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March 14,1994

Mr. Emery Paquin
Director,
Environmental Protection Division
Department of Renewable Resources
Government of the Northwest Territories
600, 5102 - 50 Avenue
Yellowknife, N.W.T.
X1A 3S8

Dear Mr. Paquin:

**Re: Information on $SO_2$ Scrubbing of Roaster Exhaust Gas at Golden Bear Mine**

Please find attached two papers covering the scrubbing of a pyrite roaster off gas stream at the Golden Bear Mine in Northwest British Columbia. I hope these will be of value to you as background information.

Regards,

Larry Connell

Larry Connell
Manager of Environmental & Metallurgical Services

cc: K. Weston

To: M.K. Witte

From: Larry Connell

Date: December 03,1992

Subject: Use of Roaster Off Gas for Cyanide Destruction at the Golden Bear Mine

## 1.0) Introduction

The Golden Bear Mine is located on Bearskin Lake in Northwestern B.C. approximately 210 miles southwest of Whitehorse close to the Alaskan border. The nearest community is Telegraph Creek. Access to the mine is via a 150 km gravel road from Dease Lake, BC.

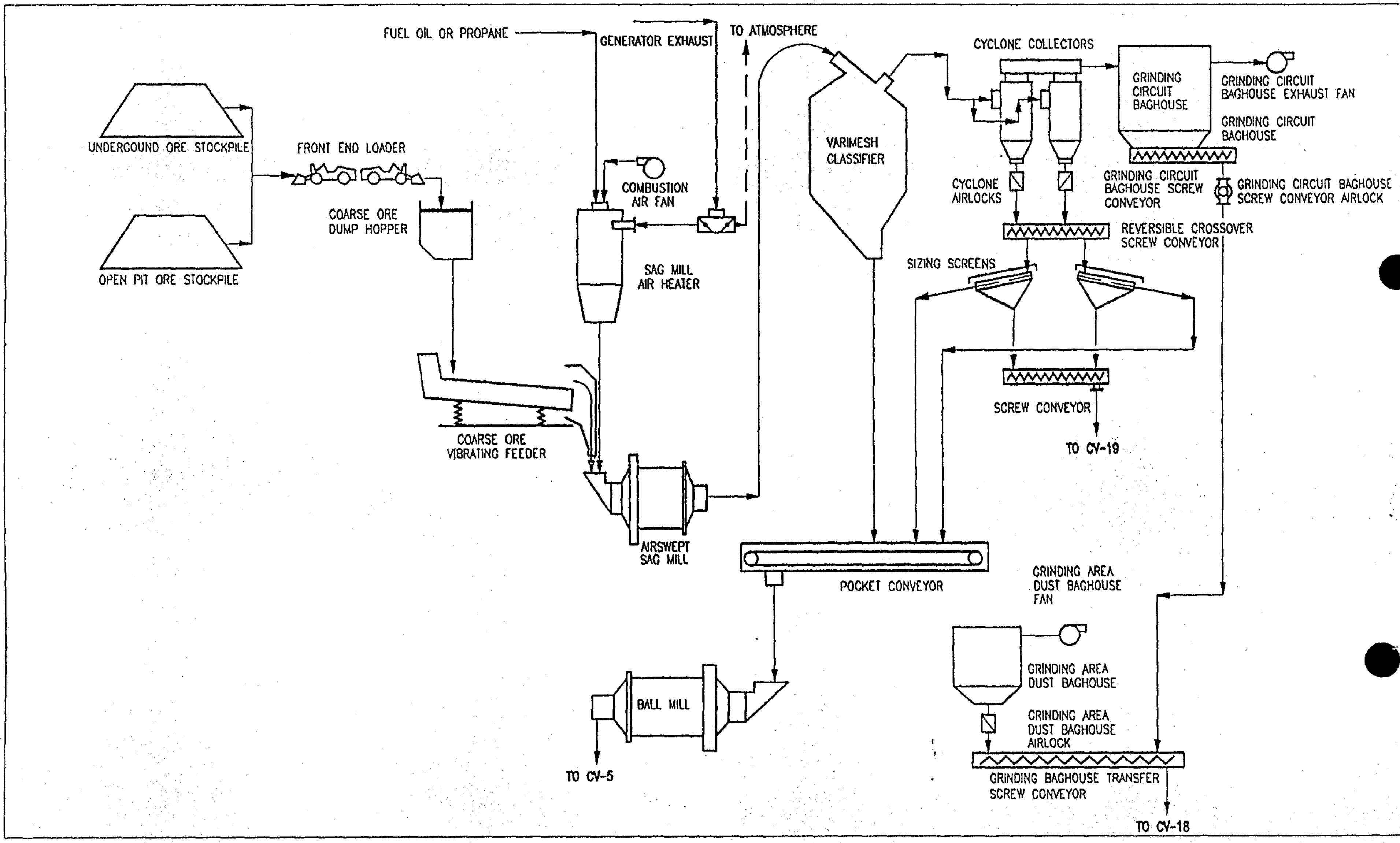
## 2.0) Milling Flowsheet

Ore is mined during the summer months from an open pit and stockpiled to keep the mill operating over twelve months. Some ore is currently being mined from underground workings. Ore is blended from a low and high sulphur stockpile to provide a combined mill feed of 2.5% S and 0.5 to 0.6 oz/t Au. The mine recovers 4800 to 5200 ounces of gold per month. Run of mine ore is fed from the stockpiles using a front end loader onto a grizzly equipped with a rock breaker. The milling rate is 360 tonnes per day. The simplified flowsheet of the dry grinding and whole ore roasting circuit is attached.

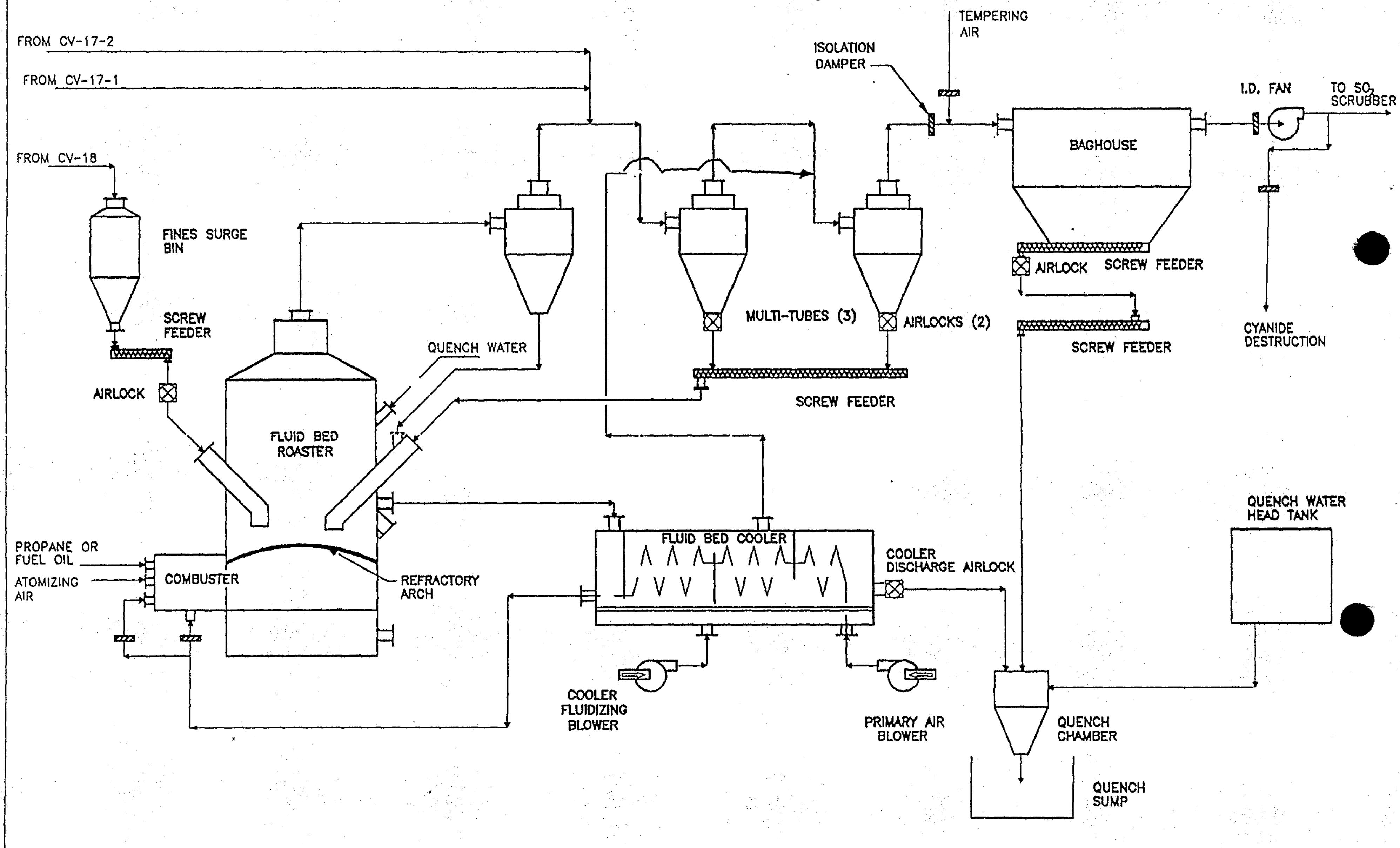
All of the ore is ground in a dry grinding circuit consisting of an airwept SAG mill equipped with a 200 Kw motor operating in open circuit. The SAG mill discharge is sized with the coarse product being reground in an open circuit ball mill. The ball mill discharge is combined with the SAG mill fines and conveyed into the roaster feed bin.

The ore has not responded to any form of pyrite preconcentration and the gold is refractory in nature. Consequently the whole ore is dry roasted with the calcines being water quenched and cyanide leached in a conventional cyanide leach - CIP circuit. Overall gold recovery is in the 89 to 90% range.

The roaster off gases are scrubbed with lime to reduce the $SO_2$ concentrations in the gas to 250 ppm. This process consumes 50 to 60 Kg of quicklime per tonne of ore treated. Buildup of calcium sulfite in the scrubbing tower necessitates the shut down of the roaster on frequent occassions to clear the scale buildup. The mine is currently experimenting with the use of a mix of soda ash and lime as a scrubbing liquor with the intent of reducing the scale buildup.




SIMPLIFIED FLOWSHEET – DRY GRINDING
FIGURE 5.1




FLUID BED ROASTING - SIMPLIFIED FLOWSHEET

FIGURE 7.1

3.0) $SO_2$ - Air Cyanide Destruction Process

The tailings slurry from the CIP Adsorption circuit is treated for cyanide destruction using the $SO_2$ - Air effluent treatment process. The flowsheet for this circuit is attached. The slurry density is 41% solids (14.8 t/h solids - 21.09 t/h water) and contains on average 80 ppm picric cyanide. The cyanide destruction circuit consists of two covered agitated tanks, both 6.5 m diameter by 7.6 m high. The first reactor is designed to destroy 90%+ of the $CN_{WAD}$ contained in the slurry while the second reactor is designed to precipitate the ferrocyanide complexes. The first reactor is equipped with a 60 Hp agitator to provide vigorous agitation while the second reactor is equipped with a 15 Hp agitator. Operating experience has shown that only the first reactor is actually required. Circuit retention time is in the order of 2 hours. The circuit is designed to remove 15 Kg/hr of $CN_{WAD}$ per hour. This rate is limited by the oxygen transfer capacity of the mixer/air system.

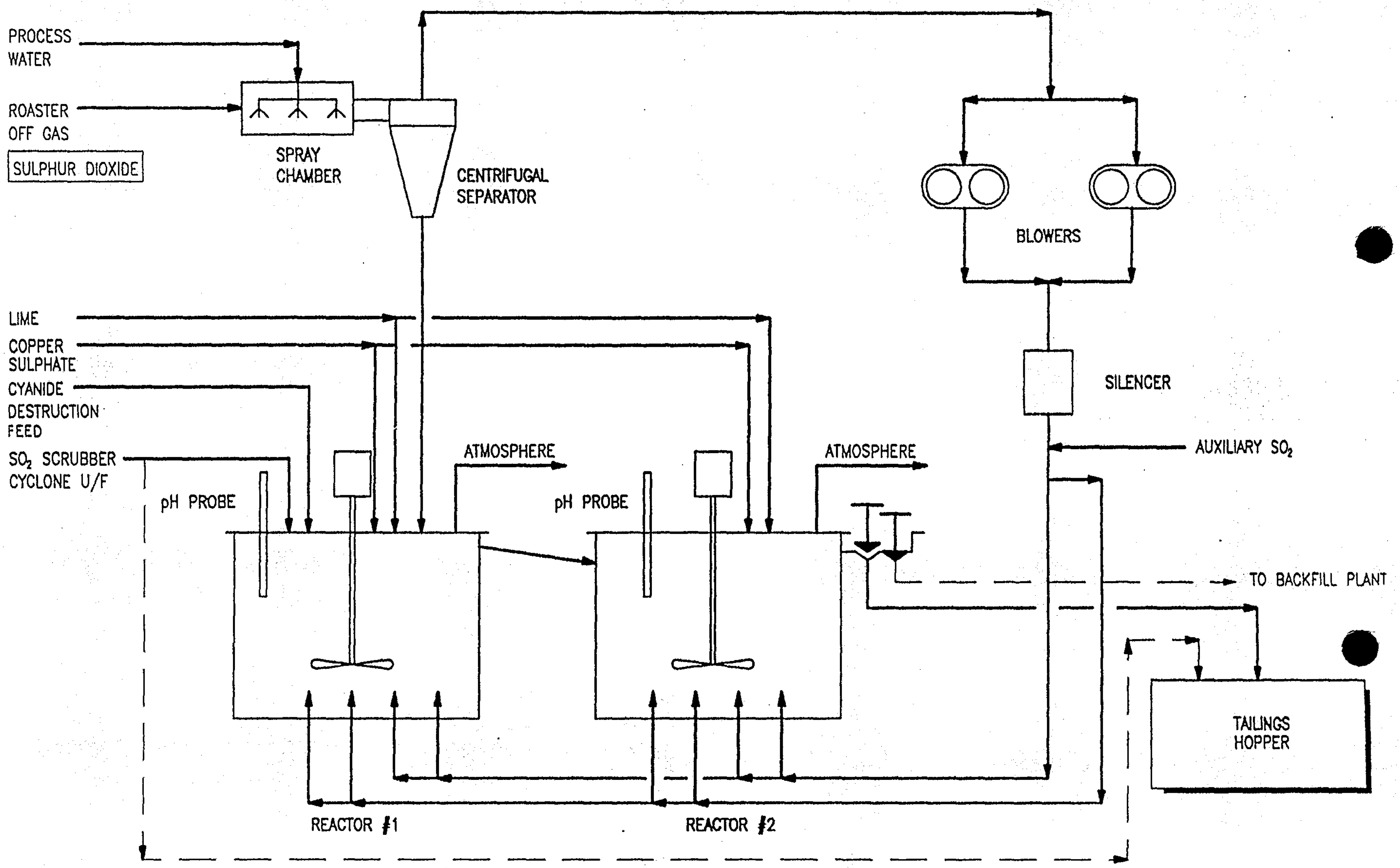
The pH in the first reactor is maintained at pH 9.0 through the automatic addition of lime. The copper needed for catalysing the cyanide destruction process and for the precipitation of ferrocyanide is provided by the addition of copper sulphate. The concentration of $Cu^{++}$ in solution is maintained at a minimum of 20 ppm or 2.5 x concentration of Fe in the CIP Tails.

Both $SO_2$ and $O_2$ are provided in the roaster off gas. The required $SO_2$ is 5 to 6 grams of $SO_2$ per gram of $CN_{WAD}$. Typically the dissolved oxygen in the first reactor should exceed 3.0 ppm.

Golden Bear is utilizing the off gas from their pyrite roaster as the primary source of $SO_2$. The off gas stream typically contains 1.5 to 3% $SO_2$. The gas is withdrawn from the duct on the positive pressure side of the roaster discharge fan, just ahead of the lime scrubber tower. The gas is moved by the positive pressure on the discharge side of the roaster fan through a 10" diameter mild steel pipe to the $SO_2$ - Air effluent treatment circuit located 250 feet away at the opposite end of the mill. Approximately 15% of the total off gas volume is used in the $SO_2$ - Air effluent treatment circuit.

The temperature of the roaster off gas as it exits the roaster fan is about 245°C. Initially the gas was both cooled and cleaned of particulate matter by means of a water spray quench system. The hot gas passed through a water spray and then through a centrifugal separator where water droplets and particulate matter were removed from the cooled gas stream. The water used in the quench system is drained into the first stage reactor by gravity as sulfurous acid ($H_2SO_3$).

Two ROOTS 616 RCS-JV rotary lobe air blowers are used to compress the cooled gas from the quench system. Each blower is powered by a 55Kw electric motor. The compressed gas at 6 psi is then fed into a common manifold connected to a single dampening/silencer chamber. Two butterfly controlled headers then split the gas flow to eight




CYANIDE DESTRUCTION CIRCUIT FLOWSHEET
FIGURE 15.1

small feeder pipes feeding the four nozzles per tank. There are four gas spargers arranged in a symmetrical pattern in the base of each reactor. Most of the $SO_2$ is fed to the first reactor with less than 10% being fed to the second reactor for final pH adjustment prior to discharge.

Piping downstream of the quench system is all of stainless steel and is subject to intense corrosion. Recently Golden Bear have replaced the water quench system with a filter element to protect the blowers from particulate matter. Experience has shown the filter elements plug relatively quickly (3 to 4 days) and are thus costly to use ($2500 per element).

The concentration of picric cyanide measured in the treated slurry is generally 0.1 to 0.2 ppm.

An auxilliary supply system of 1 tonne $SO_2$ gas cylinders is available for periods when the roaster is off line. This system is rarely used as generally the effluent treatment circuit is shutdown whenever the roaster is shut down.

## 4.0) Licensing of the Golden Bear $SO_2$ - Air Effluent Process

Golden Bear is using the $SO_2$ - Air effluent treatment process under a licensing agreement with INCO Limited. The license agreement was dated November 24, 1989 and covers Canadian patents no. 1,165,474 issued on April 10,1984, no. 1,234,931 issued on April 5,1988 and no. 1,241,774 issued on September 6,1988.

The license or user fee paid by Golden Bear is $47,000 per year to a total maximum of $258,000. This total maximum is based on ore reserves of 632,500 tonnes. The agreement contains a clause whereby the maximum total user fee is no longer in effect if the mine mills more than 759,000 tonnes (120% of ore reserve). The annual user fee is adjusted if the tonnage milled varies from the design throughput of 131,400 tonnes per year (360 tonnes per day) or if the cyanide consumed in the milling process is less than the predicted 2.5 kg per tonne of ore milled. The adjustment formulas are as follows:

Tonnes Milled:

> If the actual tonnes milled is between 115,000 and 134,000 tonnes per year then no adjustment is made to the $47,000 annual users fee. If the tonnage processed is outside this range then the fee is adjusted according to the following formula:

$$\frac{\text{Actual Tonnes Milled}}{131{,}400} \times \$47{,}000 = \text{Adjusted Annual Users Fee}$$

Cyanide Input:

The annual user fee of $47,000 is based on a cyanide useage of 2.5 Kg/tonne milled. If the actual cyanide useage is less than 2.5 kg/t then the tonnage adjusted annual users fee is further adjusted according to the following formula:

$$\frac{\text{Actual Useage of Sodium Cyanide}}{2.5} \times \text{Tonnage Adjusted User Fee}$$

If cyanide consumption is higher than 2.5 kg/t no adjustment is made to the users fee.

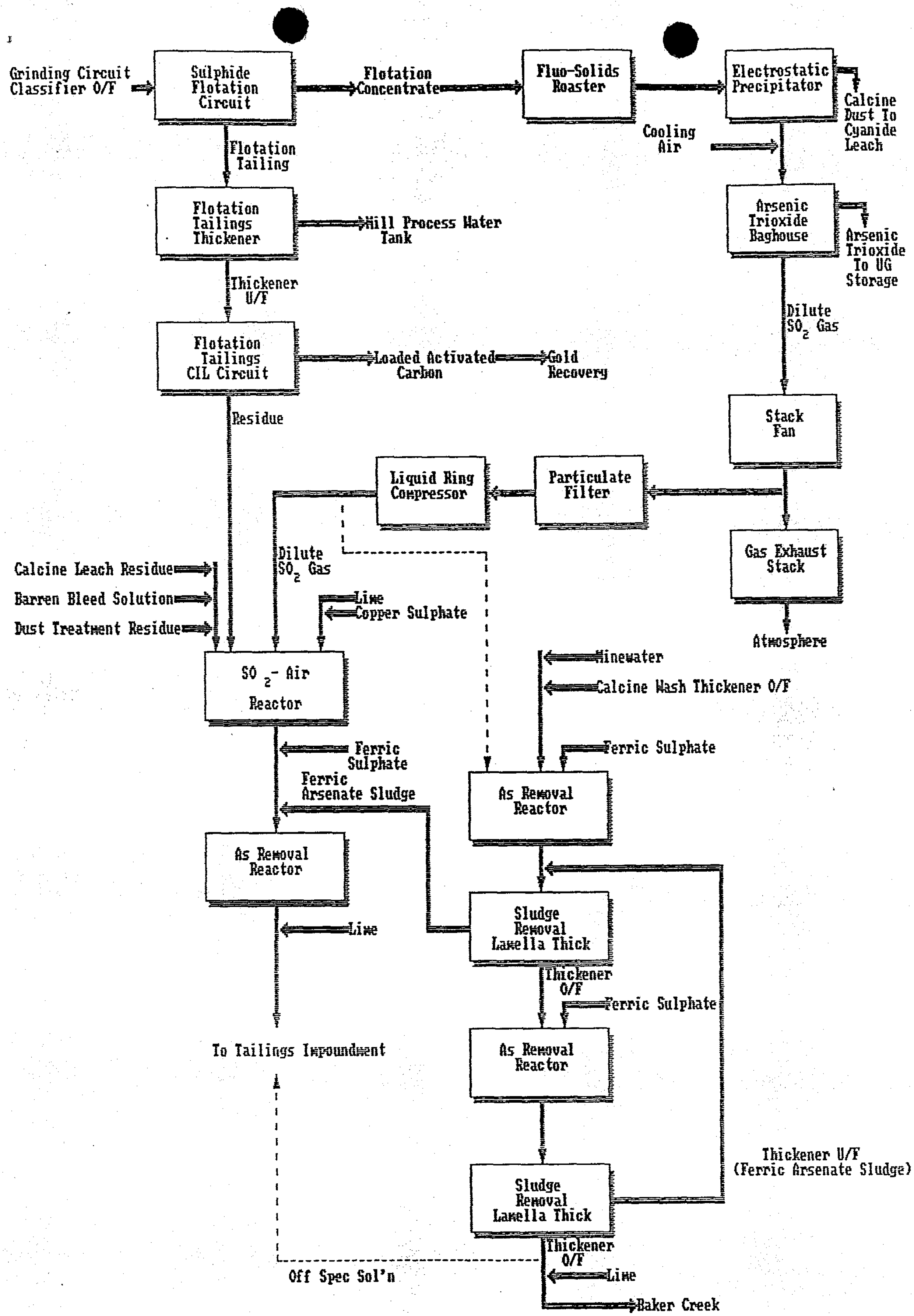
Golden Bear has been using approximately 1 Kg/t of sodium cyanide thus at their design mill throughput the user or license fee has been $18,800 per year or $0.14 per tonne milled. In terms of cyanide consumed the license fee is $0.18 per kg. A copy of the License Agreement between Inco and Golden Bear is appended.

Giant consumes on average 15,500 Kg of cyanide per month while treating 33,200 tonnes of ore (36,500 tons per month). Using the Golden Bear figures it would be fair to estimate the user or license fee for the Giant mine at $33,500 per year using cyanide consumption or $55,776 per year based on mill throughput. In 1992 Giant spent $142,000 on hydrogen peroxide for cyanide destruction, down from $332,000 in 1991.

The initial process chemistry specific to the Golden Bear mine was developed by INCO Limited at the Sheridan Park lab. The cost of the testwork was $30,000 which was paid for by Golden Bear. This expenditure was credited against the user fees payable by Golden Bear. INCO developed the process design criteria which was turned over to Golden Bear, who in turn had Minproc Engineers Ltd. design the mechanical equipment and process instrumentation.

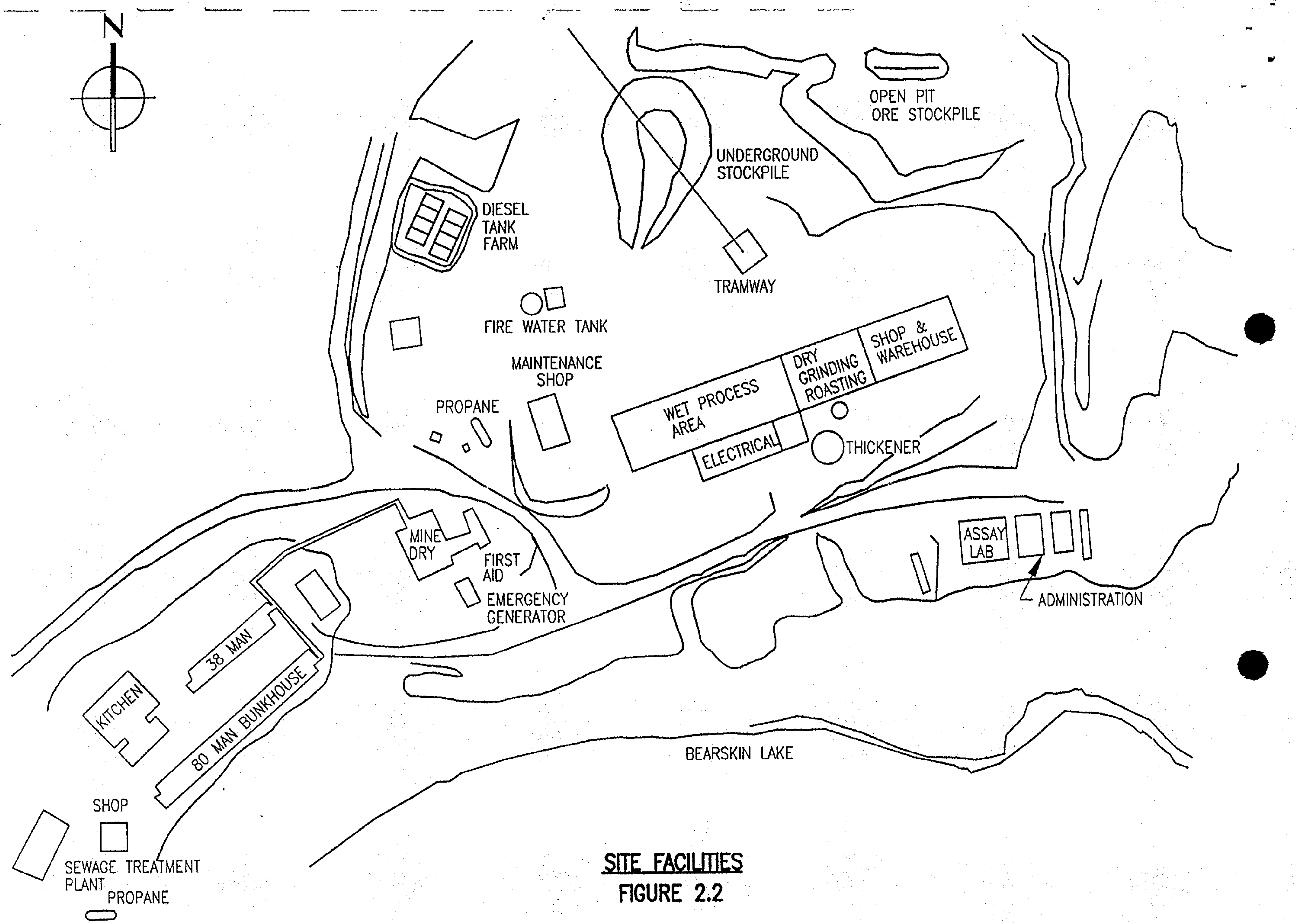
5.0) General:

The Golden Bear operation is operated as a two week in two week out remote mining operation. Crews are flown in from Vancouver or Smithers on a Convair aircraft owned by Trans Provincial Airways. The plan flies out of Vancouver early Tuesday, stopping in Smithers and then onto the minesite. The plane seats 55 and costs them $12,500 per round trip. There is only one such flight per two week rotation. Smaller charter aircraft are used to fly native employees to Dease Lake and Telegraph Creek. In the off week smaller charter aircraft are used to change management personnel through Whitehorse. The mine has a workforce of 90 in winter. The annual crew change transportation bill is in the order of $700,000.




# Royal Oak Mines - Yellowknife Division
# The Giant Mine

**Proposed Effluent Treatment Circuit**




**SITE FACILITIES**
**FIGURE 2.2**

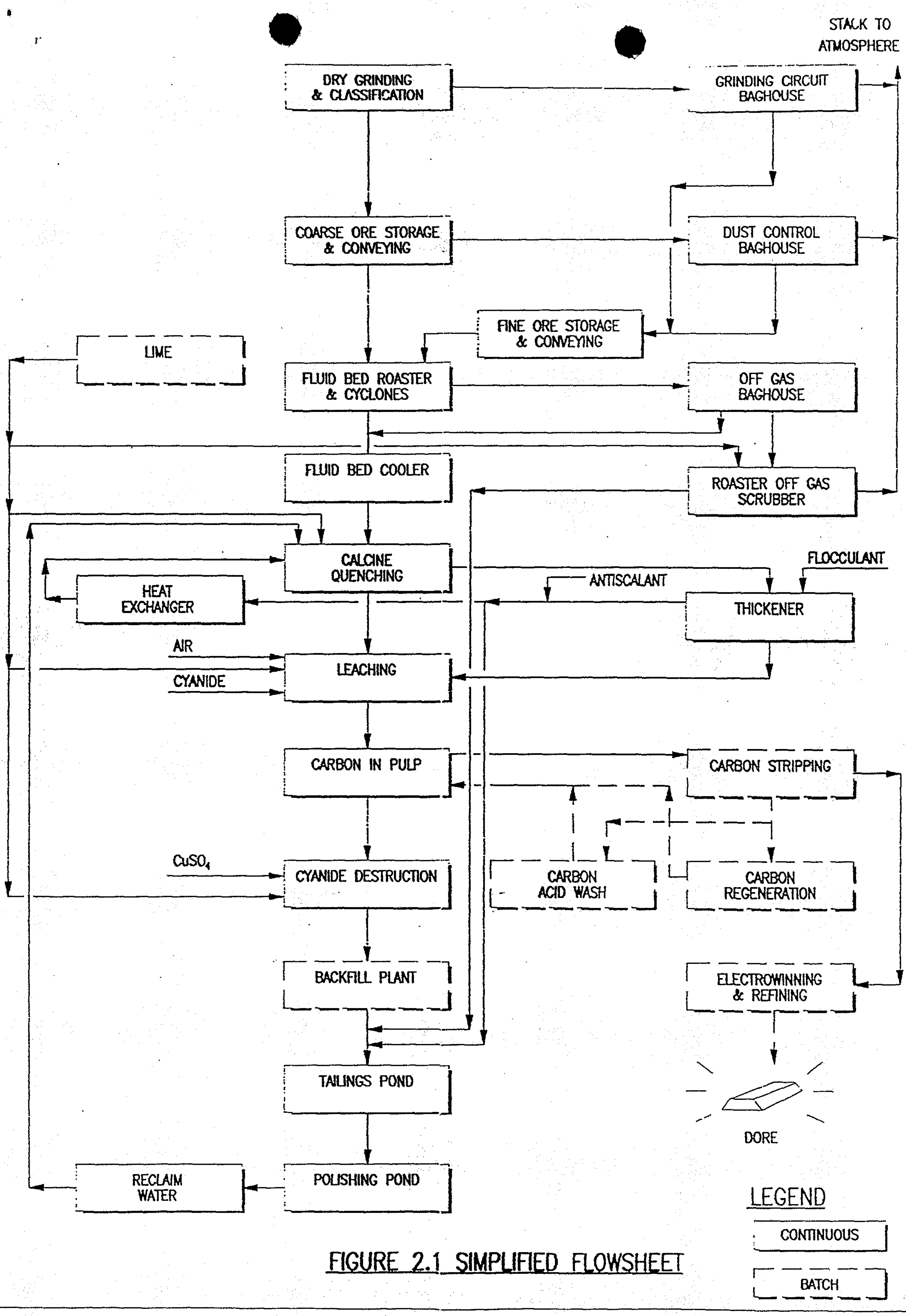



FIGURE 2.1 SIMPLIFIED FLOWSHEET

# 8.0 SULFUR DIOXIDE ($SO_2$) SCRUBBING

## 8.1 PROCESS DESCRIPTION (Refer to Figure 8.1)

After the roaster off gas has been cleaned of particulate by the Roaster Baghouse, the I.D. fan delivers the process gas to a Scrubbing System for the removal of sulfur dioxide ($SO_2$) gas. The $SO_2$ Scrubbing System is supplied by Andersen 2000 Inc. and uses slaked lime to chemically remove $SO_2$ from the gas stream.

Slaked or milk of lime is produced by reacting burnt lime (CaO) with water. This is done in the lime slaking system. The product of this system is $Ca(OH)_2$ which is called slaked lime. The slaked lime is utilized in the $SO_2$ Scrubber to remove $SO_2$ and $SO_3$ gas via the following chemical reactions:

| | | | | | | |
|---|---|---|---|---|---|---|
| $Ca(OH)_2$<br>Slaked lime<br>(slurry) | + | $SO_2$<br>Sulfur dioxide<br>(gas) | ----> | $CaSO_3$<br>Calcium sulfite<br>(solid) | + | $H_2O$ |
| $Ca(OH)_2$ | + | $SO_3$<br>Sulfur trioxide<br>(gas) | ----> | $CaSO_4$<br>Calcium<br>Sulfate<br>(solid) | + | $H_2O$ |

The main constituent of the process gas stream to be removed is $SO_2$. However, due to a chemical equilibrium in the gas stream, some small amounts of sulfur trioxide ($SO_3$) gas will be present along with the $SO_2$. The Scrubber also removes any $SO_3$ which is present.

The Scrubber is fabricated from 316L stainless steel and consists of a quench chamber, followed by a four stage absorber, chevron mist eliminator, wash section (bubble tray) and final mist elimination. The process gas must pass through all these sections before discharge to the atmosphere via the exhaust stack. Additional equipment associated with the scrubber are a recycle pump, cyclone feed pump, cyclones, and instrumentation.

The process gas enters the Scrubber at the inlet to the quench vessel, where it travels vertically downward through sprays. The sprays use a mixture of slaked lime and water to cool the gas stream, as well as beginning the $SO_2$ removal process. The gas then exits the quench vessel and travels horizontally into the 4 stage tray absorber. The absorber is a cylindrical chamber consisting of 4 stages having concentric baffles. The gas stream flows upward through the stages while the scrubbing liquor (slaked lime and water), flows counter currently by gravity. The baffles provide intimate mixing of the scrubbing liquor and the gas, completing the removal of $SO_2$ from the gas stream. Located above the top stage of the absorber and in the same vertical cylindrical shell is a chevron mist eliminator, which removes any liquid carry-over from the four trays. After passing through the chevron mist eliminator, the process gas goes through a wash stage where clean water is sprayed into the stream to remove any of the calcium salts that have formed in the scrubbing liquor. The gas finally passes through a cheaf aerosol mist eliminator, where any aerosol acids are removed from the stream. The clean gas stream is then exhausted to atmosphere via the exhaust stack. The motive force to drive the gas stream through the scrubber and out the stack is provided by the roaster I.D. fan.

The base of the absorption tower acts as an integral liquor recirculating tank. The recycled solution, clean spray water and slaked lime slurry are all collected in this tank. The tank feeds two pumps, one is a recirculation pump while the other is a cyclone feed pump. The recirculation pump provides the scrubbing liquor to the quench vessel sprays as well as the 4 stage main absorber.

As a result of the formation of calcium salts, $CaSO_3$ and $CaSO_4$ as solid precipitates and the addition of slaked lime and process water, some material has to be bled out of the circuit to maintain a balance. This is accomplished by pumping a portion of the scrubbing liquor to cyclones. The cyclone underflow, containing the majority of the precipitated calcium salts is bled by a horizontal pump to the tailings pumpbox while the cyclone overflow returns to the bottom of the absorber.

## 8.2 EQUIPMENT DESCRIPTION

### 8.2.1 $SO_2$ Scrubber (Refer to Figures 8.2 to 8.6)

The $SO_2$ Scrubber is comprised of two main sections, the quench vessel and the absorber tower. The quench vessel is constructed of 7 gauge 316L stainless steel and has a 28 inch diameter inlet which expands out in a 45 degree angle cone to 36 inches diameter. Below the expansion is situated a 6 inch cylindrical section where four full cone spray nozzles are mounted. The nozzles are 3/4 inch diameter and rated for a rate of 19 gallons per minute at 30 psi pressure. The sprays are oriented in a downward fashion at an angle of 30 degrees. Also included in the cylindrical section are 4-3/8 inch pipe nozzles which introduce liquor at 7.25 gallons per minute, per nozzle, tangentially into the vessel. The gas stream and liquor exit the quench vessel through a 60 degree conical section narrowing to a 19 inch diameter fabricated "T". The stream travels horizontally through the side outlet of the "T" and enters the absorber.

The absorber is 54 inches in diameter, has an overall height of 39 feet 6 inches and is constructed of 316L stainless steel. The bottom of the absorber acts as the reservoir for the scrubbing liquor and is complete with an overflow at a height of 7 feet from the bottom. The gas stream enters about 2 feet above the overflow level. Once into the absorber, the liquor drops to the reservoir while the gas stream is forced upward through four sections of absorption.

Each absorber stage consists of a horizontal plate mounted in the absorber with a 38 inch diameter hole in it. Mounted 12 3/8 inches above the plate, is a 38 inch diameter cover plate. The main flow of 215 gallons per minute of scrubbing liquor is introduced via a 4 inch pipe and directed downward onto the cover plate of the last absorption stage. The liquid spills over the edge of the plate and down on top of the plate above the previous absorber. The gas flow is counter current to the liquor and the gas stream passes through the annular opening in each stage and around the cover plate and in doing so, gas/liquid contact is provided, enabling the scrubbing reactions to take place.

At the top of the four absorption stages is a chevron type mist eliminator. Process water is sprayed onto the bottom of the Chevron at 42 gallons per minute to wash out any liquor carry over from the absorption stages. The chevron mist eliminator is made of 30 chevron blades, each 12 inches deep running the width of the tower. These blades channel the gas stream into parallel streams, each taking a zig-zag path upward to the top of the mist eliminator.

The process gas stream continues up and passes through a wash tray which has numerous 1/4 inch holes in it. Process water is distributed over the top of the tray and further liquid/gas contact occurs. A cheaf mist eliminator is located above the wash tray and serves as the final stage in the tower scrubber. The cheaf is a single cloth of style 272 cheaf media backed by 4 mesh wire cloth, supported on a frame of 3 inch square 4 millimeter diameter wire. The cloth is arranged in a multiple peak manner. The cheaf serves to capture any fine droplets which may be contained in the gas stream. The stream exits the top of the scrubber via a 24 inch diameter duct.

### 8.2.2 Scrubber Recirculation Pump

The scrubber recirculation pump is a Gardner-Denver model, 5 X 4 X 14 rubber lined, horizontal, centrifugal unit. It is driven, via V-belts, by a 20 hp 1800 rpm motor. This enables the pump to deliver the required 400 gallons per minute of scrubbing liquor at a discharge head of 35 psi.

### 8.2.3 Cyclone Feed Pump

The cyclone feed pump is identical to the recirculation pump and is designed to deliver 526 gallons per minute to a bank of eight cyclones.

### 8.2.4 Cyclones (Refer to Figure 8.7)

The 8 cyclones used for the removal of the calcium salt precipitate are supplied by Krebs. The 8 model U4B-1426 cyclones are arranged in two lines of four cyclones fed by dual in-line manifolds. Each cyclone has a 1.6 inch

I.D. vortex finder and 7/8 inch apex. The cyclones have been designed to cut at 16 micron size with a pressure drop of 25 psi. They are complete with 2 inch manual isolating gate valves, overflow and underflow launders and support frame.

### 8.2.5 Cyclone Underflow Pump

The cyclone underflow is pumped by a BGA 2 x 1½ inch horizonal pump to the tailings box. The pump is driven at 917 rpm by a 5 hp, 1750 rpm motor, via V-belts.

## 8.3 PROCESS OPERATION

### 8.3.1 Introduction

This section describes how the $SO_2$ Scrubbing Circuit is to be operated, the functions of the controls, the operating parameters and the significance of the alarms and interlocks.

### 8.3.2 Operating Objectives

The aim of the sulfur dioxide removal system is to continuously clean the gas from the roaster before it is exhausted to the atmosphere. Dangerous gases such as $SO_2$ and $SO_3$ are removed by reacting slaked lime with them. The $SO_2$ and $SO_3$ are converted to calcium sulfite and sulfate, which can be settled in the tailings pond with no harmful effects to the environment.

### 8.3.3 Process Control

#### 8.3.3.1 General (Refer to Figures 8.8 to 8.12)

The control of the $SO_2$ Scrubbing process is carried out using separate loops for scrubbing liquor pH, level in the tower sump, quench and tower liquor flows and cyclone feed flow. The loops are operated in either manual or automatic mode and are accessed by two operator terminals which interface with a computer controlled programmable logic controller. A number of graphic displays are available for process monitoring of variables and parameters in the Scrubbing circuit. The summary process window for the Scrubber loops is shown in Figure 8.8.

#### 8.3.3.2 Scrubbing Liquor pH (Loop 210), (Refer to Figure 8.9)

The pH of the scrubbing liquor comprised of slaked lime slurry and process water is automatically controlled by adding slaked lime to the bottom of the quench vessel via a 1½ inch automatic control valve. A pH probe is used to send a signal of the liquor pH to a controller which compares the present actual value to the setpoint value pH of 8.0 and then generates an output signal to the lime addition control valve. The control valve opens or closes as required to maintain a pH of 8.0. As lime is consumed in the chemical scrubbing reaction, the pH of the liquor will tend to drop unless more lime is added to the system. A setpoint pH of 8.0 is used in order to attain a high enough alkalinity to effectively remove the $SO_2$ and $SO_3$ gases while at the same time being neutral enough to minimise the calcium salt scaling within the Scrubber.

8.3.3.3 Scrubbing Liquor Level (Loop 2253), (Refer to Figure 8.10)

The level in the recycle tank formed by the bottom of the absorber tower is controlled by the addition of process water to the wash tray between the chevron and cheaf mist eliminators in the tower. The level controller receives a signal from the differential pressure level transmitter mounted in the bottom of the tower. The controller compares the actual level to the desired setpoint and sends an appropriate output signal to the level control valve on the process water line to the wash tray. The level control valve is not allowed to fully close, thus ensuring a wash in the scrubber to prevent acid mist carryover.

8.3.3.4 Quench Vessel Scrubbing Liquor Flow (Loop 2258), (Refer to Figure 8.11)

The flow of scrubbing liquor to the quench vessel is measured by a flowmeter. Flow feeding the main spray and tangential spray nozzles on the quench vessel is directed from the recirculation pump discharge.

8.3.3.5 Absorber Scrubbing Liquor Flow (Loop 2257), (Refer to Figure 8.11)

The flow of the scrubbing liquor to the 4 stage absorber in the main tower is measured by a flowmeter mounted on the line from the recirculation pump feeding the top absorber baffle. Control of this flow is done by manual adjustment of a butterfly valve in the line.

### 8.3.3.6 Cyclone Feed Flow (Loop 2265), (Refer to Figure 8.12)

Cyclone feed is controlled manually by a flow indicating controller and a flow control valve in the line from the cyclone feed pump going to the cyclone feed distributors. The controller sends a signal to the air actuated flow control valve. The cyclones operate at 25 psi with overflow and underflow densities of 5% and 15% solids respectively.

### 8.3.4 Operating Parameters and Alarms

Process variables in the $SO_2$ Scrubber are monitored in order to allow the circuit to perform its function. Alarms are annunciated when the variables reach levels that could cause problems with the safe and efficient operation of the circuit. The analog alarms alert the operator that the process is in need of adjustment. Discrete alarms notify the operator of the status of the different control loops. The graphic display of the computer controlled PLC provides the operator with a schematic status indication of the various loops in the $SO_2$ Scrubbing Circuit.

### 8.3.4.1 Analog Parameters and Alarms

The following table lists the variables which are displayed in the $SO_2$ Scrubber graphics package, their description, range, normal operating value or setpoint and alarm type where applicable.

| Loop | Description | Instrument Range | Normal Operating Range | Alarm Type | Alarm Point |
|---|---|---|---|---|---|
| pHIC210 | Scrubber liquor pH | 0-14 | 8.0 | high/low | 8/6 |
| pHIC210 | Scrubber liquor pH controller | 0-100% | - | | |
| FCV210 | Lime addition valve | 0-100% | - | | |
| pHIT212 | Scrubber liquor pH | 1-14 | 7 | | |
| pH237 | Scrubber liquor pH | 6-12 | 7 | | |
| LIC2253 | Recycle tank level | 0-60 inches | 48 | | |
| LIC2253 | Level controller output | 0-100% | - | | |
| LCV2253 | Process water control valve | 0-100% | - | | |
| FI2257 | Absorber liquor flow | 0-233 gpm | 215 | | |
| FI2258 | Quench vessel liquor flow | 0-233 gpm | 105 | | |
| FIC2265 | Cyclone feed flow | 0-510 gpm | 400 | | |
| FIC2265 | Cyclone feed valve | 0-100% | 95 | | |

### 8.3.4.2 Discrete Alarms

| Loop | Description | Message |
|---|---|---|
| pHIT210 | Scrubber liquor pH | 212/211 |
| FCV210 | Lime addition valve | manual/auto |
| pHIC210 | Scrubber liquor pH controller | manual/auto |
| pHIT211 | Scrubber liquor pH | 212/211 |
| LCV2253 | Level controller | manual/auto |
| FCV2265 | Cyclone feed controller | manual/auto |

## 8.4 START-UP PROCEDURES

The start-up procedure is presented for two conditions. The first is for start-up after a maintenance shutdown and the second is for start-up after a short Roaster shutdown.

### 8.4.1 Start-up Following Maintenance

1. Open all access doors and check for any debris in the system. Clean out any items found. Check the integrity of the chevrons, cheaf mist eliminator and wash stage to ensure that these internal components have not shifted.

2. Check the valve arrangement of the makeup water loop piping. The 2 inch ball valves on either side of the makeup water control valve should be open. The 2 inch ball valve used as a bypass around the makeup water control valve should be closed. The two 3/4 inch ball valves for the chevron and cheaf wash nozzle should be closed.

3. Place the level controller in manual. Cycle the controller output from fully closed to fully open several times and ensure that the makeup water control valve responds properly. Place this controller in the automatic mode and set the controller setpoint to 58 inches.

4. Turn on the manual isolating valve controlling makeup water to the Andersen piping. Water should now start flowing into the recirculation tank. Observe the level controller process variable signal. The level in the recirculation tank should begin to fill. Allow the tank

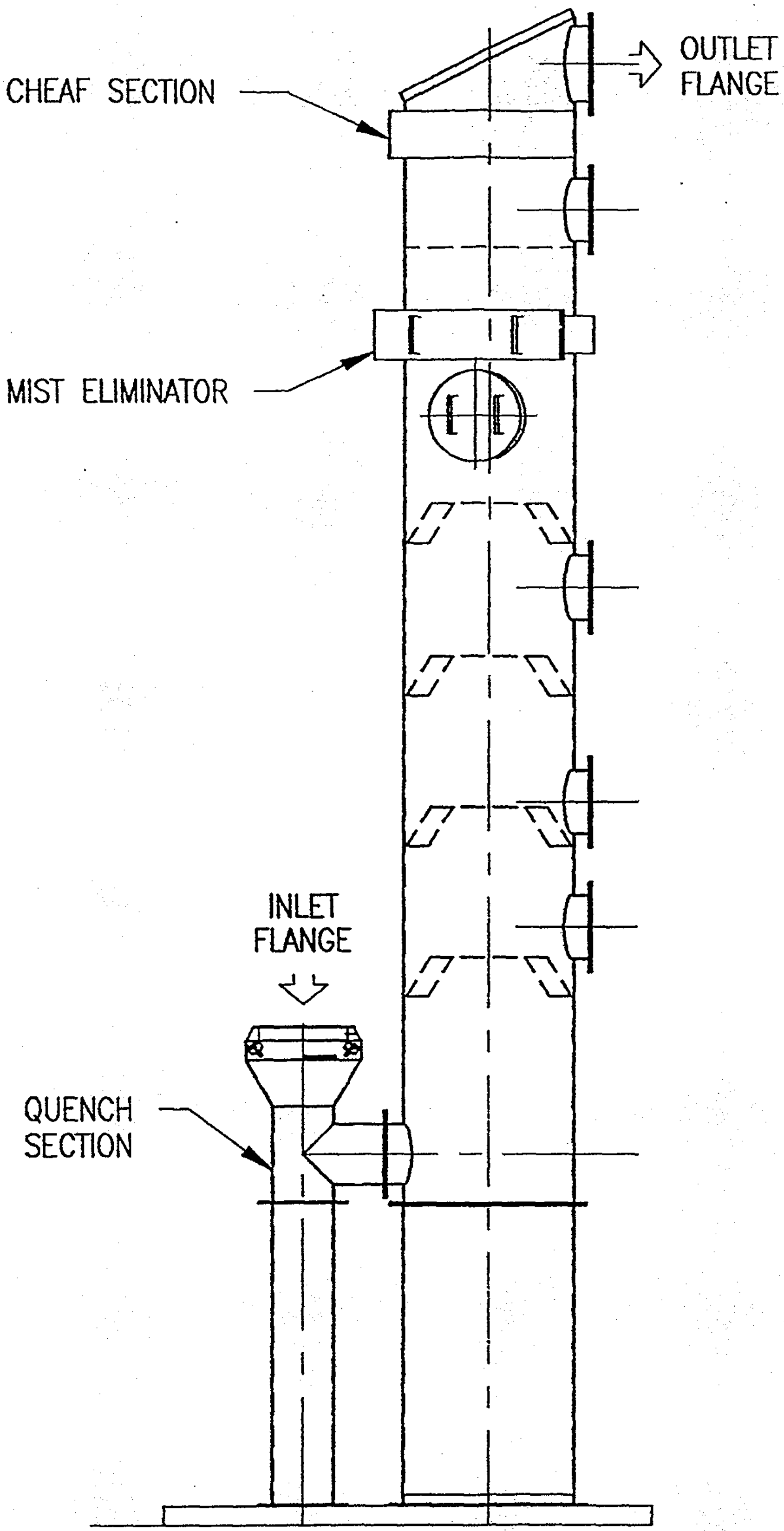
to fill to 58 inches and observe to see if the make-up controller shuts off the makeup water control valve.

5. Check the position of all the manual valves in the recirculation piping loop. The valve on the pump suction should be open. The 4 inch butterfly valve in the absorber feed line should be set at 50%. All ball valves in front of pressure gauges should be open. The 6 inch butterfly valve in the cross-over loop between the recirculation pump piping and the hydrocyclone pump piping should be closed. The ½ inch gate valve in the seal water line going to the recirculation pump should be opened until flow is indicated in the sight flow meter.

6. Start the recirculation pump and allow water to circulate through the system. Adjust the flows to the absorber and quench. First, adjust the absorber flow by opening or closing the 4 inch absorber butterfly valve until a flowrate of 215 gallons per minute is established. Next, check the quench flowrate, it should be near 105 gallons per minute. Readjust the absorber feed as required to achieve the proper split in flow. Finally, recheck the seal water flow indicator to make sure seal water is still flowing to the pump.

7. The next step is to set up the valves for the cyclone feed pump. Make sure the pump suction butterfly valve is open. Open both 4 inch butterfly valves located on either side of the pump discharge control valve. Make sure the 4 inch butterfly valve used as a bypass around the control valve is closed.

8. Place the cyclone feed flow controller in the manual mode and cycle the control valve open several times to




**SCRUBBER**

FIGURE 8.2

ensure that the controller will drive the control valve. Then set the control valve at 85% open.

9. Start the cyclone underflow pump.

10. Start the cyclone feed pump and establish liquid flow in the piping system. Adjust the flow controller, in the manual mode, until the flow of 370 gallons per minute is reached. Set the setpoint to 370 gallons per minute and place the unit in automatic.

11. Remove the pH probe and calibrate the pH probe and meter using buffer solutions of 4.0 and 7.0. Reinstall the probe.

12. Ensure the lime supply valve is open. Open both 1½ inch ball valves on either side of the control valve. Close the bypass valve. Put the pH controller in the manual mode, cycle this valve open and close. Then set the pH controller to automatic and set the setpoint to 8.0.

13. Open the manual valve for water to the cheaf wash nozzle.

14. Once every four hours, open the 3/4 inch manual ball valves leading to the chevron wash nozzle and wash this unit for three minutes.

15. The scrubber unit is now in operation.

### 8.4.2 Start-up Following a Short Shutdown

1. Check with your supervisor to insure that everyone is ready for the system to be started.

2. Check the MCC to make certain that the equipment needed is on and ready for use.

3. Check all valves and instruments to insure they are positioned for start-up.

4. Check the recirculation tank (it should be full).

5. Put the level controller for the recycle tank into the automatic mode.

6. Put the pH controller into the automatic mode.

7. Put the cyclone feed controller into the manual mode and set the control valve to approximately 85% open.

8. Turn the seal water on to all pumps that are to be used.

9. Make certain that the lime system is ready and that process water is available.

10. Start the recirculation pump.

11. Start the cyclone underflow pump.

12. Start the cyclone feed pump. When flow is established, adjust the flow control valve opening to the desired flow.

13. Establish gas flow to the Scrubber.

14. Open the manual valve for water to the cheaf wash nozzle.

15. Check all flows and equipment to insure proper operation.

16. Once operation has been established, the chevron wash nozzle should be opened for three minutes every four hours to wash it out.

## 8.5 SHUTDOWN PROCEDURE

The following steps should be taken to shutdown the $SO_2$ Scrubbing unit.

NOTE: NOT ALL OF THE EQUIPMENT IS TO BE SHUT OFF

1. Stop the process airflow to the Scrubber. Let the fan come to a complete stop before going to the next step.

2. Stop the cyclone feed pump.

3. Stop the recirculation pump.

4. Stop the cyclone underflow pump.

5. Turn the cheaf wash nozzle water off.

6. Unless the Scrubber is to be down for an extended time, the unit is now down.

### Cold Weather Shutdown

Proceed with a normal shutdown.
Drain all tanks, piping and pumps.

## 8.6 ROUTINE CHECKS AND TROUBLESHOOTING

### 8.6.1 Routine Checks

1. Fill out the shift report sheet provided.

2. Monitor the Scrubber pH and levels.

3. Monitor the Scrubber alarm summary and perform troubleshooting as required.

4. Note unusual occurrences or items requiring maintenance on the shift report sheet and advise your supervisor.

5. Check the operation of the cyclones, ensure that all cyclones being used are operating satisfactorily by checking for a flared underflow discharge.

6. Monitor the pressure drops in the different sections of the Scrubber.

7. Ensure adequate flow of gland water to the cyclone feed and scrubber recirculation pumps

8. Check pH probe indication against hand cut samples for possible drifting of probe calibration.

9. Monitor the area around the $SO_2$ Scrubber for excessive $SO_2$ gas leakage.

### 8.6.2 Troubleshooting

Occasionally, problems may develop in the operation of the Scrubbing system which must be repaired or corrected in the field. Some of these problems and their solutions are listed below:

A. Scrubbing Efficiency Decreases Dramatically

1. The most frequent cause of this problem is loss of scrubbing liquid supply. This can be caused by nozzle pluggage, pump failure, or cavitation of the pump due to low liquid level in the recirculation tank or impeller wear. All of these problems can be solved by correcting the pump difficulties.

2. Low pH of the recirculating liquid will also cause decreased collection efficiency. This can be caused by problems with the lime feed system failure of the pH controller, or incorrect calibration of the pH probes.

B. Higher Than Expected Differential Pressure Across the Scrubber

1. The first thing that should be checked is the inlet gas flow from the roaster to the quench. If the gas flow is much greater than the design gas flow, increased differential pressure will result.

2. Excessive scrubbing liquid feed rate to the quench and/or baffle absorber can result in higher gas pressure drops. Check the flow rates and adjust as required.

3. Failure of the roaster I.D. fan speed controller can cause excessive gas flow to the system which will increase the pressure drop across the Scrubber.

4. Blinding of the cheaf media with insoluble particles will increase the Scrubber pressure drop. Replace the media. Check to see if the particulate loading to the Scrubber has increased above design levels.

C. Rapid Erosion of the Quench Nozzles

This is indicative of higher than expected suspended solids in the recirculated liquid. Increase the bleed rate of cyclone underflow to tailings which will decrease the percentage of suspended solids.

## 8.7 OPERATIONS MAINTENANCE

Like all industrial equipment, some periodic maintenance will be required on the Scrubber system. Operators will be required to perform the following:

1. Whenever conditions permit, check each of the quench nozzles for excessive wear or plugging. If nozzles are worn, then they must be replaced. This also indicates that the solids level in the Scrubber is too high. If the nozzles are plugged, then thoroughly clean the nozzles.

2. The pH probe should be calibrated on a daily basis. Use buffer solutions of pH 4.0 and 7.0 to calibrate the

probe and meter. This calibration can be done with the Scrubber on-line, simply by turning the pH controller to the manual mode during calibration. This locks the output at one position, so the time spent on recalibration should be kept to a minimum. Do not forget to turn the pH controller back to the automatic mode.

3. The cheaf media will gradually blind off due to excessive build-up. Most of this build-up will be removed when the cheaf section is washed. However, some insoluble particles will lodge in place and eventually restrict the air flow through the cheaf. When the pressure drop across the cheaf exceeds 13 inch w.g., remove the cheaf assembly and replace the media.

4. On shutdowns, the quench vessel and tower absorber must be inspected and cleaned of scale, if required.

## 8.8. $SO_2$ SCRUBBING SAFETY

### Sulfur Dioxide

$SO_2$ (sulfur dioxide), formed in the roaster when the iron pyrite is oxidized, can cause irritation to the eyes, nose and lungs. If a burning feeling is noticed in the eyes, nose or lungs, the area should be ventilated and the source of gas found and eliminated.

### Carbon Monoxide

The combustion air from the roaster could be bringing carbon monoxide (CO) into the Scrubber circuit. This colorless, odorless gas can be extremely hazardous at relatively low concentrations. Symptoms of carbon monoxide poisoning include dizziness, headaches and/or nausea. If any of the symptoms are noticed, you should get to fresh air and your supervisor must be notified.

Before any equipment is entered, especially if carbon monoxide has been detected, the equipment and surrounding area must be flushed with fresh air.

There are gas monitors in the $SO_2$ Scrubbing area for CO gas, combustible gases and $SO_2$ gas. Should a gas alarm occur, a horn will sound. If this happens, **EVACUATE THE MILL IMMEDIATELY AND REPORT TO THE ASSAY LABORATORY OFFICE FOR FURTHER INSTRUCTIONS FROM YOUR SUPERVISOR.**

### Quicklime or Milk-of-lime

Quicklime is a dry white powder that will dry the skin if handled without gloves. It can be very dusty and could cause burns of the nose and throat if inhaled. If the lime is allowed to get into the eyes, severe burns could result.

## 8.9 SUPPORT EQUIPMENT

The $SO_2$ Scrubber is supported by several other circuits which must be operating properly in order for the $SO_2$ Scrubber to perform in an efficient and safe manner. It is the operator's responsibility to check on the status of the support equipment. The equipment used indirectly by the $SO_2$ Scrubber are:

a) air compressors
   - process air
   - instrument air

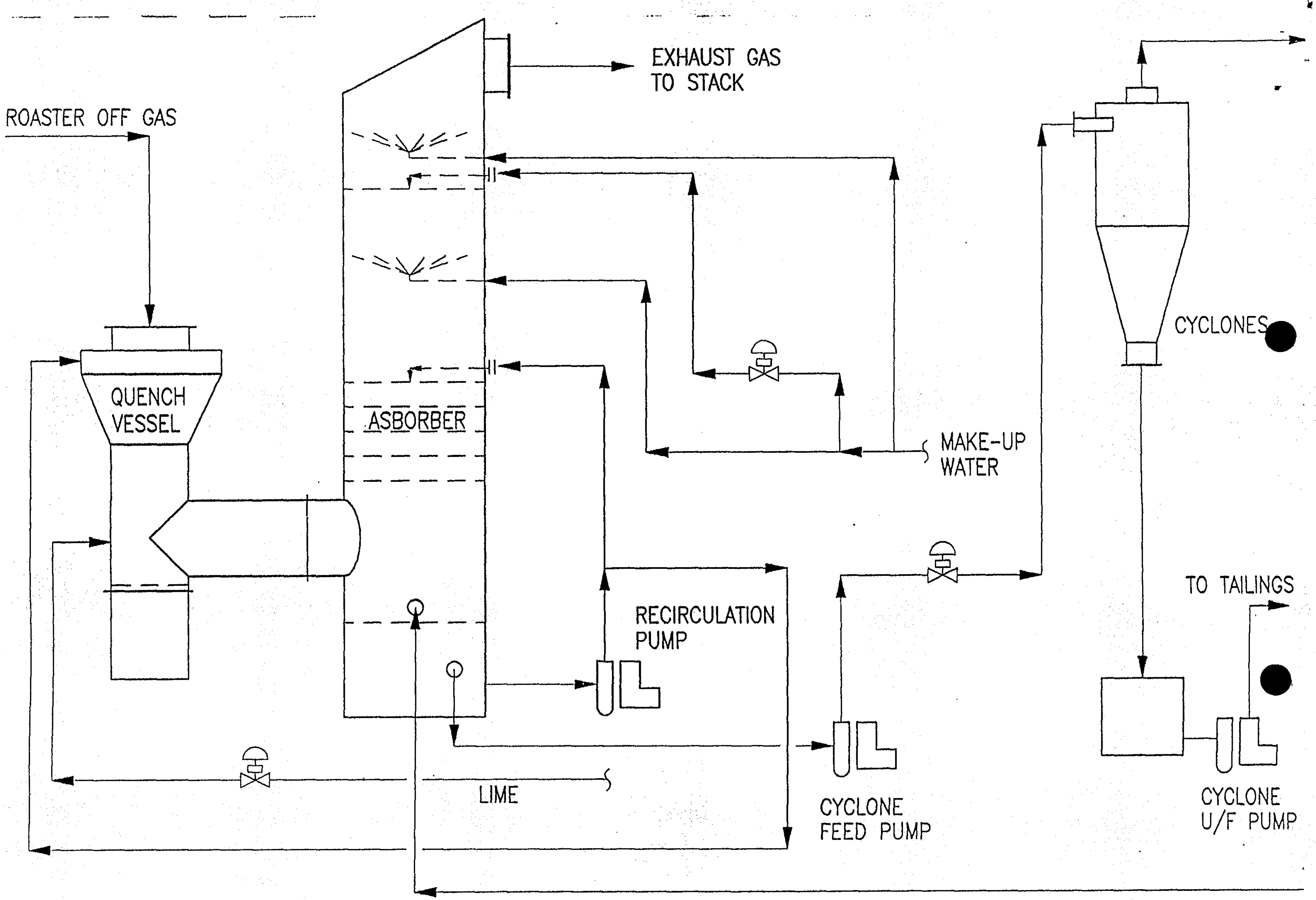
b) process water

c) lime slaker
   - lime holding tank
   - lime distribution pump

## 8.10 JOB DESCRIPTION

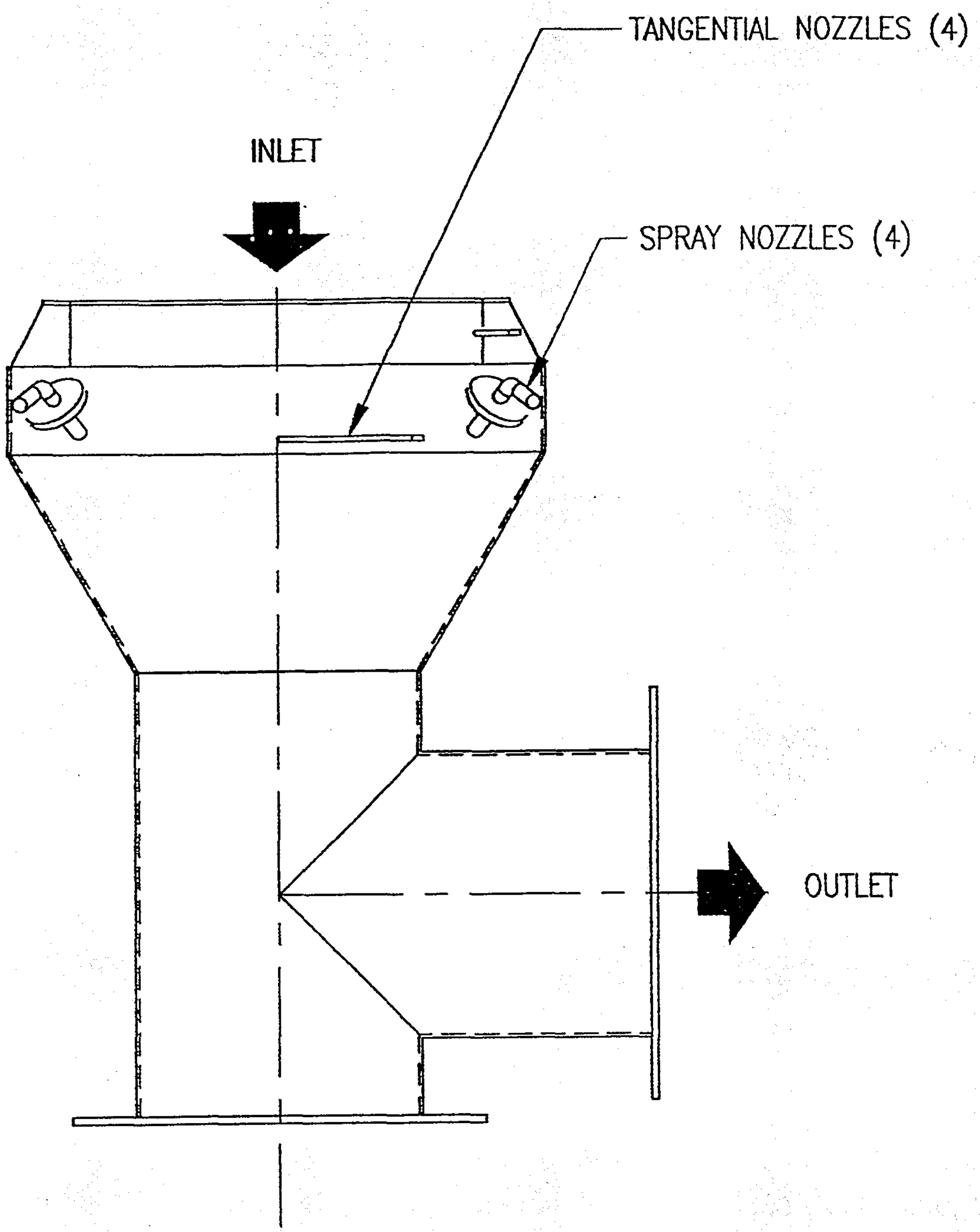
The $SO_2$ Scrubber operator is responsible for the safe and efficient operation of the $SO_2$ scrubber, recirculation and cyclone feed pump, cyclones, cyclone underflow pump and all liquor valving, nozzles and pH control. Process variables must be monitored and control loops adjusted as a result of ongoing routine checks and troubleshooting.

The operator in charge of this area must keep a close watch on the process and support equipment and report any malfunctions. The operator will also be responsible for the housekeeping and cleanup in the area as well as for taking samples as directed. The operator will also perform maintenance on the scrubber when directed by the supervisor.



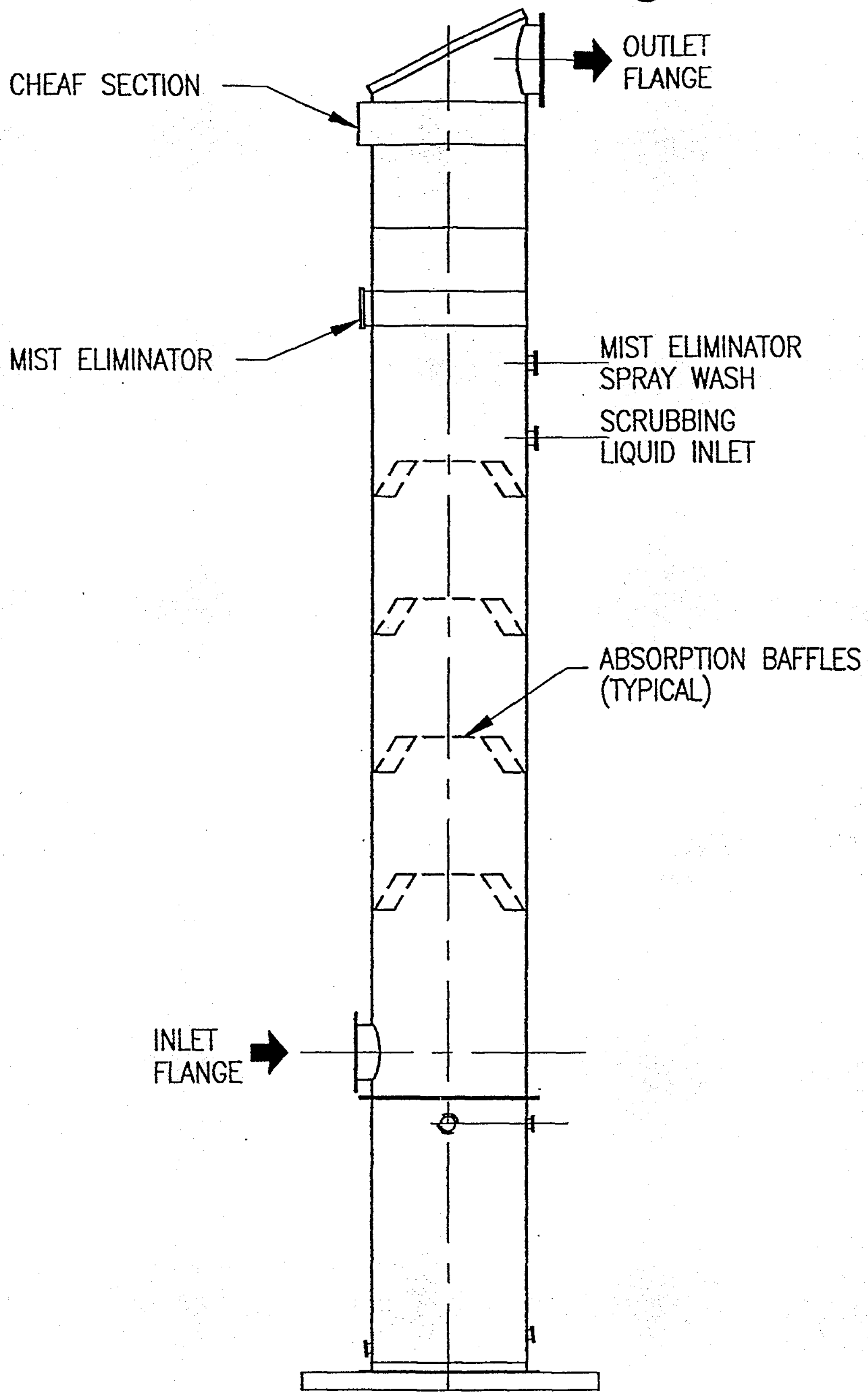

$SO_2$ SCRUBBER - SIMPLIFIED FLOWSHEET

FIGURE 8.1

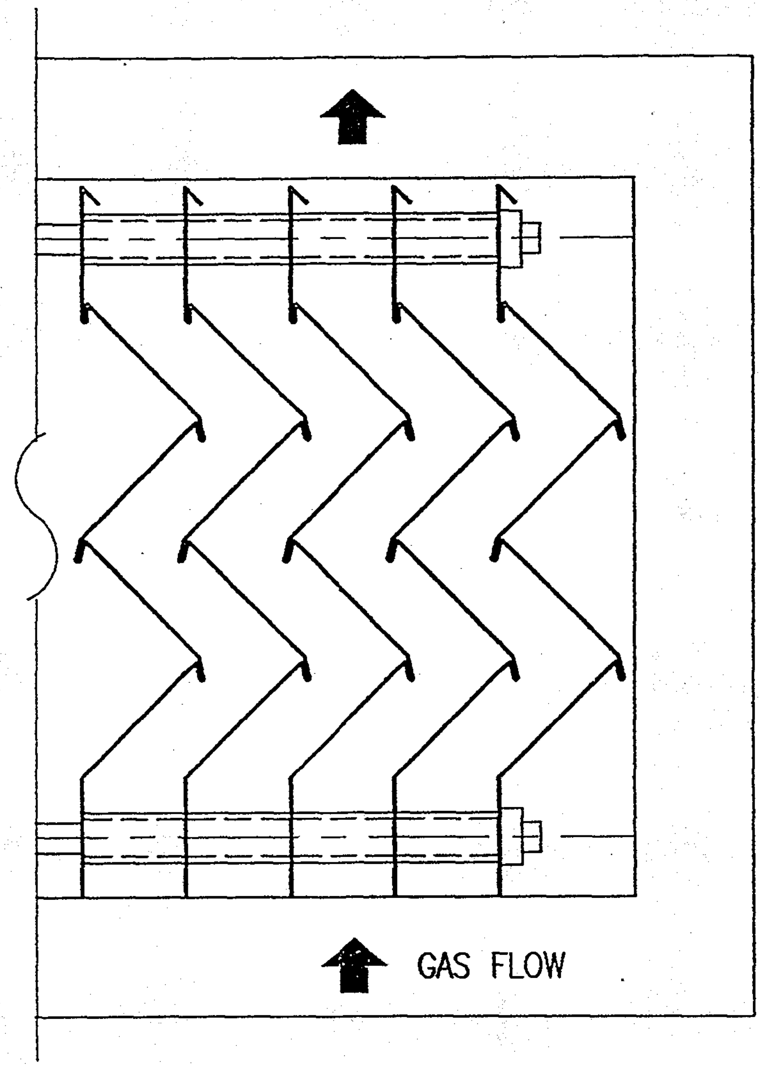



QUENCH SECTION

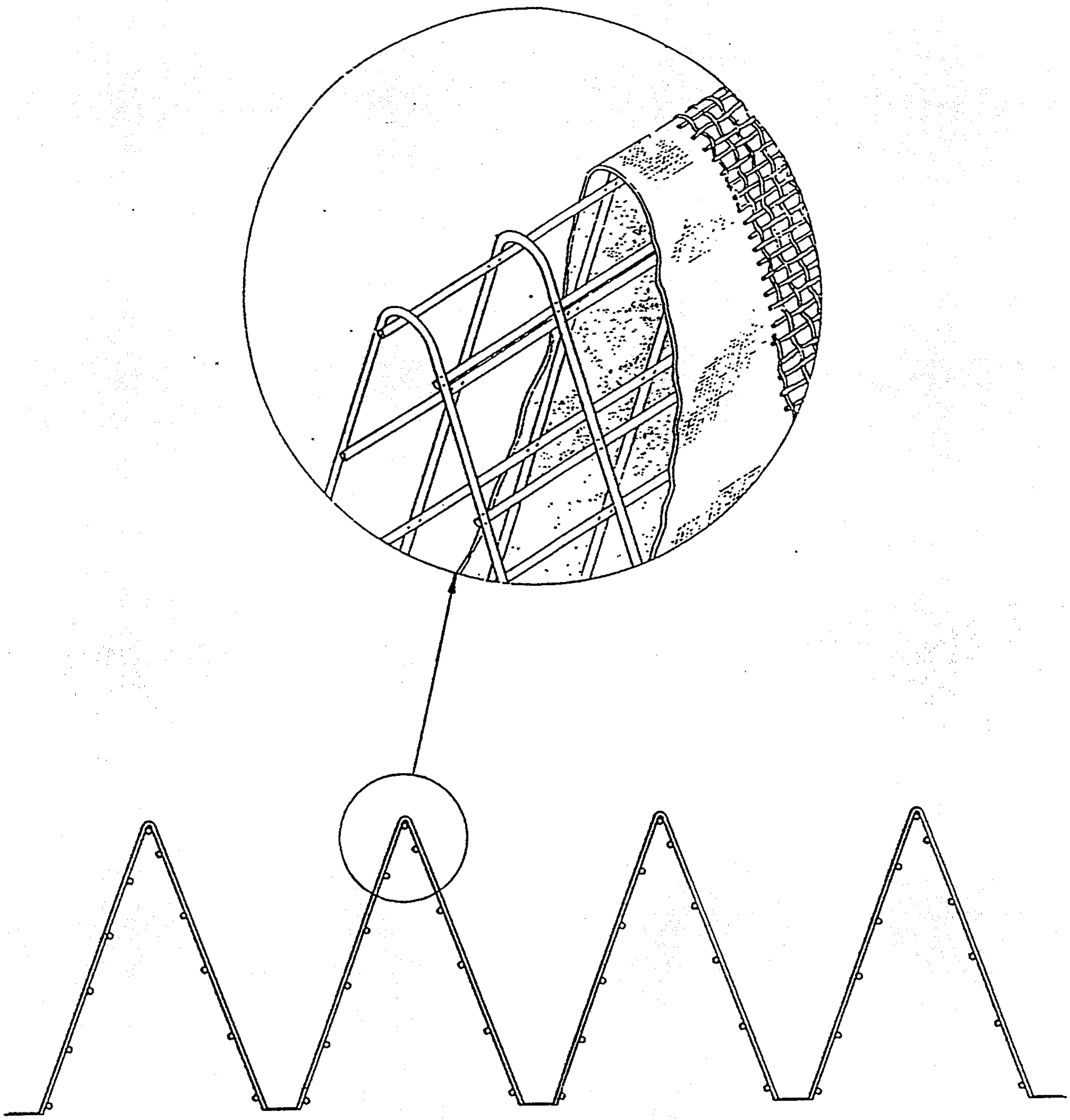
FIGURE 8.3




SCRUBBER ABSORPTION TOWER
FIGURE 8.4

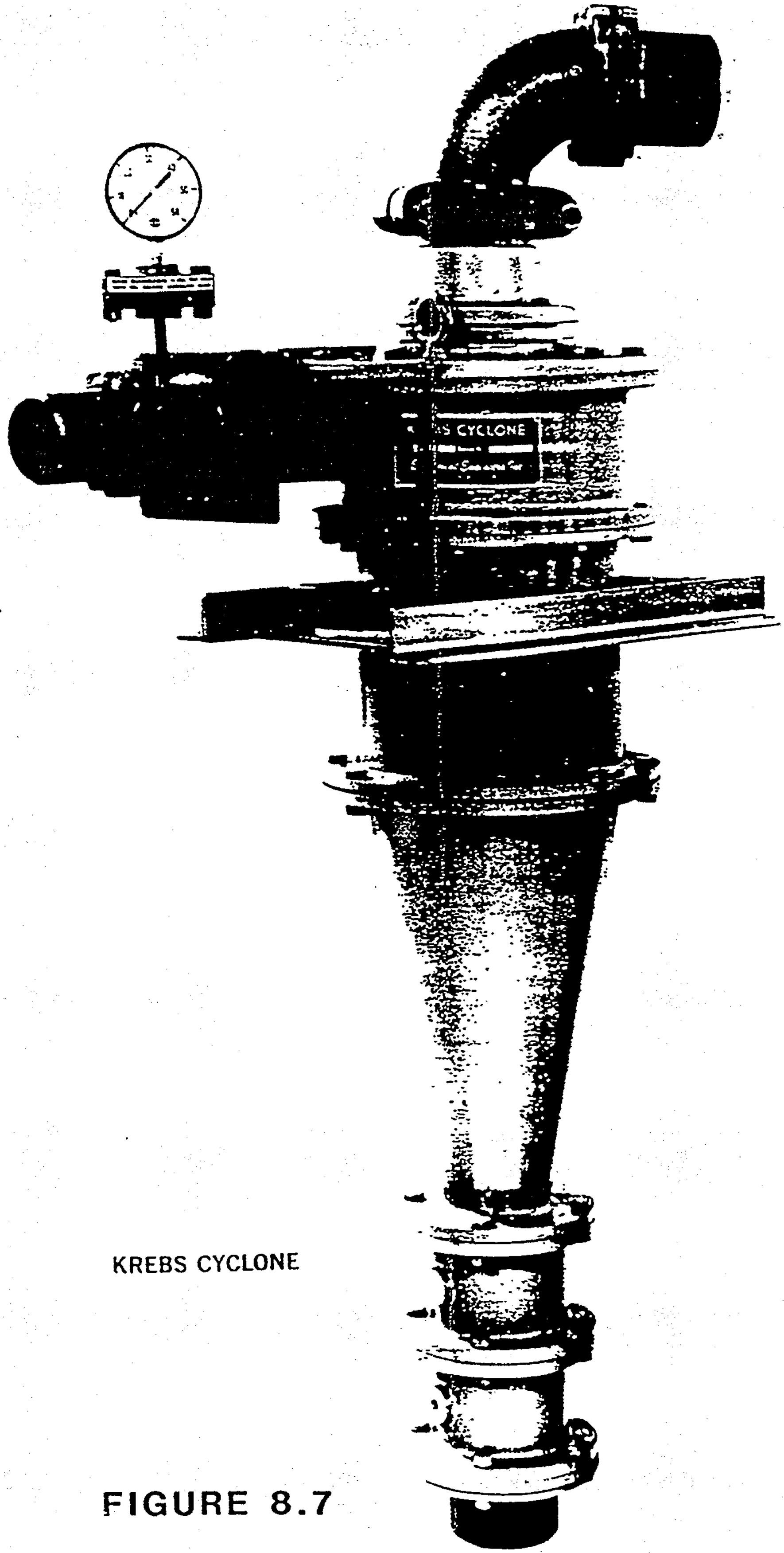



CHEVRON MIST ELIMINATOR
FIGURE 8.5



CHEAF MIST ELIMINATOR

FIGURE 8.6



KREBS CYCLONE

FIGURE 8.7

FIGURE 8.12

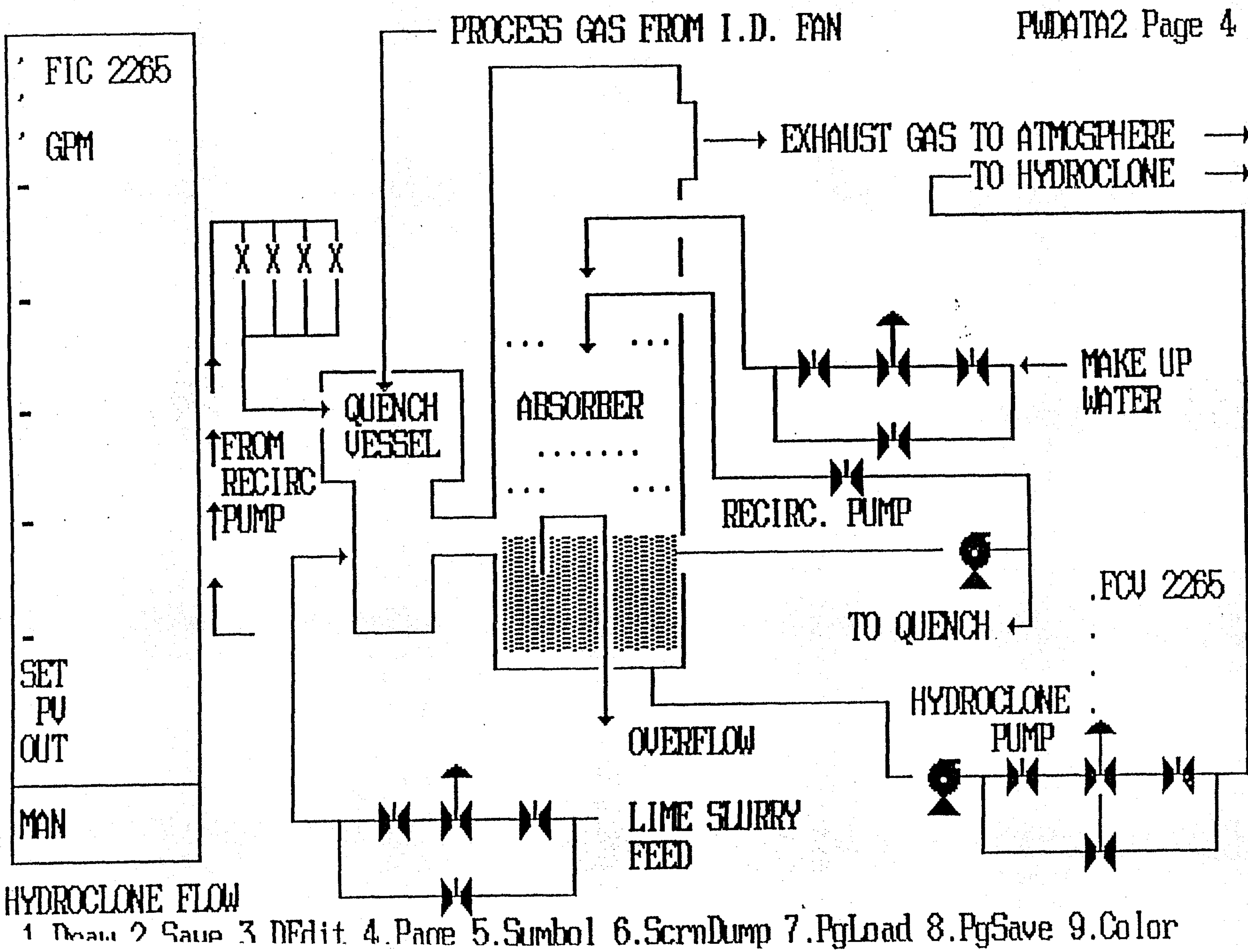

PROCESS GAS FROM I.D. FAN
PWDATA2 Page 4
FIC 2265
GPM
EXHAUST GAS TO ATMOSPHERE
TO HYDROCLONE
MAKE UP WATER
QUENCH VESSEL
ABSORBER
FROM RECIRC PUMP
RECIRC. PUMP
FCV 2265
TO QUENCH
HYDROCLONE PUMP
OVERFLOW
SET
PV
OUT
MAN
LIME SLURRY FEED
HYDROCLONE FLOW
1.Draw 2.Save 3.DFdit 4.Page 5.Symbol 6.ScrnDump 7.PgLoad 8.PgSave 9.Color

FIGURE 8.11

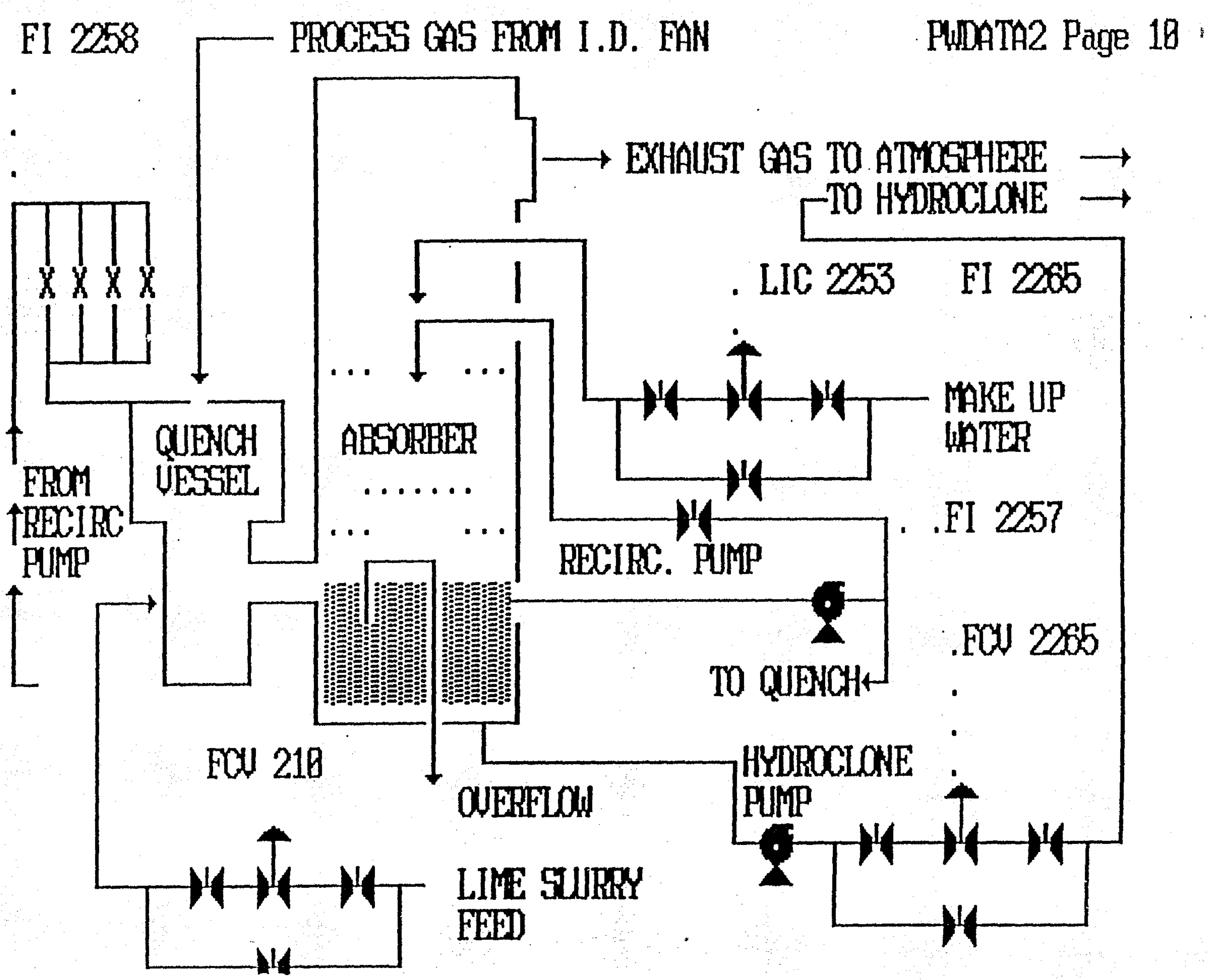

FI 2258
PROCESS GAS FROM I.D. FAN
PWDATA2 Page 10
EXHAUST GAS TO ATMOSPHERE
TO HYDROCLONE
LIC 2253
FI 2265
QUENCH VESSEL
ABSORBER
MAKE UP WATER
FROM RECIRC PUMP
FI 2257
RECIRC. PUMP
FCV 2265
TO QUENCH
FCV 210
OVERFLOW
HYDROCLONE PUMP
LIME SLURRY FEED

FIGURE 8.10

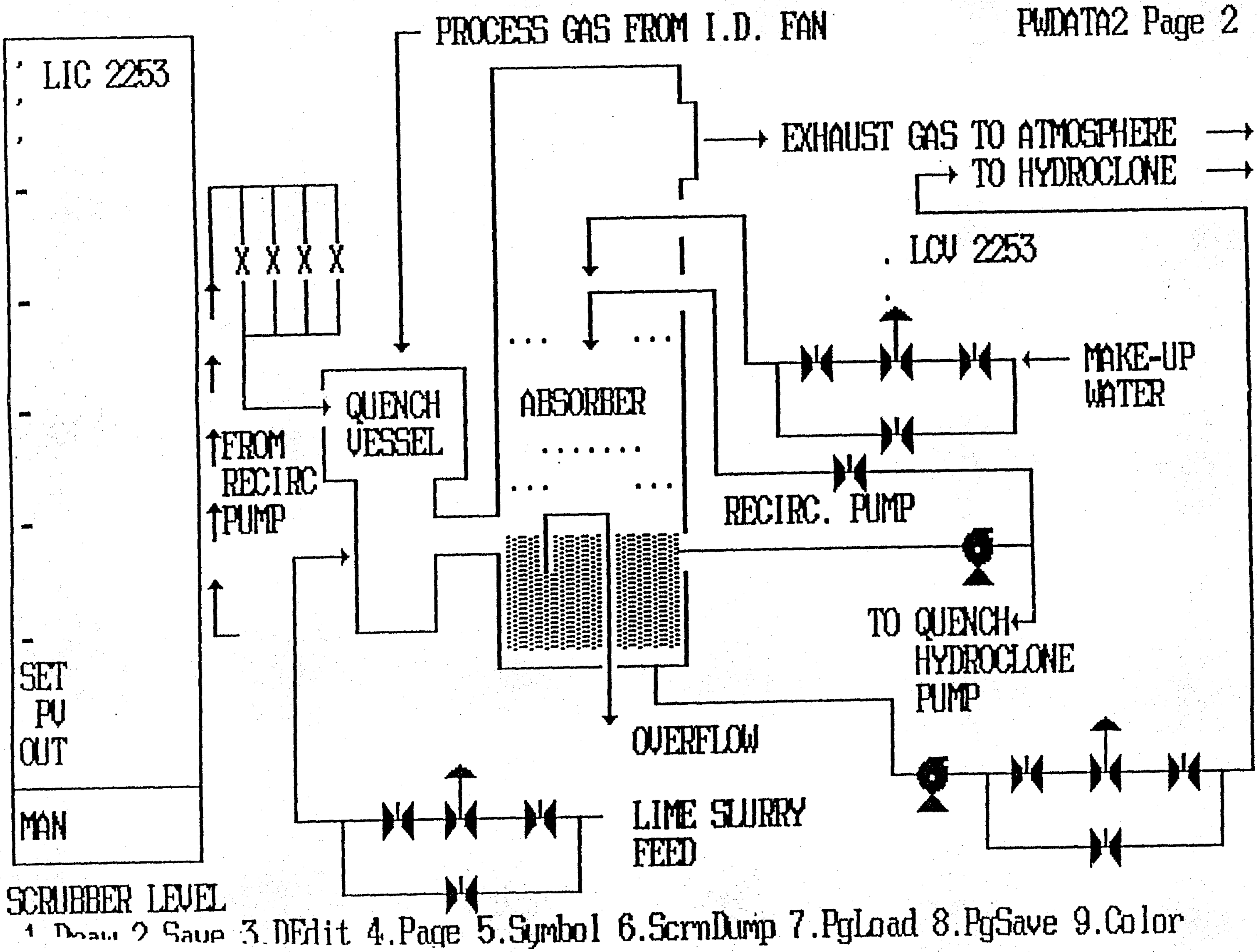
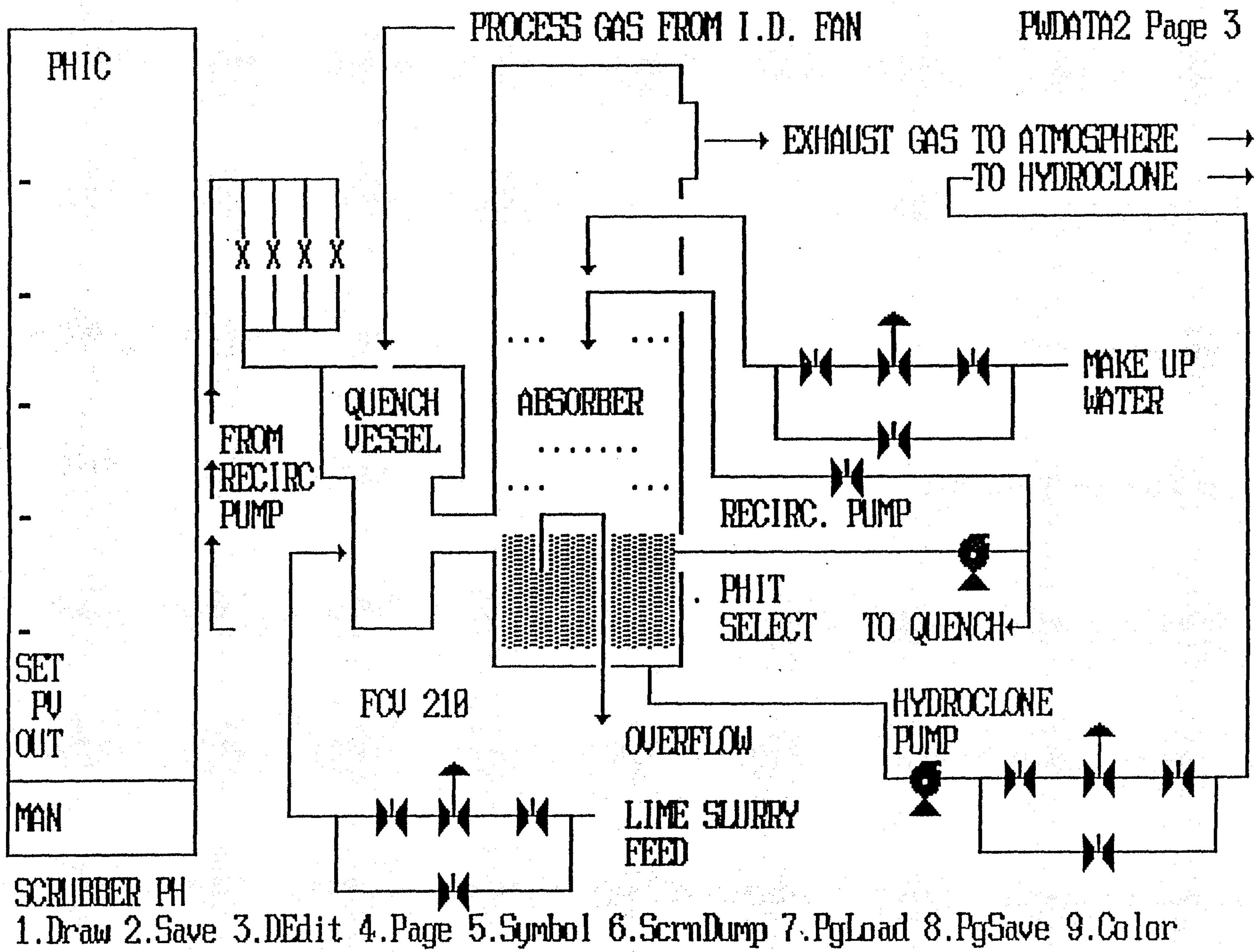

PROCESS GAS FROM I.D. FAN
PWDATA2 Page 2
LIC 2253
EXHAUST GAS TO ATMOSPHERE
TO HYDROCLONE
LCV 2253
MAKE-UP WATER
QUENCH VESSEL
ABSORBER
FROM RECIRC PUMP
RECIRC. PUMP
TO QUENCH
HYDROCLONE PUMP
OVERFLOW
LIME SLURRY FEED
SET
PV
OUT
MAN
SCRUBBER LEVEL
1.Draw 2.Save 3.DEdit 4.Page 5.Symbol 6.ScrnDump 7.PgLoad 8.PgSave 9.Color

FIGURE 8.9


PROCESS GAS FROM I.D. FAN
PWDATA2 Page 3
PHIC
EXHAUST GAS TO ATMOSPHERE
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ABSORBER
MAKE UP WATER
FROM RECIRC PUMP
RECIRC. PUMP
PHIT SELECT
TO QUENCH
SET
PV
OUT
MAN
FCV 210
OVERFLOW
HYDROCLONE PUMP
LIME SLURRY FEED
SCRUBBER PH
1.Draw 2.Save 3.DEdit 4.Page 5.Symbol 6.ScrnDump 7.PgLoad 8.PgSave 9.Color

## SO2 SCRUBBER SCREEN SUMMARY PAGE

## FIGURE 8.8

PWDATA2 Page 1

**Process Window Screen Summary**

| | | | |
|---|---|---|---|
| F1 | Screen Summary Menu | F6 | Huslander 17-1 & 2 |
| F2 | SO2 Scrubber Level | F7 | Roaster Baghouse |
| F3 | SO2 Scrubber PH Controller #1 | F8 | Roaster Indicator Overview |
| F4 | SO2 Scrubber Hydroclone Flow | F9 | Roaster Indicator Overview |
| F5 | S02 Scrubber MOL Addition | F10 | SO2 Scrubber Overview |

NOTE:
USE PgUp/PgDn
TO SWITCH SCREEN

| | |
|---|---|
| A | Alarm Summary Page |

1.Draw 2.Save 3.DEdit 4.Page 5.Symbol 6.ScrnDump 7.PgLoad 8.PgSave 9.Color