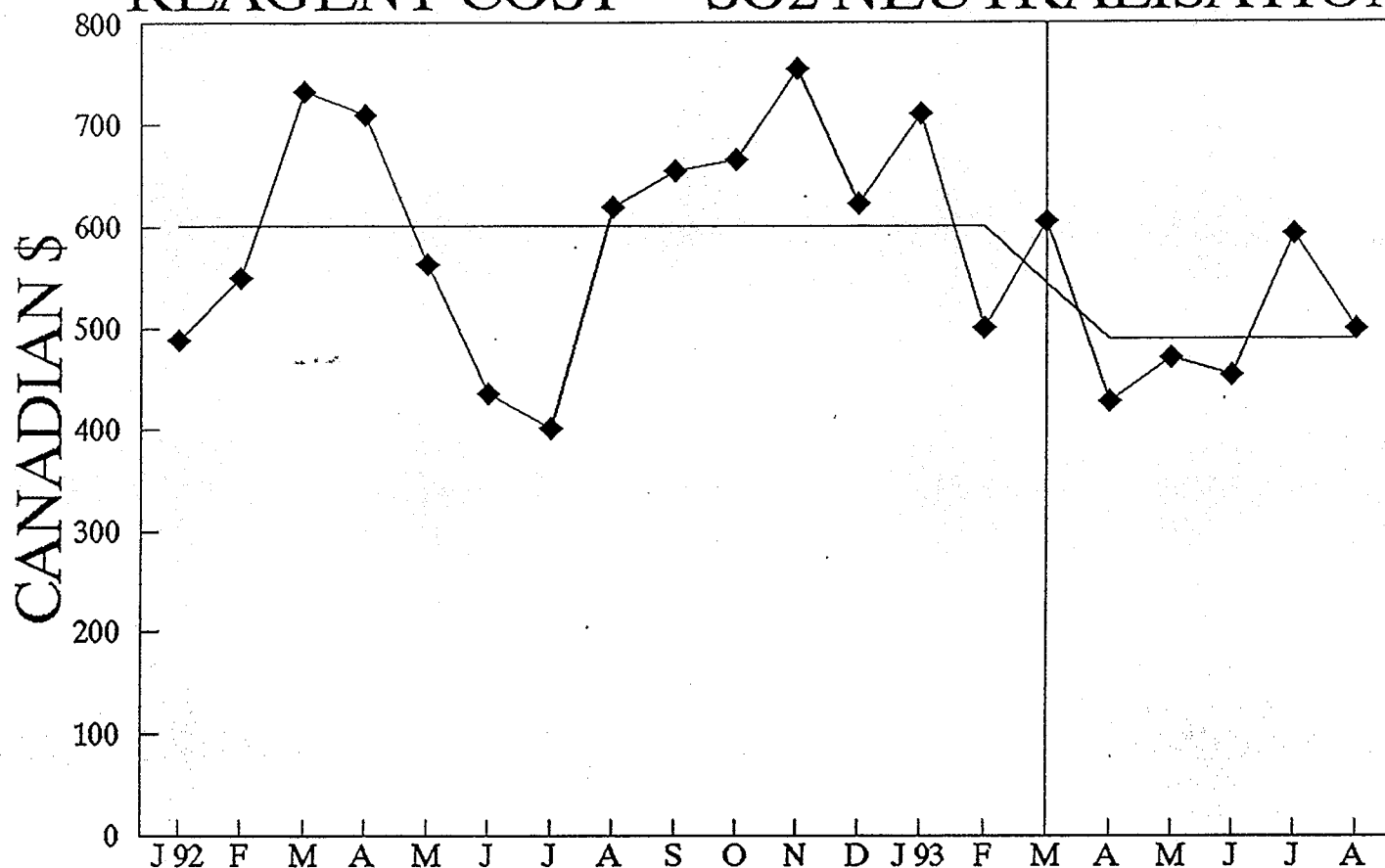
## SO2 CONTINUOUS EMISSIONS MONITOR



Permit for 1500 Milligram SO2 per Cubic Meter

# FIGURE 3

## REAGENT COST – SO<sub>2</sub> NEUTRALISATION



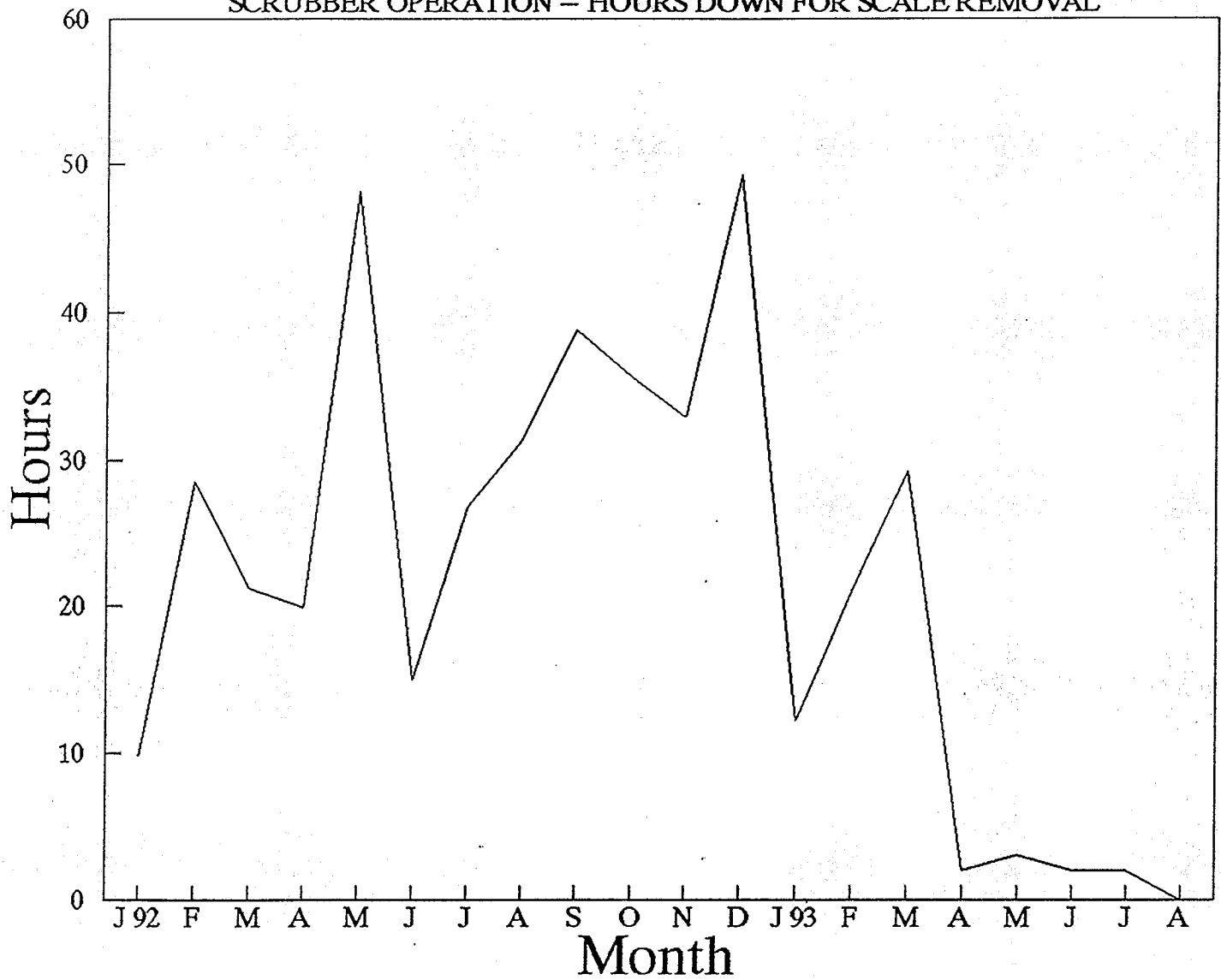
— Average Reagent Cost

◆ Cost per Tonne S= Oxidised

Cost Before March 93 ( Transition Month ) Averaged \$601 per Tonne of S= Oxidised  
 Costs After March 93 Averaged \$489 per Tonne of S= Oxidised

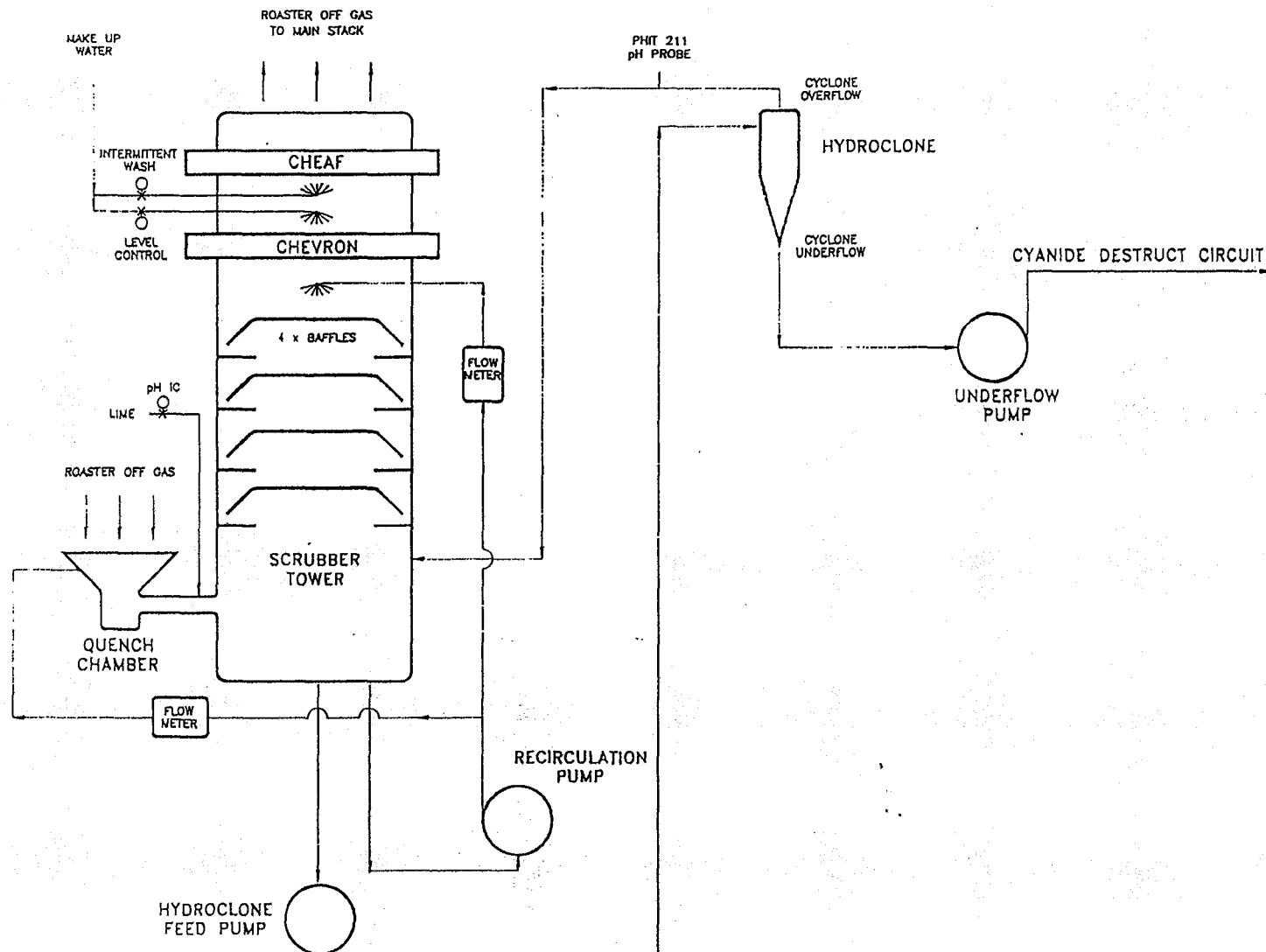
# FIGURE 4

SCRUBBER OPERATION – HOURS DOWN FOR SCALE REMOVAL



# SIMPLIFIED SCRUBBER FLOWSHEET ORIGINAL LIME SYSTEM

Figure 5



# SIMPLIFIED SCRUBBER FLOWSHEET DUAL ALKALI SYSTEM

Figure 6

