

## 15.0 CYANIDE DESTRUCTION

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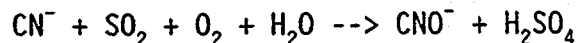
### 15.1

#### INTRODUCTION

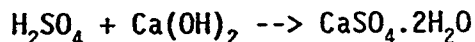
The slurry leaving the CIP adsorption circuit will contain residual cyanide complexes in solution. These tailings are to be treated in the Cyanide Destruction Circuit to ensure that all management guidelines and environmental requirements are met for tailings disposal.

The INCO  $\text{SO}_2/\text{Air}$  process destroys weak acid dissociable cyanide ( $\text{CN}_{\text{WAD}}$ ) and transforms it into the less toxic cyanate ( $\text{CNO}^-$ ) using sulphur dioxide ( $\text{SO}_2$ ) and air, as an oxidizing agent, in the presence of a copper catalyst in a controlled pH range.

The main cyanide destruction reaction is:



The formation of sulphuric acid ( $\text{H}_2\text{SO}_4$ ) lowers the pH. However, milk-of-lime additions form an insoluble product, calcium sulphate and control the pH.

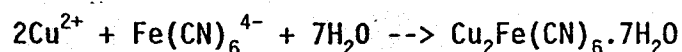
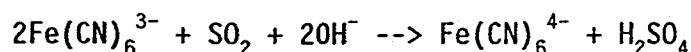


Base metals present as cyanide complexes will be precipitated as metal hydroxides e.g.  $\text{Cu}(\text{OH})_2$ ,  $\text{Zn}(\text{OH})_2$ ,  $\text{Ni}(\text{OH})_2$ .

The resilient iron cyanide complexes are not destroyed but are reduced to the ferrocyanide form  $(\text{Fe}(\text{CN})_6)^{4-}$  under the influence of copper, acting as a reaction catalyst. This ferrocyanide ion then precipitates to the stable copper  $2^+$  (cupric) ferrocyanide  $(\text{Cu}_2\text{Fe}(\text{CN})_6 \cdot 7\text{H}_2\text{O})$ . This product is

stable and will only dissolve in significant quantities in a solution above pH 12.

These reactions are given below:



Under ideal conditions, the cyanide concentration can be reduced from 500 ppm cyanide content in the CIP slurry to under 4 ppm in the treated effluent, leaving the destruction circuit.

It is very important to remember that oxygen ( $\text{O}_2$ ) and sulphur dioxide ( $\text{SO}_2$ ) are both needed to destroy cyanide ( $\text{CN}^-$ ). Copper is needed as a catalyst for cyanide destruction and as a reactant in the precipitation of the iron cyanide complex.

## 15.2

### PROCESS DESCRIPTION (Refer to Figure 15.1)

Pulp tailings from the #8 CIP adsorption tank are pumped over the Carbon Safety Screen to recover any partially loaded carbon or any fine carbon that occurs due to natural breakage from tank agitation. The screen retains any plus 28 mesh (500 micron) carbon and returns it to the head of the adsorption circuit.

The CIP tails slurry underflow gravitates to the cyanide destruction feed pumps. The slurry is pumped with one of the two vertical pumps into the top of the first of two covered cyanide destruction reactors. The process of 'killing' the weak-acid dissociable cyanide ( $\text{CN}_{\text{WAD}}$ ) is performed in these reactors through vigorous agitation of the pulp with

controlled additions of Sulphur Dioxide ( $\text{SO}_2$ ), Oxygen ( $\text{O}_2$ ), Copper Sulphate ( $\text{CuSO}_4$ ) and Lime. Virtually all of the  $\text{CN}_{\text{WAD}}$  is destroyed in the first reactor with the residual iron cyanide complex being removed in the second stage. The pH is controlled to 9.0 in the first reactor.

The required sulphur dioxide is available as a by-product of the roaster off-gas stream. If the roaster operation is down, liquid  $\text{SO}_2$  is available from cylinders as a back-up source. A third source of  $\text{SO}_2$  is available from the underflow of the roaster  $\text{SO}_2$  scrubbing system cyclones producing a separated product consisting of a  $\text{CaSO}_3/\text{CaSO}_4$  slurry mixture. Piping and valving to automatically route the  $\text{SO}_2$  scrubber cyclone underflow to the cyanide destruction feed pumps on a demand basis is in place.

The oxygen ( $\text{O}_2$ ), required for the various chemical reactions, is also present in the roaster off-gas as a component of the contained air.

The copper catalyst needed for cyanide destruction and for the precipitation of the copper-iron cyanide complex is supplied from the copper sulphate reagent mixing system. Monitored lime additions are made to both cyanide destruction tanks.

The treated slurry overflows the first reactor into the second cyanide destruction reactor, where the pH is lowered to 8.0 by the addition of  $\text{SO}_2$  to aid the precipitation of the cupric ferrocyanide complex. The treated effluent then flows by gravity into the backfill cyclone feed hopper, (if backfill is required), or direct by to the tailings hopper for disposal.

### 15.3 EQUIPMENT DESCRIPTION

#### 15.3.1 Cyanide Destruction Tanks

Barren pulp in the two 6.5 m diameter by 7.6 m high baffled, covered cyanide destruction reactors is mixed by Lightnin agitators. In the first reactor a heavy duty, top entry shaft single impeller agitator with four (4) urethane covered blades is driven by a 45 kW motor, geared down to give an output speed of 68 rpm.

The 2.7 m diameter steel blades are situated 1.1 meters above the reactor bottom.

The second 'ageing' reactor is equipped with a top entry, dual impeller agitator mechanism. Complete with three (3), 2.6 m diameter urethane covered steel blades, the gearbox arrangement is designed to give a final output speed of 45 rpm from a 7.5 kW, 1150 rpm electric motor.

For each reactor there are four (4) gas nozzles arranged in a symmetrical pattern in the base of the tank. Cooled roaster gas (57°C) from the centrifugal separator is pressurized by two low pressure gas blowers which discharge the SO<sub>2</sub> flow into a common manifold connected to a single dampening/silencer chamber. Two butterfly valve controlled headers then split the gas flow to eight small feeder pipes feeding the four nozzles per tank.

Most of the SO<sub>2</sub> from the roaster gas will enter the first cyanide destruction reactor, less than 10% will be added to the second reactor for final pH adjustment prior to discharge.

### 15.3.2 Low Pressure Air Cyanide Destruction Blowers

Two ROOTS 616 RCS-JV rotary lobe air blowers supply cooled roaster off-gas to the two cyanide destruction reactors.

The blowers are powered by 55 kW, 1,750 rpm electric motors.

The two blowers suck the cooled roaster gas from the spray chamber separator. By closing the two discharge butterfly valves the internal pressure required to lubricate the screw bearings increases until such time that the blower will start to unload. By opening the gas distribution valves, the gas will pass through a common manifold connected to a dampening silencer. Temperature control of the roaster off-gas after the scrubbing system to a temperature of 57°C or less is required to prevent overheating of the blowers.

Depending on the SO<sub>2</sub> concentration in the roaster gas and the cyanide concentration of the barren adsorption product, one or both of the blowers will be needed.

### 15.3.3 Spray Chamber Separator

The main source of SO<sub>2</sub> for cyanide destruction is the by-product of the ore roasting process.

A portion of the roaster off-gases is drawn from the roaster induced draft fan discharge line and piped across the mill building through a 200 mm diameter line. The temperature of this roaster off-gas is <sup>245</sup>/<sub>120</sub>°C. The hot gas is first quenched in a spray chamber utilizing a temperature controlled valving system, relaying the cooled roaster gas temperature exiting from the centrifugal separator column to the process water valve feeding the spray nozzle. The cooled roaster gas enters

the separator where any water droplets are removed before it enters the two low pressure air blowers. The collected process water used in the spray quench system is drained into the first reactor by gravity as dilute sulphurous acid,  $\text{H}_2\text{SO}_3$ .

## 15.4

### CYANIDE DESTRUCTION PROCESS REAGENT SERVICES

#### 15.4.1

##### Lime Slurry Addition

The storage and mixing of bulk quicklime is described in the Reagent System section of this manual. Lime addition to the cyanide destruction reactors is briefly described in Section 18.2.3.

Lime, added separately to the two reactors, is required to maintain the correct pH. The pH in the first reactor is measured with a pH probe and a signal is transmitted to a time-controller. Whenever this measured value falls below the required set point, an air-activated solenoid valve opens and closes the red jacket pinch valve on the lime loop feed line. This valve is then closed when the measured value is above the desired set-point. If the pH is low ( $\text{pH} < 7.5$ ) there is a potential for hydrogen cyanide gas evolution and sulphur dioxide to be given off. There is no safety hazard if the pH in the reactor is too high.

The pH in the first reactor is designed to be 8.0 to 9.0 and the pH in the second reactor is designed to be 8.0.

#### 15.4.2 Copper Sulphate Addition

The storage and mixing of Copper Sulfate is described in the Reagent Systems section. Copper sulphate, in the hydrated crystalline form  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , is mixed to a 20% solution. The solution is delivered to the two cyanide destruction reactors by a positive displacement metering pump, capable of supplying 300 litres/hour of solution.

Copper sulphate is added to the first reactor to obtain a copper dosage of 20 mg  $\text{Cu}^{2+}$  per litre and is also added to the second reactor to obtain a dosage of 20-60 mg  $\text{Cu}^{2+}$  per litre.

#### 15.4.3 Auxiliary $\text{SO}_2$ System

Auxilliary  $\text{SO}_2$  can be supplied to the two reactors from large cylinders of liquified  $\text{SO}_2$ . The supply of pure  $\text{SO}_2$ , through the auxiliary system, is to be used as a last resort and is only used when the roaster is off-line.

The sulphur dioxide is added as a gas to the cyanide destruction process air spargers. The liquified  $\text{SO}_2$  is supplied in specially designed 0.9 tonne pressure cylinders stored on site.

The liquid sulphur dioxide is withdrawn from the 'tonners' at a slow rate, converted to gas by a vaporizer, then introduced into the cyanide destruction air sparger system. Check valves in the roaster off-gas piping will prevent the  $\text{SO}_2$  from entering other parts of the process air system. The liquid  $\text{SO}_2$  is withdrawn from the cylinder by the cylinder's internal vapour pressure. No air is used to maintain the cylinder pressure.



The sulphur dioxide vaporizer is a heavy steel-walled chamber that is immersed in a water bath tank. The liquid  $\text{SO}_2$  is delivered to this vaporizing chamber. The water bath temperature is thermostatically controlled to a set point in the range of 80 to 90 degrees Celsius, vaporizing the  $\text{SO}_2$  to gas.

A safety pressure relief valve is installed on the gas discharge line to avoid potential high pressures within the unit due to possible entrapment of liquid  $\text{SO}_2$  in the vaporizer. Gaseous  $\text{SO}_2$  pressure, temperature and flowrate are monitored on the inlet and outlet lines.

## 15.5

### PROCESS OPERATION

#### 15.5.1

#### Introduction

This section describes how the circuit is to be operated, the functions of the controls and the significance of the operating parameters.

For operation details, instrumentation process control, reagent systems and requirements, sampling procedures, start up and shut down procedures and trouble shooting techniques refer to the INCO  $\text{SO}_2$ /Air CYANIDE DESTRUCTION CIRCUIT OPERATING MANUAL.

### 15.5.2 Operating Objectives

The aim of cyanide destruction is to detoxify the process plant tailings at the required rate prior to impoundment in the tailings pond.

The cyanide destruction circuit consists of two agitated tanks in series. The circuit has been designated to treat up to 37.7 m<sup>3</sup>/hour of plant residue slurry containing a maximum of 150 kg/hour of 500 ppm total cyanide. Cyanide destruction residence time is 127 minutes (Stage I) and 93 minutes (Stage II).

The SO<sub>2</sub> consumption should be approximately 5 g/g cyanide in the CIP tailings slurry which equates to 45 kg SO<sub>2</sub> consumed per hour based on 250 ppm CN<sub>WAD</sub>. Sparged air is supplied on a mole to mole bases with SO<sub>2</sub> equating at 22.5 kg O<sub>2</sub> consumption per hour. Lime consumption should be approximately 1.5 kg/kg SO<sub>2</sub> added, equating to a slurry addition of 0.76 m<sup>3</sup>/hour.

The target CN<sub>WAD</sub> concentration after the cyanide destruction process is 2 ppm or less.

### 15.5.3 Controls

The pH in the first Cyanide Destruction reactor is controlled automatically by the addition of lime. A three way solenoid valve is activated by the pH controller to open or close the lime addition pinch valve. A high pH alarm on CP3 will annunciate at pH 10.0 and a low pH alarm at pH 8.0.

The pH in the second reactor is controlled manually and can be changed by manual adjustment of a timer in the back of the CP3

control panel. This timer is used to activate a solenoid and pinch valve on the lime line to the No. 2 Cyanide Destruction tank.

The copper sulfate addition rate is controlled manually by adjustment of the variable speed metering pump. The speed of the pump is determined by the amount of cyanide in the CIP tails stream. This is measured by the Picric Acid method.

#### 15.5.4 Picric Acid Test Method

The samples taken from the first reactor and from the discharge from the Cyanide Destruction circuit are analyzed for cyanide using the Picric acid reagent. (The assay lab has several copies of the procedure used to prepare the buffered Picric acid reagent.) The prepared reagent is diluted in the assay lab with one (1) part Picric acid reagent to two (2) parts de-ionized water to obtain the buffered reagent. The procedure to determine the weak acid dissociable cyanide content is as follows:

1. Filter the pulp sample.
2. Take 25 ml of the clear filtrate and put it in a beaker.
3. Add 75 ml of the buffered Picric acid reagent to the beaker and heat the mixture near boiling for thirty minutes.
4. Compare the colour of the resultant solution to that of the prepared standards to determine the  $CN_{WAD}$  content.

## 15.6

START-UP PROCEDURE

As summarized from INCO SO<sub>2</sub>/air operations manual.

1. Fill reactor #1 with slurry.
2. Check reactor slurry discharge dart valves are in the desired position for backfill operation or final tailings position.
3. Check that the pH controllers is at the desired set point and all air activated solenoid valves have available instrument air.
4. Check the lime loop distribution pump is running and that the isolating valves ahead of the lime control valve are open.
5. Start the agitators.
6. Check that water supply to spray chamber separator is open.
7. Check that blower fan suction and discharge valves are all open.
8. Start the blowers.
9. Determine required copper sulphate flowrate in Reactor #1, check the inlet and outlet valves are open and start metering pump. Adjust flow to 3 x normal rate to ensure adequate Cu<sup>2+</sup> to start the reaction.
10. Start carbon safety screen and associated spray water.

11. Start the vertical cyanide destruction feed pump.
12. Sample reactor #1 for free cyanide content.
13. If cyanide is low, reduce copper sulphate flow to pre-determined setting.

When the roaster circuit has stopped or the free cyanide level ( $CN_{WAD}$ ) in reactor #1 is more than 10 ppm, the cyanide destruction circuit will need to be placed on hold until such time as conditions allow the process to restart.

## 15.7

### ROUTINE CHECKS AND TROUBLESHOOTING

#### 15.7.1

##### Routine Checks

1. Take regular 'grab' samples from the first reactor to determine the  $CN_{WAD}$  concentration in the incoming feed. The Picric acid method is used for this determination.
2. Maintain data sheets of CIP adsorption tailing assays as well as cyanide destruction tailings assays.

This information will provide necessary information for troubleshooting.

3. Check and maintain copper sulphate flowrates into the reactors for optimum catalytic activity.
4. Check and maintain the correct pH in the first reactor.
5. Clean pH probe on a regular basis to ensure correct calibration in pH control operation.

6. Maintain correct sampling procedure for all grab and composite samples.
7. Check gas blowers, mixers and temperature indicators are working correctly.
8. Take regular 'grab' samples from the second reactor to determine the  $CN_{WAD}$  concentration in the cyanide destruction discharge. Use the Picric acid method for this determination.

#### 15.7.2 Troubleshooting

<u>Problem</u>	<u>Likely Cause</u>
Low pH in Reactor 1	<ul style="list-style-type: none"> <li>- Lime valve plugged</li> <li>- Lime distribution pumps turned off</li> <li>- pH probe faulty</li> <li>- Lime tank empty</li> </ul>
High pH in Reactor 1	<ul style="list-style-type: none"> <li>- No <math>SO_2</math> roaster gas being added</li> <li>- Instrument air controlling lime feed valve turned off</li> <li>- Valve to solenoid valve closed</li> <li>- pH probe faulty</li> </ul>

**High  $CN_{VAD}$  in Reactor 1**

- Insufficient  $SO_2$  for incoming cyanide concentration
- Roaster off-line, no  $SO_2$  being added.
- Blowers/mixers turned off
- Insufficient copper sulphate (catalyst)
- Low sulphur ore being fed to roaster circuit

**High total cyanide in tails**

- Iron cyanide complex not being precipitated
- Insufficient copper sulphate addition
- Incorrect pH in Reactor 1 and 2

For further troubleshooting problems please refer to INCO  $SO_2$  Cyanide Destruction Circuit, Operating Manual.

**15.8 OPERATIONS MAINTENANCE**

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

- On shut-downs, perform regular checks and clean-up of the pH probes in the reactors.
- Maintenance of the auxiliary  $SO_2$  system for use when the roaster section is down.

15.9

**CYANIDE DESTRUCTION SAFETY****Sulphur Dioxide, SO<sub>2</sub>**

Can cause irritation to eyes, nose and lungs. If burning feeling in eyes, nose or lungs, the area should be ventilated and the source of the gas leak found and eliminated.

**Milk of Lime, CaO**

Milk of lime is caustic and, particularly if hot, can cause damage to the skin. The eyes are highly sensitive to lime.

**USE EXTREME CAUTION WHEN HANDLING LIME****pH**

If the pH in the reactors is low (<7.5) evolution of HCN gas can occur.

15.10

**SUPPORT EQUIPMENT**

The cyanide destruction circuit is supported by several other circuits which must be operating properly for pulp tailings treatment to perform in an efficient and safe manner. It is the operator's responsibility to check on the status of this support equipment.

**Equipment used:**

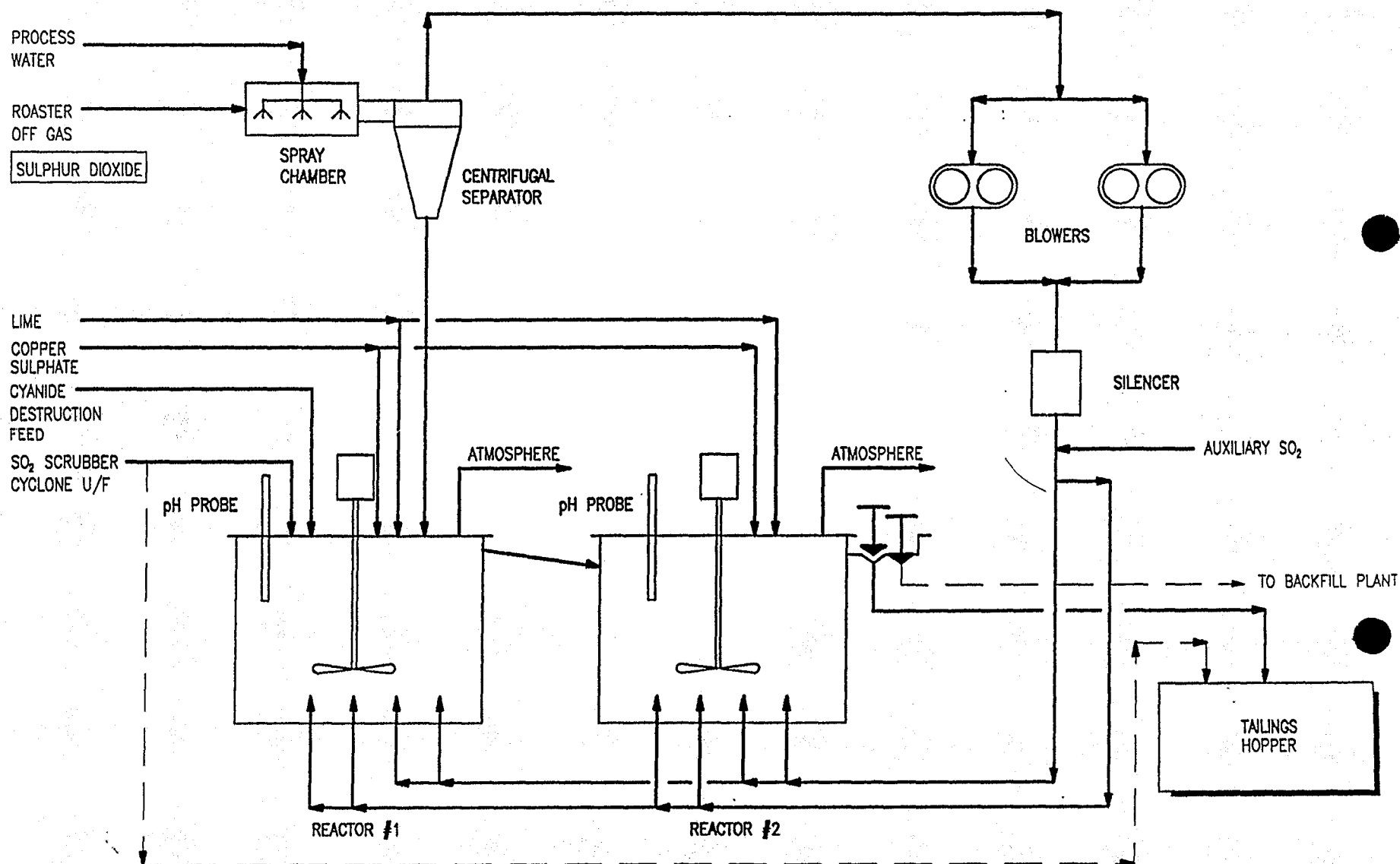
- the air compressors (plant and instrument air).



- the lime slaking system, distribution pump and closed loop supply system.
- fluid bed roaster.
- the auxiliary liquified SO<sub>2</sub> system.
- the copper sulphate mixing system.

**15.11****JOB DESCRIPTION**

The Cyanide Destruction Circuit operator is responsible for the safe and efficient operation of the circuit. Duties that must be carried out include the recording and monitoring of process variables and parameters as well as general housekeeping within the cyanide destruction area. It is the operator's responsibility to ensure that all equipment in the circuit is operating safely and in accordance with operation goals. Routine checks and troubleshooting must be done on an ongoing basis with any abnormal occurrences reported and corrected as soon as possible.



**CYANIDE DESTRUCTION CIRCUIT FLOWSHEET**  
**FIGURE 15.1**