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OPERATORS GUIDELINES
FOR TREATMENT OF GRUM ORES

prepared for

ANVIL RANGE MINING CORPORATION

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Project No. L.R. 4922

NOTE:

This report refers to the samples as received.

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Synopsis

The Grum ore is a very complex, massive sulphide ore, with highly variable processing characteristics. Hence, to maintain respectable metallurgical results, the circuit must be operated with precise control and great understanding. This updated version of operator guidelines is intended to provide information to metallurgists and operators, generated throughout a very long test program, carried out from 1977 to the present, with short breaks.

It is very difficult to prescribe the right recipe for each ore type. However, through observations of froth conditions, appearance of froths related to circuit behaviour, knowledge of the operation can be significantly improved and so can the metallurgical results.

It should be remembered that each unit operation, such as grinding, roughing, regrinding and cleaning, are clearly interrelated, so the performance of these units must be closely maintained within operating ranges and with minimum circuit disturbance.

Most of all, drastic changes in the reagents must be avoided at all times, because very often a disturbance in the circuit may be operational rather than due to reagents.

These guidelines are part of the general guidelines issued in September 1996 and shown in Appendix 1.

Operator Guidelines

1. Grinding Circuit

1.1. Key things to know about the grinding circuit

- ***Fineness of grind at all times and how to correct grinding fineness when disturbances occur.***
- ***Cyclone operation without roping and plugging.***
- ***Accurate reagent and pH control.***
- ***Reagent start-up procedure.***

This may be a check list for every operator at start up and during a shift.

1.2. Maintaining constant fineness of grind

The fineness of primary grind will always be constant if the following parameters are kept under good control.

- ***Proper charging of the mills with steel.***
- ***Constant feed rate.***
- ***Stable pulp density in the cyclone feed and overflow.***
- ***Minimum surges of the cyclone feed.***
- ***Cyclones do not plug.***

Ideally, for the ore treated in the plant, fineness of grind should be above 82% <200 mesh. A finer grind would not hurt the circuit, but a grind coarser than 80% <200 mesh will.

The effect of the above factors on fineness of grind are described as follows:

- If the feed rate varies, two things happen. First, the cyclone pump surges, which reduces cyclone efficiency. Coarse fractions would go to the cyclone overflow, resulting in a coarser product. Second, an increase in recirculation load would occur, which in turn, reduces grinding efficiency.

SOLUTION:

If variation in the feed rate occurs, stabilize it as soon as possible. While working on stabilization of the feed rate, slightly reduce pulp density in the cyclone feed to minimize variation.

- The pulp density of each of the cyclone classification products is one of the controlling parameters of the fineness of grind. Lower pulp density in the cyclone overflow gives a finer grind and better classification. However, there is a limitation to this because the flotation cells would not tolerate too low a density (i.e. below 32% solids).

  Lower pulp density also reduces surges in the circuit. The operating range for pulp density in the tertiary mill circuit is 32% to 38% solids. Too high a level (i.e. >40% solids) should not be practised under any circumstances.

HINTS:

Monitoring and maintaining stable pulp densities in the cyclone overflow and underflow is essential for good performance of the circuit. Periodic pulp density checks should be made on all ball and rod mills during the shift.

The following are pulp density ranges in the primary grinding circuit:

Rod Mill Discharges	**70 - 75% solids**
Primary Ball Mills	**72 - 75% solids**
Tertiary Ball Mills	**72 - 75% solids**
Primary Ball Mill Cyclone O/Flow	**40 - 45% solids**
Tertiary Ball Mill Cyclone O/Flow	**32 - 38% solids**

- Cyclone operation is essential for good performance of the grinding circuit. Cyclones plugging and roping must be avoided at all times. Roping is indicative of a) frequent pump surges, b) too high a pulp density in the cyclone feed or, c) a worn cyclone spigot or cone section. All of these should be checked and monitored.

1.3. Reagent Additions and pH

- The following are the operating ranges for reagents and pH values to the grinding circuit:

- *pH Values*

The pH is quite critical when using lime, since too low or too high a pH may reduce flotation of lead. The operating range for pH in the grinding circuit depends on pyrite content in the ore and ranges from 9.0-10.0. Table No. 1 shows operating pH ranges related to iron content of the ore.

Table No. 1 :
Lead Rougher pH versus Iron Assays of the Head

Pb Rougher pH	% Iron in Feed
9.0	<12
9.2	12-15
9.4-9.5	16-20
9.6-9.8	21-25
9.8-10	26-35

The pH in the grinding circuit must not be kept below 9.0.

IMPORTANT:

An important factor with respect to pH control is that the pH of each grinding line must be similar. If, for example, the pH of one grinding line drops to below 9.0, the lead from the ore ground in this particular line would not float and recovery would drop. It is therefore essential that the pH in each line be kept constant. In other words, "protective alkaline" must be maintained for cyanide to work.

The clever eye of the operator can identify, by the froth appearance, if the pH is OK, too high or too low. Here are some hints:

- **The appearance of a pyritic dry froth in the rougher-scavenger is an indication that pH is too low.**

- **Large bubbles and poorly mineralised froth in the rougher is an indication of too high a pH (i.e. providing the normal amount of collector is being added).**

- **Heavily mineralized froth in the rougher with a leady-colour and an empty froth at the end of the scavenger is an indication of optimum pH and good lead flotation.**

EXCEPTION:

There is ore in the Grum deposit with an acidic natural pH (i.e. <5.5). For this ore, the rougher pH is kept relatively high (10.5-10.8). This is because such an ore contains high levels of soluble iron and $SO_4^{=}$, which depress gold flotation.

- ***Cyanide/SD200 Addition.***

  It has been well established that lead from the Faro region **DOES NOT FLOAT** without the presence of cyanide. Table No. 2 shows lead recovery as a function of level of cyanide for different Faro Pb-Zn ores.

Table No. 2 :
Effect of Level of Cyanide on Lead Flotation from Faro Ores

NaCN Add'n g/t	% Lead Rougher Recovery			
	Faro 3	Vangorda	Grum Quartzite	Grum Massive Sulphide
0	20.8	10.1	18.3	5.0
20	50.2	40.3	50.2	15.8
40	68.3	55.6	75.4	33.6
60	79.0	77.3	83.8	56.8
80	85.5	82.4	88.4	70.3
100	93.1	86.6	90.2	75.6
150	93.5	90.2	92.1	82.5
200	94.0	93.6	90.5	90.5

Introduction of SD200 in the cyanide mix results in improved rate of lead flotation, better pyrite rejection and reduction in cyanide consumption.

IMPORTANT:

A lower level of cyanide/SD200 addition does not mean improved lead middlings flotation. It is the opposite; higher cyanide means both faster liberated lead and lead middlings flotation. A constant effort to optmize NaCN/SD200 in the plant for various ore types is essential.

- ***Xanthate Addition.***

  Xanthate for the grinding circuit is added to the overflow box and should represent 80% of the total xanthate addition to the lead rougher-scavenger stage. The level of xanthate depends on; a) lead head grade, b) amount of graphitic carbon in the ore, and c) natural pH of the ore (i.e. acidic, alkaline). The optimal level of xanthate addition is 30 g/t to 40 g/t, depending on the ore type.

VERY IMPORTANT:

Drastic changes in the level of xanthate addition must not be practised in the plant because such changes usually cause large disturbances in both the lead rougher-scavenger and cleaners.

For example, if the current addition of xanthate is 2,200 cc/minute, xanthate must not be reduced to 1400 cc/min. The increment changes should be a maximum of 200-300 cc/min.

- *Collector 3418A*

  3418A is mostly a gold and silver collector and also helps recovery of copper and fine galena. It is recommended that this collector is added at a fixed rate of 10 g/t to both tertiary ball mills. When gold in the head is over 2 g/t, the addition rate should be 20 g/t.

1.4. Reagent start-up procedure

In order to avoid contamination of the zinc circuit with lead, the following grinding reagent start-up procedure must be observed at all times:

- **Start collector and frother MIBC to the lead rougher feed box and then start up the tertiary ball mill.**
- **Start the secondary ball mills and after start up of the mills, start lime and cyanide to the rod mills.**
- **Start up rod mills + feed.**

IMPORTANT:

If the collector is not started ahead of the mills, an appreciable amount of lead would enter the zinc circuit and removing it would take quite a long time.

2. Lead Flotation

2.1. Lead rougher-scavenger flotation

The essentials for lead rougher-scavenger flotation can be summarized as follows:

- **froth appearance**
- **froth depth**
- **collector-frother addition to the lead scavenger**
- **pulling rates of the lead rougher-scavenger**

- ***Froth appearance*** can tell a great deal about what is happening in the circuit, including: a) too coarse a grind, b) under-collected, c) frother deficiency, d) over-collected, e) too high or too low a pH, etc. The knowledge of identifying the problem by froth appearance is earned by constant observation and relating froth changes to the changes in the controllable parameters listed (a to e). Below is a summary of froth appearances related to different events:

* When the grind is too coarse, the froth becomes too heavy and difficult to move. In such a case, the rougher concentrate grade would drop rapidly to below 24% Pb. Still, the lead rougher-scavenger recovery can be maintained.

* Under-collected froth is bright and leady, has larger bubbles with an appreciable amount of lead floating in the lead scavenger stage. The lead rougher grade would increase rapidly to over 38% Pb.

* Over-collected froth becomes heavy with the appearance of a pyritic froth in the lead scavenger.

* Loose froth with large bubbles, poorly mineralized and watery is an indication of too high a pH (i.e. when collector addition is normal). Appearance of pyritic froth in the rougher with a high tailing is indicative of low pH.

- ***Froth depth.*** The optimum froth depth in the lead rougher depends on the level of MIBC frother additions. Under normal levels of MIBC (90 cc/min to 120 cc/min), froth depth in the lead rougher should be 20-30 cm. In the scavenger, it should be maintained between 15-20 cm.

- ***Collector-frother additions to the lead scavenger.*** Collector additions to the lead scavenger should always be about 20% of the collector addition to the rougher, so when collector changes are made, they should be changed in both the rougher and scavenger stages to keep the same ratio. The same should apply for frother additions.

  There is a tendency sometimes to over-dose the scavenger with frother, adding up to 40 cc/min in each bank. This is asking for trouble, because the high dosage of frother is not noticeable in scavengers, but the lead cleaners would ***run out of control,*** without you realizing why.

- ***Pulling rates in the rougher and scavenger.*** Under normal reagent additions, the pulling rate is controlled by froth level and air rate. When we fix the froth depth, the pulling rate is controlled by air only. In this way, the rougher should be pulled in a way that maintains a rougher concentrate grade of between 32-36% Pb. The scavenger is pulled to maintain the lowest possible tailing (i.e. 0.4-0.5% Pb). Successful rougher-scavenger flotation under stable conditions is a prerequisite for good performance of the lead cleaning circuit.

2.2. Lead regrind

The lead regrind is one of the most important unit operations in the lead circuit and without a stable regrinding circuit, satisfactory lead metallurgical results cannot be obtained. Stable regrind means that the required fineness of lead rougher concentrate is achieved at all times and that the recirculating loads within the circuit are stable. When modification of this circuit is completed by installing cyclones designed for fine classification, it would be essential to establish the optimum number of cyclones in operation with a minimum number of cyclones operating automatically. With the present cyclones, some operating strategies should be practised. Changing the number of cyclones in operation, too often creates inefficient regrinding conditions and consequently builds up large recirculation loads, resulting in pumps overflowing and too coarse a regrind. The number of the cyclones must be selected according to cyclone underflow pulp density. The pulp density in the regrind cyclone underflow should always be maintained between 68-72% solids. Because there is no real quick measurement of regrind performance, the regrinding parameters must be developed through plant surveys and then maintained by the operators.

IMPORTANT:

- Check cyclone overflow and underflow pulp densities every 2 hours during the shift. In this way, problems can be detected before it is too late.

- When the pulp density in the cyclone underflow drops below 68% solids, it is almost certain that the regrinding efficiency will drop. Pulp density must be adjusted at once by adjusting the number of cyclones.

2.3. Lead cleaners

If the roughing and regrind operate properly, the lead cleaners usually perform well if optimum reagent additions are used in the lead regrind mills. There are several key operating parameters that must always be carefully controlled. These are:

- **Level and points of NaCN/SD200 addition**
- **Pulling rate from each cleaner**
- **Regrinding fineness**

Successful control of the above parameters would determine overall metallurgy in each cleaner.

- ***Level and points of NaCN/SD200 addition.*** The NaCN/SD200 is added in each regrind mill. The established addition rates at the plant are as follows:

Regrind Mill No. 1	**2000 cc/min to 3500 cc/min**
Regrind Mill No. 2	**1000 cc/min to 3000 cc/min**
Regrind Mill No. 3	**2000 cc/min to 3500 cc/min**

The circuit must be operated within these ranges. Note that too low a cyanide/SD200 addition usually results in reduced rate of lead flotation, especially fine galena, and results in a heavy loss of lead.

IMPORTANT:

NaCN/SD200 must not be added to the 3rd and 4th cleaners, as the presence of NaCN in these cleaners would result in voluminous froths.

- *Xanthate* additions must only be made to Regrind Mill No. 1 cyclone underflow and Regrind Mill No. 2 cyclone underflow.

  Note that the xanthate line to the cyclone underflow of Regrind Mill No. 2 will shortly be installed. The operating ranges of xanthate additions are as follows:

Regrind Mill No. 1 Cyclone U/Flow	**150 cc/min to 450 cc/min**
Regrind Mill No. 2 Cyclone U/Flow	**Fixed 50 cc/min**

  If insufficient xanthate is added to the regrind mill, the froth in the Pb 1st cleaner would be voluminous and poorly mineralized, in which case, difficulties in maintaining low I bank tail will be experienced.

VERY IMPORTANT:

Xanthate to I bank feed must not be added since pyrite would be promoted and build up of pyrite in the lead cleaners will occur. If collector is required in I bank, a small amount of 3418A (i.e. 20 cc/min) should be added. Frother MIBC should be added if required to the I bank rougher and scavenger feed, up to 10 cc/min maximum.

- ***Pulling rate in the lead cleaners*** must be maintained as constant as possible. It should be remembered that the distributors do not distribute pulp evenly to "A" and "B" banks and that pumps are surging. Because of this slow pulling rates of the lead cleaners will cause enormous problems in the circuit due to the build up of lead recirculating loads.

  Note that the pulling rate must be adjusted in such a way that when pump surging decreases, cleaners must still have froth discharge.

- ***Fineness of regrind*** determines lead concentrate grade. Table No. 3 shows the relationship between regrind fineness and lead concentrate grade at a constant lead recovery of 80%. These data show that if lead concentrate grade is kept high at coarser grind, losses in the lead recovery will occur. Therefore, the grade of the lead concentrate must be adjusted according to the fineness of regrind in order to maintain high lead recovery and to produce a saleable zinc concentrate in the subsequent zinc circuit.

Table No. 3 :
Lead Grade vs Regrind Fineness at Different Overall Lead Recoveries

Overall Regrind K_{80} µm	% Pb Conc Grade at 80% Pb Rec'y	% Pb Conc Grade at 75% Pb Rec'y
25	55	59
20	58	61
18	61	63
16	63	65
14	65	68

3. Zinc Circuit

The zinc circuit performance depends on the performance of the lead circuit. Another important feature of the sphalerite in the Grum ore is that the iron content of the sphalerite varies. This changing sphalerite characteristic determines basic zinc operating conditions.

3.1. Zinc conditioning and rougher-scavenger operation

pH value in the conditioning and zinc rougher determines froth stability and controls froth dryness. Therefore, the pH in the zinc rougher should be controlled according to froth characteristics. The operating pH range for the rougher is 10.5-11.0. Note that for dry froth, the pH must always be increased in order to avoid problems with froth discharge. The safest way to operate the zinc circuit is at a pH of 10.8.

Reagent additions are as discussed in the original operating guidelines. The $CuSO_4$ and collector additions should be adjusted according to the head grade (see Appendix I - page 19 and 20). The frother addition should be kept to a minimum and should not exceed 120 cc/min. The reagent additions to the zinc scavenger stage are quite important for controlling zinc recovery, especially frother. The collector-frother ranges to the scavenger are as follows:

Xanthate	**150-250 cc/min**
Frother	**10-25 cc/min**

VERY IMPORTANT:

When K and L bank rougher discharge boxes are filled up with froth, the reagents do not mix well with the pulp and they do not have any effect on zinc recovery. Therefore, the water sprays must always be used to break froth in the discharge boxes.

3.2. Zinc regrind and high intensity conditioning

pH in the zinc regrind and high intensity conditioning should be kept in the same range as the rougher pH. The pH in the J bank controls dryness of froth and recovery. The operating pH of this circuit should be 10.5-11.

Reagent additions. The following reagent addition rates should be used:

$CuSO_4$ to regrind	**1000 to 3000 cc/min**
Xanthate to HIC	**300 to 500 cc/min**

Note that without collector addition to the HIC, the HIC's are not effective.

3.3. Zinc cleaners

Column operation in the present configuration would serve the purpose of controlling the recirculation load in the "J" bank and must be carefully controlled. The optimum operating conditions for the column are as follows:

Air Flow	**550 to 750 L/min**
Sparger Water	**27 L/min**
Froth Depth	**1.0 to 1.3 m**

Note that reducing froth depth below 1 m would result in reduction in selectivity.

J Bank. The tailing of J bank should be kept to below 4.0% Zn. This can be easily achieved by adjusting collector and frother to the J bank scavenger feed and collector to the HIC.

The collector-frother addition rates to the J bank scavenger feed should be kept as follows:

Xanthate	**150 to 300 cc/min**
Frother	**15 to 25 cc/min**

D and C Banks. The froth in the D and C banks should be kept tight. This is achieved by controlling pH values in the cleaners. For example, lower pH gives a tighter froth (i.e. pH 10.3-10.8), while higher pH would give a more voluminous froth. Tightness of froth can also be controlled by the level of collector added to the HIC. A higher level of collector gives a tighter froth and faster zinc flotation.

From the operation point of view, the D bank should be pulled hard while the C bank should be adjusted to maintain constant concentrate grade.

Appendix

Original Operators Guidelines

Operators' Guidelines for Operation of the Concentrator

prepared by Srdjan Bulatovic, P. Eng.

PREFACE

Here are some practical operating instructions for processing Grum ore. Just reading these guidelines will not make you a good flotation operator, but it will tell you some of the things to do in order to become one.

Even if the control room "is full of nice gadgets", the grinding area and flotation floor are the place where things happen. Which adds up to a simple conclusion: "There is no flotation plant in the world than can be run from the control room".

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1. General Considerations

Successful plant operation depends largely on the understanding of each unit operation and what it is for. Unit operations refer to: grinding, lead roughing, lead regrinding, lead cleaning etc. Performance of each unit operation is inter-related with other units. It should be remembered that there is no prescribed recipe for running the plant, and therefore, every effort must be made to understand the circuit from an operating perspective and the conditions that are required to be maintained. Of prime importance for the operator is the ability to detect deviations from set conditions and to correct them immediately.

These guidelines are intended to provide operators with information on the methodology of circuit operation along with the major parameters that should be observed and controlled at all times. The overall circuit is broken into unit operations and the general operating conditions for each unit are described.

2. Operator Guidelines

2.1. Grinding Circuit (Figure 1)

Proper operation of the grinding circuit is a key factor in achieving good metallurgical results. It should be remembered that a problem with coarse grinding cannot be identified without checking the fineness of the grind, but a coarse grind can reduce circuit recoveries considerably.

There are two sets of parameters that should be closely controlled by the operator:

1) grinding pulp densities and fineness
2) reagent additions to the grind.

2.1.1. Grinding Pulp Densities and Fineness of Grind

Under steady operating conditions (i.e. feed rate and constant water flow) the pulp densities would remain steady throughout the shift. The following is a usual procedure for maintaining stable grinding circuit performance.

1. At the beginning of the shift, check the pulp densities of the grinding mill discharge and cyclone overflow.
2. Check the feed rate of each rod mill and adjust the set points.
3. Adjust pulp densities to set points, if required.

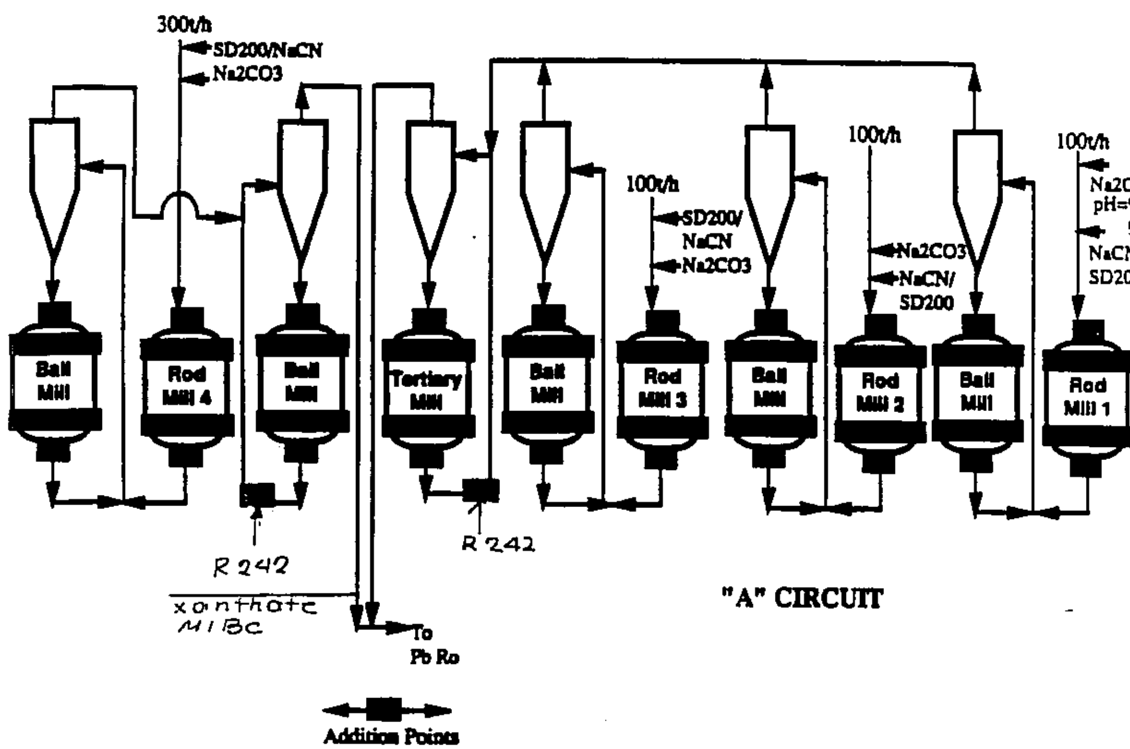
4. Check each cyclone for operational performance. Cyclones are performing well if the underflow discharge is spreading (looks like an umbrella). If it is straight and very heavy, it is called roping. Such a discharge indicates that the cyclone is not functioning properly and should be shut-down for repair. A spare cyclone should be substituted.

5. Check each pump's performance once a shift. If the pump level is fluctuating often, the number of cyclones should be reduced. Sometimes, it is a sign that the pulp densities are not correct.

After inspecting and adjusting the circuit at the beginning of the shift, the circuit is normally monitored throughout the shift by inspecting grinding and cyclones at least once every 2 hours. The circuit monitoring also includes checking the size distribution at least twice during the shift. The following procedure is used:

- Fill up a pycnometer with pulp to measure pulp density.
- Screen the pycnometer pulp content on 200 mesh screen. Observe if there is any unusually coarse material on the screen.
- Return the screen oversize to the pycnometer.
- Fill up the pycnometer with water and measure the pulp density of the screen oversize.
- Calculate the weight difference between the feed sample and the plus 200 mesh fraction.
- Based on the weight differences of the feed sample and the plus 200 mesh fraction, calculate the percent of the plus 200 mesh fraction.

Figure No. 1 : Grinding Circuit Configuration



2.1.2. Reagent Additions and Control

Although reagent additions eventually will be automatically controlled from the control room, it is necessary to inspect reagent flows every 2 to 3 hours during the shift. This is because the automatic control valves may not feed the target rates as shown on the screen because of mechanical problems with the valves or due to possible plug-ups of the valve.

Reagents such as MIBC and R242 are not controlled from the control room and should be inspected several times during each shift.

2.1.3. Mechanical and Operational Performance of the Grinding Equipment

It is the duty of the operation crew of each shift to inspect and record any malfunction of the grinding equipment, including measurement of its operational performance.

Knowledge of the equipment and its function is a key in keeping the equipment at top operating performance.

The following are key check-points to be checked and inspected at least once per shift:

- gland water for each pump
- oil flow at each point of the mill
- leaking bolts
- operation of the cyclones
- water flow (pressure drops, etc)
- excessive ball discharge
- excessive breakage of rods
- are spare pumps in operating condition
- are pinch valves functioning properly
- are there enough balls and rods in the mill

With respect to operational performance, this has to be checked by the plant metallurgist at least once every 2 weeks. The measured performance is determined through a plant survey and sizing of the grinding and classification products.

2.2. *Lead Rougher-Scavenger Flotation*

The performance of the lead rougher-scavenger unit operation depends on three sets of major operating parameters. These include:

1. fineness of grind, pulp density and pH
2. reagent additions
3. air flow, pulp level (froth depth) and rate of froth discharge.

Apart from the fineness of grind, pullp density and pH, all of the other parameters are controlled and maintained by the flotation operator.

2.2.1. Fineness of Grind, Pulp Density and pH

Fineness of grind and pulp density are controlled by the grinding operator and usually these data are accessible to the flotation operator.

1. Normal pulp density is between 35-38% solids. For viscous ores with less pyrite, the pulp density should be kept at about 30% solids.

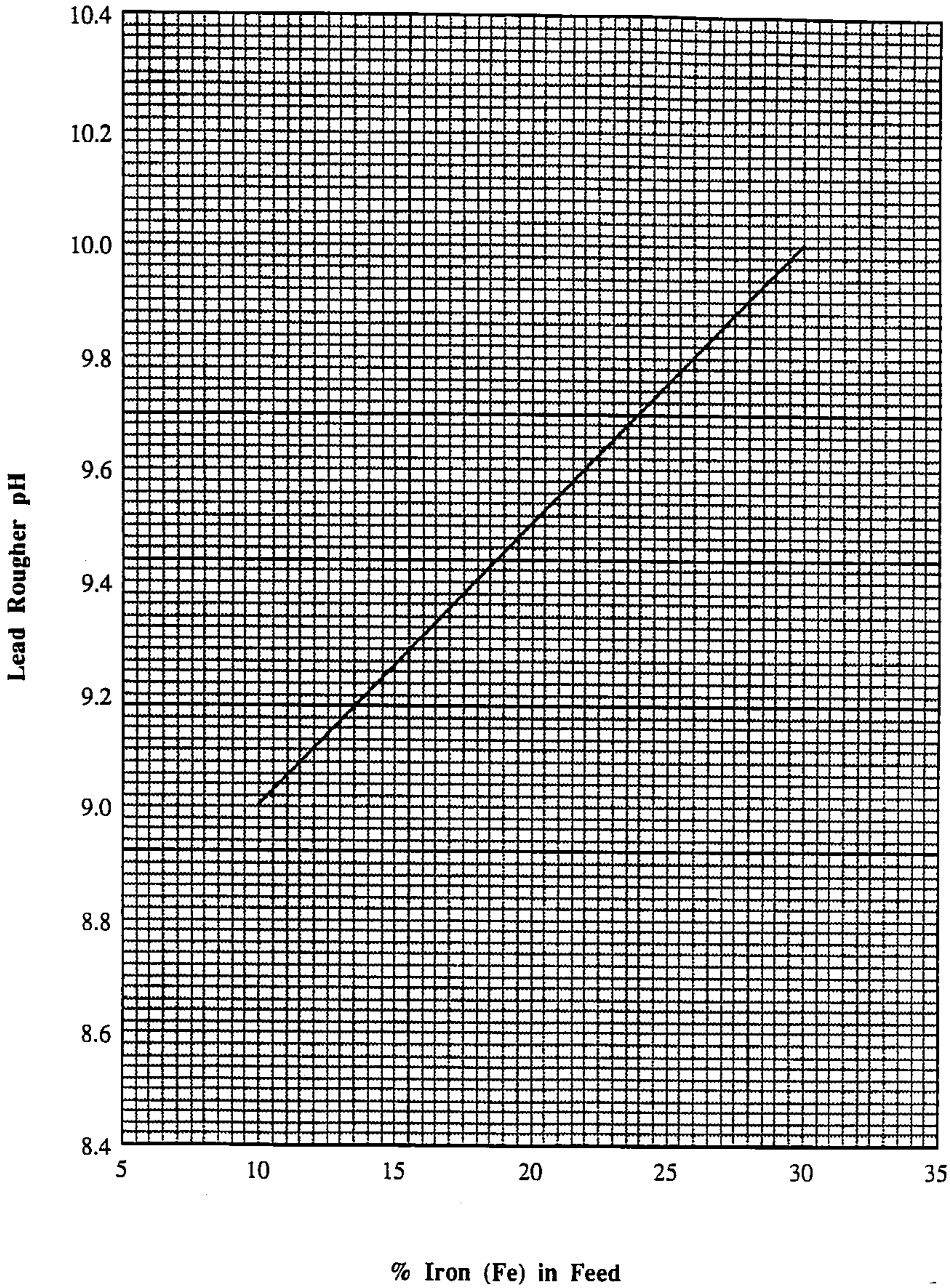
2. The pH is quite critical, especially when using lime, since too low or too high a pH may reduce flotation of lead. The lead rougher pH range is between 9 and 10.1 (when controlled with lime). The guideline for pH adjustment is the iron content of the feed. Figure 2 shows the relationship between pH and iron assay of the feed. Therefore, the pH range should be set according to the iron content of the feed.

One of the most important factors with respect to pH control is that the pH of each grinding line must be similar. If, for example, the pH of one grinding line drops to below 9.0, the lead from the ore ground in this particular line would not float and recovery would drop. It is therefore imperative that the pH of each grinding unit be checked every 2 hours. Lime or soda ash flow must be inspected periodically by both the grinding and flotation operators.

The clever eye of the operator can identify by froth appearance if the pH is OK, too high or too low. Here are some hints:

- The appearance of pyritic froth in the rougher and scavenger is an indication that the pH is too low.
- Large bubbles and poorly mineralized froth in the first two rougher cells is an indication of too high a pH (i.e. providing that a normal amount of collector is being added).
- Heavily mineralized froth in the rougher with a leady colour and an empty froth in the scavenger is an indication of optimum pH and good lead flotation.

Lead Rougher pH Vs Iron Assay of the Feed



2.2.2. Reagent Additions

Optimum levels and steady flows of reagents are the two most important parameters for both lead and zinc flotation. Steady flows can be maintained by a good control system but finding the optimum levels is more difficult. When difficulties arise, upon deciding what level would be optimum, it is best to stay within the established ranges.

This section describes reagent addition level ranges as guidelines for how much of each reagent should be used.

a) ***NaCN/SD200 is prepared*** as 15% solution and is used as a pyrite and zinc depressant during lead flotation. Table No. 1 shows NaCN/SD200 addition chart to the primary grind at a feed rate of 600 tonnes per hour. Table No. 2 shows NaCN/SD200 addition chart to the regrind mills also at 600 tonnes per hour. To change NaCN/SD200 addition to the regrind according to feed rate, Figure No. 3 should be used.

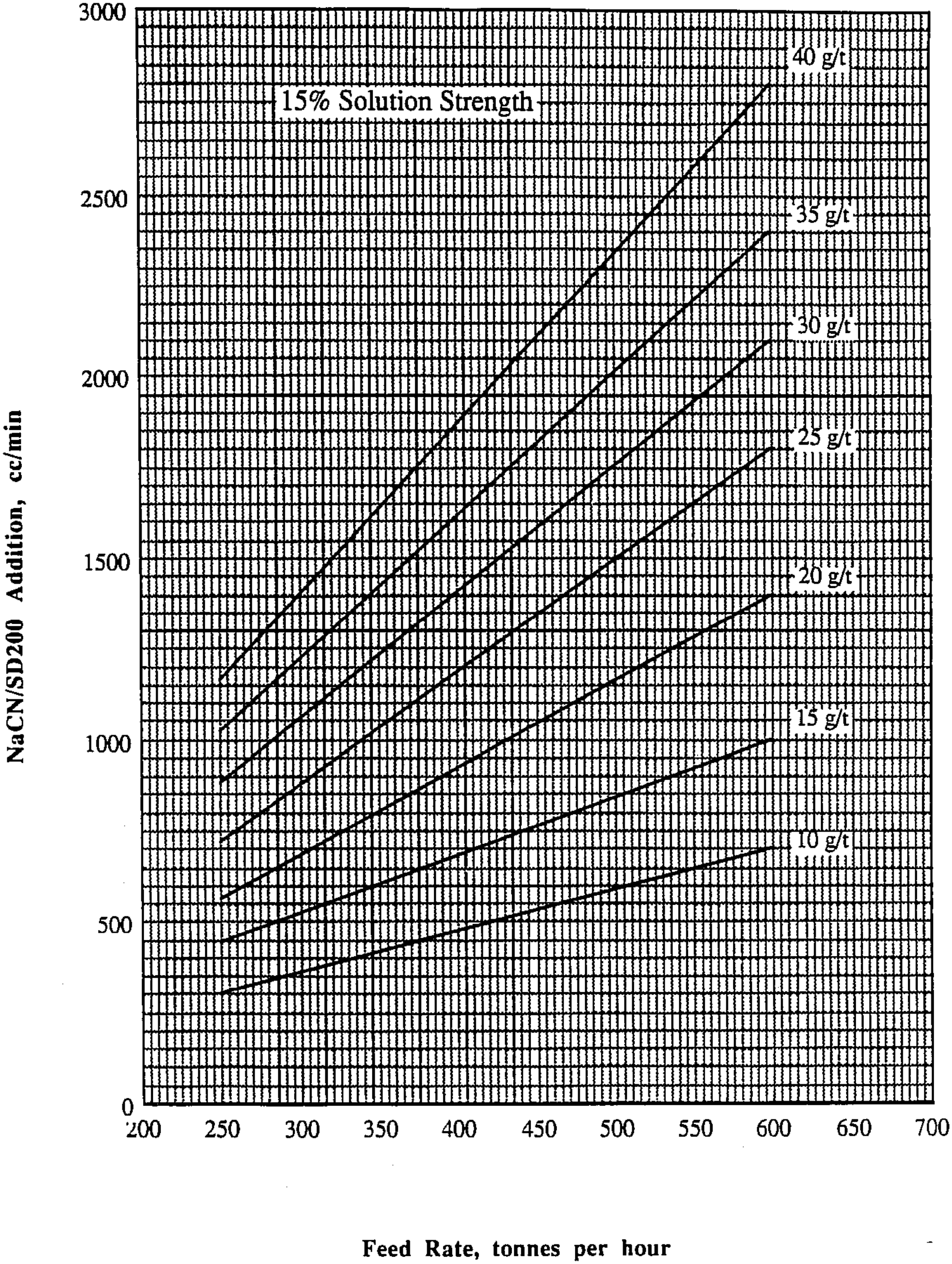
Table No. 1 :
NaCN/SD200 Addition Chart to Primary Grinding at a Full Feed Rate of 600 t/h

Addition Rate g/tonne ore	Equivalent cc/min			
	Rod Mill No. 1	Rod Mill No. 2	Rod Mill No. 3	Rod Mill Total
100	1,100	1,100	1,100	3,300
120	1,300	1,300	1,300	3,900
140	1,550	1,550	1,550	4,650
160	1,760	1,760	1,760	5,280
180	1,980	1,980	1,980	5,940
200	2,210	2,210	2,210	6,630

Table No. 2 :
NaCN/SD200 Addition Chart to the Lead Regrind Mills at a Full Feed Rate of 600 t/h

Addition Rate g/tonne ore	Equivalent cc/min		
	Regrind Mill No. 1	Regrind Mill No. 2	Regrind Mill No. 3
10	700	700	700
15	1050	1050	1050
20	1400	1400	1400
25	1750	1750	1750
30	2100	2100	2100
35	2450	2450	2450
40	2800	2800	2800

Feed Rate Vs NaCN/SD200 Addition to the Regrind Feed



The NaCN/SD200 addition ranges shown in Tables 1 and 2 are the normal operating ranges. Lower or higher additions should not be exercised unless the ore belongs to some extreme case, which is unlikely to occur.

The so-called average additions of NaCN/SD200 are as follows:

- 140 g/t to primary grind
- 30 g/t to the regrind mills

The major factors that would dictate an increase in NaCN/SD200 to the lead circuit are as follows:

- Too much zinc in the lead concentrate
- Low lead grade in the rougher or final cleaners
- High lead in the lead scavenger tail when higher collector additions do not reduce lead losses in the tailing.

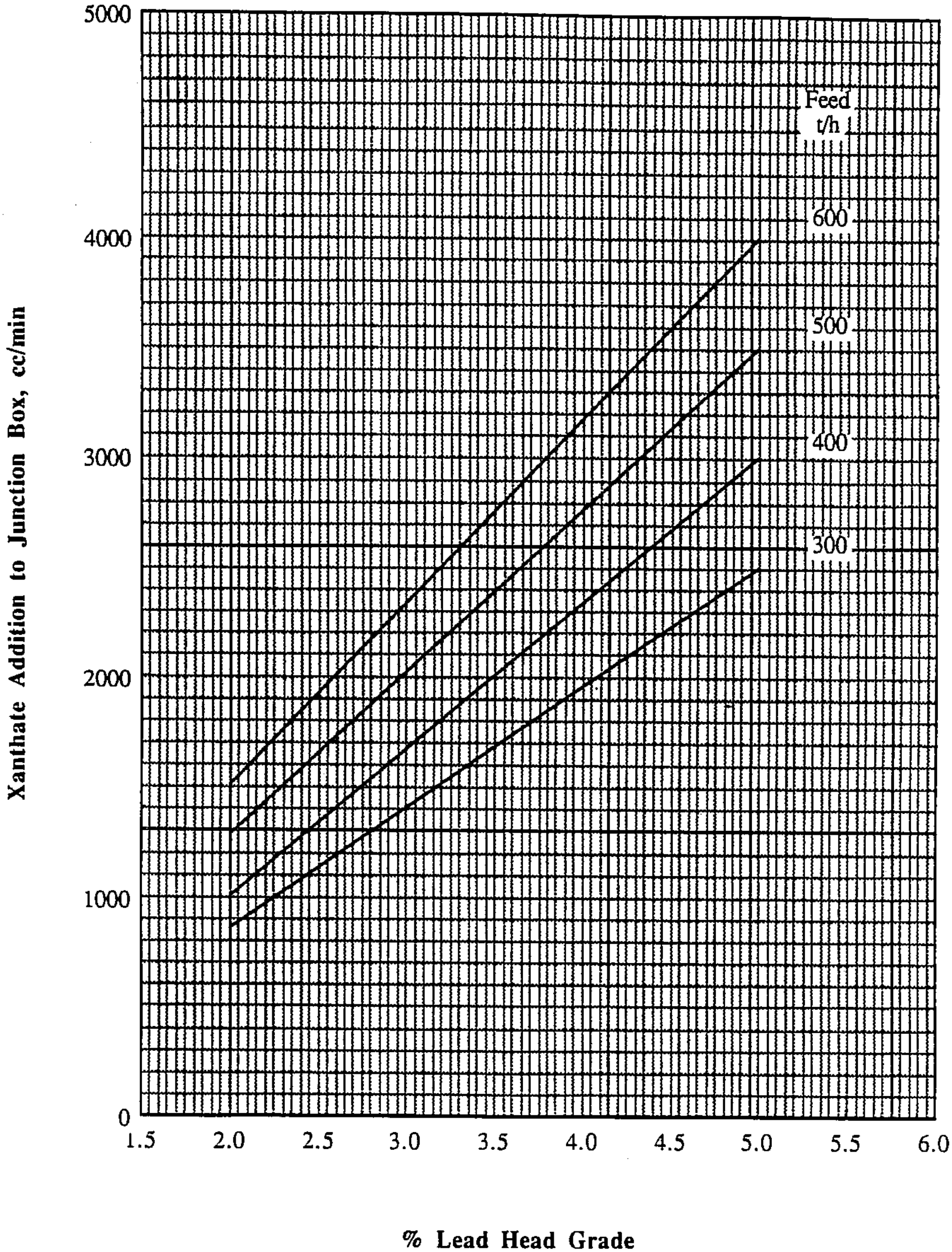
b) ***Collector R242*** is usually added at a fixed addition rate of 50 cc/min. This collector level should not be changed. Addition rate should be checked periodically as this reagent is added via metering pumps from the drum.

c) ***Xanthate Collector*** is prepared as a 20% solution. The levels of xanthate addition depend on i) lead head grade and ii) rate of lead flotation (i.e. slow or fast). If too much xanthate is added to the circuit, its harmful effect can only be detected in the lead cleaners, when it is too late. In order to avoid such problems, changes in the levels in xanthate addition must be minimal. The optimal level of xanthate addition should be between 30 and 40 g/t. Extremely high additions should only be used in the case of treatment of oxidized carbonaceous ore types. Table No. 3 shows xanthate additions at a fixed feed rate of 600 t/h.

To change xanthate addition according to lead head grade, the chart shown in Figure 4 should be used. This chart is based on a standard level of xanthate addition of 40 g/t at a head grade of 3.5% Pb.

To change xanthate addition according to feed rate, Figure 5 should be used. It should be noted that low addition of xanthate should be exercised in cases when too much zinc is floating in the lead concentrate.

Level of Xanthate Addition Based on Head Grade



Feed Rate Vs Xanthate Addition to the Junction Box

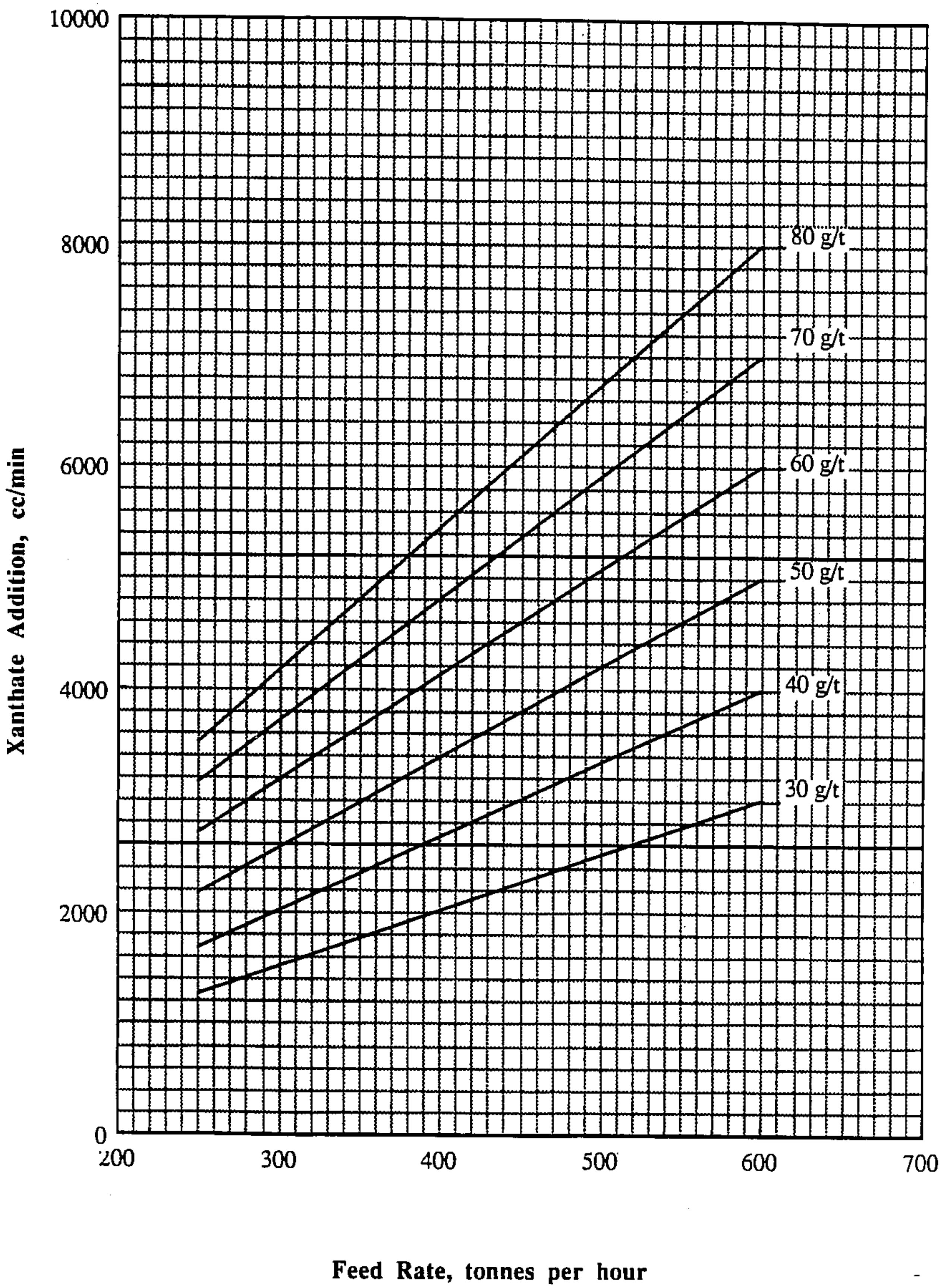


Table No. 3 :
Xanthate Addition - Pb Circuit at 600 t/h Feed

Addition Rate g/tonne ore	Equivalent cc/min		
	Junction Box	Pb Scav (G,H)	Pb Cl Scav (I)
10	-	2 x 500	500
15	1500	2,750	750
20	2000	-	-
25	2500	-	-
30	3000	-	-
35	3500	-	-
40	4000	-	-
45	4500	-	-
50	5000	-	-
55	5500	-	-
60	6000	-	-
65	6500	-	-
70	7000	-	-
75	7500	-	-
80	8000	-	-

Xanthate addition to the Pb scavengers (G and H banks) should be 20% of the xanthate added to the Junction Box as per Figure 5.

d) MIBC additions are made according to requirements and addition ranges cannot be prescribed. Table 4 shows possible additions with normal rates between 10 and 20 grams per tonne. Only a high carbonaceous ore would require more than 30 g/t of MIBC. If requirements exceed 30 g/t, then there must be something very wrong with the circuit.

To change MIBC rates according to feed rate, the chart shown in Figure 6 should be used (to the Junction Box). It should be remembered that adding too much MIBC can result in significant reduction in concentrate grade. Moreover, overflowing of pump boxes would occur. Additions to the scavenger (G,H banks) should not exceed 20% of that added to the Junction Box.

Feed Rate Vs MIBC Addition to the Junction Box

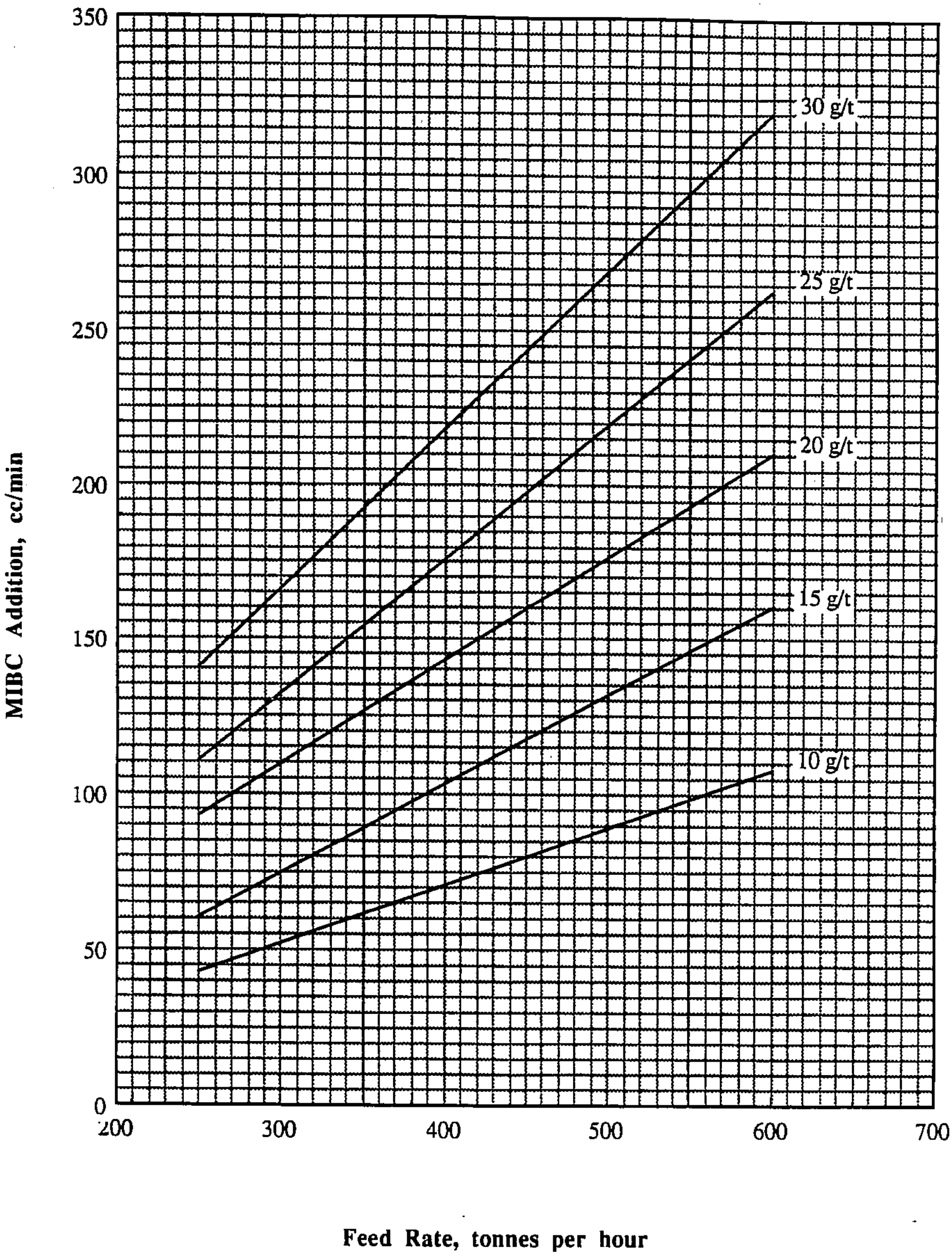


Table No. 4 :
MIBC Additions at a 600 t/h Feed Rate

Addition Rate g/tonne ore	Equivalent cc/min		
	Junction Box	Pb Scav (G,H)	Pb Cl Scav (I)
2.5	-	2 x 13	25
5.0	-	2 x 28	55
10.0	110	-	-
15.0	165	-	-
20.0	220	-	-
25.0	275	-	-
30.0	330	-	-
35.0	385	-	-
40.0	440	-	-

2.2.3. Operational Performance of the Pb Rougher-Scavenger and Possible Problems and Solutions

The most important factor for good performance of the rougher-scavenger circuit is to keep the froth discharge constant, without surges. Froth depth in the Pb rougher should be maintained at about 20 cm below the cell lip. The froth depth in the lead scavenger cells should be at about 15 cm below the cell lip.

Usual problems that occur in the lead rougher and scavenger flotation are as follows:

- ***Feed surges,*** caused by tertiary grinding cyclone pump surges. This usually results in a unsteady froth discharge and problems with stability of the overall circuit. To reduce surges in the circuit, attempts should be made to reduce the number of cyclones used in tertiary grinding.

- ***Heavy froths*** (i.e. overloading) and dry froth result in difficulties in froth removal. The froth usually collapses and consequently results in loss of lead in the tailing. This is caused by either too much xanthate addition to the circuit or a deficiency of frother. Such problems must be immediately corrected.

2.3. *Lead Regrind*

For processing of the Grum ore, fineness of lead regrinding is a most important parameter. However, during periods with a low feed rate, adjustment in the regrind is required.

The optimization of the lead regrinding stage is an on-going process and operating conditions have to be determined. Several variables for each regrind mill must be carefully considered:

- The number of cyclones must be kept to a minimum for all three regrinding mills.
- Pulp densities of the cyclone overflows should not exceed 25% solids.
- For good performance of the lead circuit, the lead rougher-scavenger should be kept as steady as possible.
- Overflowing of launders and pumps should be avoided at all times, as the spills are returned to the regrind mills and cause a significant disturbance in the circuit.

2.4. *Lead Cleaning*

The performance of the lead cleaning circuit largely depends on the performance of the lead rougher-scavenger and regrinding unit operations. Any problem in these two unit operations is directly translated to the cleaners. Therefore, both the rougher-scavenger and regrind must be kept under tight control in order to provide good performance of the lead cleaners.

Operating parameters that are critical for good lead cleaning performance can be described as follows:

pH Values in the Cleaners

- ***The pH in the first cleaner*** is controlled by lime additions to lead regrind No. 1 and 2 mill feeds. The pH control probe is located at lead first cleaner cell No. 1 (B bank) which may delay for sometime the reaction to changes. Therefore, when correcting pH a time of 20 minutes should be given. The first cleaner pH should be maintained at about 9.5 to a maximum of 10.0. The 10.0 pH refers only when highly active pyrite appears in the circuit. It should be remembered that too high a pH reduces lead recovery.

- ***The pH in the 2nd cleaner*** normally should be run at 10.0. The operating range should be 10.0-10.5.

- ***The 3rd and 4th cleaners*** are usually operated without pH adjustments. Excessive lime additions and high pH must not be exercised here because both lead grade and recovery would deteriorate. In extreme cases when pyrite depression is a problem, the pH in these two cleaners should be controlled at between 10-10.5.

Reagent Additions to the Cleaners

- ***NaCN/SD200 additions.*** The NaCN/SD200 is added only to the regrind mills. The operating range of this reagent is between 10 g/t and 40 g/t, as shown in Figure 3, and the normal addition is 20 g/t. High rates of up to 40 g/t should be exercised when a problem in rejecting zinc from the lead concentrate or a lead grade problem occurs.

- ***Xanthate.*** No xanthate should be added to the cleaners. A xanthate addition is made to the lead first cleaner scavenger feed and should be used to control lead losses in the cleaner scavenger. Xanthate additions to the cleaners would automatically reduce lead concentrate grade.

- ***MIBC.*** As for xanthate, the MIBC should only be added to the lead first cleaner scavenger feed (I bank).

Operation of the Cleaners

The following are the most important parameters that are imperative for good performance of the cleaners. These can be described as follows:

- The lead first cleaner should be pulled fairly hard in order to maintain high recovery.

- Froth removal slightly lower than in the first cleaner should be maintained in the second cleaner.

- Still slower rates of froth removal should be maintained in the lead 3rd and 4th cleaners. The removal rates should always be adjusted by air. The froth in the cleaners should be tight and heavily mineralized. A loose, voluminous froth is an indication that a) too high a pH, b) deficiency of collector in the rougher, or c) too much NaCN/SD200.

- Too high a recirculation load of lead in the cleaners must be avoided at all times. If such a situation occurs, froth discharge in the 3rd and 4th cleaners should be slowly increased and lead should be "bled out". The high recirculation load in the cleaners may be a result of the following:
  a) a problem with regrinding
  b) too slow lead flotation in the cleaners
  c) too high a pH in the cleaners
  d) too much NaCN/SD200 in the regrind.
  These are only a few of the most common factors that influence build-up of a recirculating load.

2.5. Zinc Circuit

The zinc circuit performance depends largely on the performance of the lead circuit as well as on adjustment of reagents in the individual units. It is much more difficult to provide optimum reagent additions in the zinc circuit than in the lead circuit than for the lead. This is because if levels of reagents are not right, both zinc grade and recovery deteriorate.

2.5.1. Zinc Conditioning and Rougher-Scavenger Operation

- ***pH Value.*** The optimum rougher pH for successful zinc flotation is 10.5 to 11.0. High pH must be avoided because zinc rougher-scavenger flotation deteriorates.

- ***Reagent Addition*** rates is one of the most critical factors in operating the zinc circuit. In order to avoid problems in over-dosing or under-dosing the zinc circuit with copper sulphate and xanthate, fixed additions of $CuSO_4$ based on head grade have been established. The only changes will be in collector addition. Addition of $CuSO_4$ to conditioner No. 1 should be 135 g/t per 1% of zinc. Table No. 5 shows the $CuSO_4$ that should be used for different feed rates and ore grades.

Table No. 5 :
CuSO4 Additions to Conditioner No. 1 Feed

Feed t/h	Addition Rate, cc/min								
	% Zn in Head								
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
250	8,440	9,800	11,250	12,708	14,200	15,600	17,100	18,500	20,000
300	10,125	11,750	13,500	15,250	17,000	18,750	20,550	22,250	24,000
350	11,800	13,700	15,750	17,800	19,800	21,900	24,000	25,950	28,000
400	13,500	15,600	18,000	20,250	22,700	25,000	27,400	29,700	32,000
450	15,200	17,600	20,250	22,900	25,500	28,100	30,800	33,400	36,000
500	16,900	19,600	22,500	25,400	28,300	31,200	34,250	37,100	40,000
550	18,500	21,500	24,700	27,900	31,100	34,400	37,700	40,800	44,000
600	20,250	23,500	27,000	30,500	34,000	37,500	41,000	44,500	48,000

- ***The addition of xanthate*** added to the rougher conditioner should be based on the amount of $CuSO_4$ used and is usually in a ratio of 1:0.079. Therefore, xanthate is calculated as follows:

  $$\text{g/t } CuSO_4 \times 0.079 = \text{g/t xanthate}$$

  Example: if we add 500 g/t ore of $CuSO_4$, then the addition of xanthate would be 500 x 0.079 = 39.5 g/t xanthate.

Table No. 6 :
Xanthate Addition at a Feed Rate of 600 t/h

Addition Rate g/tonne ore	Equivalent cc/min		
	Zn Cond No. 2	Zn Scav (K,L bank)	Zn Cl Scav (J bank)
5	500	2 x 250	250
10	1000	2 x 500	500
15	1500	-	-
20	2000	-	-
25	2500	-	-
30	3000	-	-
35	3500	-	-
40	4000	-	-
45	4500	-	-
50	5000	-	-

Xanthate additions are illustrated in Table No. 6. Addition of $CuSO_4$ and xanthate in the proper ratio would provide good activation of sphalerite and reduce froth dryness. The addition of xanthate to the zinc scavengers (K, L) would be 20% of the xanthate addition to the conditioner No. 1.

Operational performance of Zinc Rougher-Scavenger Stages.

Most of the problems involved in the zinc rougher-scavenger flotation are associated with froth dryness and difficulties in froth removal. This is because in most cases, too little $CuSO_4$ is added to conditioner No. 1 and too much xanthate is added to conditioner No. 2. Under these conditions, the froth becomes dry and unselective. To avoid such conditions, $CuSO_4$ and xanthate must be added in the ratio described in the section "Reagent Additions".

The froth in the roughers should be well mineralized and easy to discharge. The froth in the scavenger should be almost empty and should consist of larger bubbles. This is an indication of good rougher-scavenger performance.

The froth levels in the zinc rougher-scavenger stages are somewhat different than those for the lead circuit. The following froth levels should be maintained: Zn Rougher = 20 cm depth
Zn Scavenger = 25 cm depth

In some cases, when pump surges are severe, readjustment of froth depth may be required in order to avoid pulp spillages in the concentrate launders.

Air pressure and mechanical performance of the cells should be checked once per shift.

2.5.2. Zinc Regrind and Zinc 1st Cleaner

- ***The pH*** in the zinc first cleaner usually ranges between 10.8 and 11.0 (i.e. slightly higher than that of the zinc rougher-scavenger). Too high a pH in the first cleaner should be avoided since at higher pH, high zinc losses in the zinc first cleaner scavenger stage may occur. Lime additions must be made to the regrind mill feed only.

- ***$CuSO_4$ addition*** to the zinc regrinding mill should be 20% of the $CuSO_4$ added to the zinc rougher conditioner No. 1.

- ***Xanthate additions*** are made to HIC and to the Zn 1st cleaner scavenger feed (J bank). These additions should be kept as follows:
  High Intensity Conditioner = 10% of the xanthate added to the zinc rougher conditioner
  Zn 1st Cleaner Scavenger = 20% of the xanthate added to zinc rougher conditioner No. 2.

- ***Frother additions*** should be made to the high intensity conditioners only.

Operational Performance of the Zinc Regrind and 1st Cleaner

Under optimum flotation conditions and proper reagent additions, zinc flotation in the first cleaner is relatively fast and selective. Under such conditions, the froth in the zinc first cleaner scavenger should look like the froth in the scavenger stage. If too much zinc appears in the zinc first cleaner scavenger, this may be an indication of:

- Poor performance of the columns and the scalp (i.e. high recirculation load)
- Too high a pH in the first cleaner feed
- A deficiency of frother-collector in the high intensity conditioner.

In such a case, the problem must be identified and eliminated immediately. An indication of good performance of the zinc cleaners would be heavily mineralized froth in the first cleaner.

The froth levels in the first cleaner scavenger should be kept as follows:

Zn 1st Cleaner (J)	= 30 cm below lip
Zn 1st Cl Scav (J)	= 20 cm below lip

During the shift, the following should be checked and adjusted:

- Air flow to the cell
- Reagent addition rate
- Operational performance of the regrind cyclones.

2.5.3. Column Cleaning and Zinc Scalp

Proper operation of the columns is quite a tricky task, especially when their performance depends on about 6 major parameters, including: air flow, feed rate, sparger water flow, wash water flow, froth depth in the columns, and reagent additions to the columns. It has been observed that each shift crew has its own operating philosophy, which further complicates achieving steady column operation. It is imperative that operating conditions of the columns be set and remain constant all the time.

Fiddling with column set points numerous times during the shift creates serious problems in maintaining both zinc concentrate grade and recovery. Until the wash water system is corrected, columns should be operated without wash water at constant set points. The recommended froth depths for the columns should be 1.5 m for the rougher column and 1.3 m for the scavenger column. The condition of the zinc scalp is a good indicator of the performance of the columns. This flotation stage should be run very slowly to avoid contamination of the zinc concentrate with pyrite.

The column pH range should be 11.0 to 11.5. Lime should be added to the rougher feed pump only. Frother should be added to the sparger water feed to provide stable froths in the columns.