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Pilot Plant Testing

of

Grum Ores

Toronto December 12, 1977

The Noranda Milling Committee

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CONTENTS

Summary

Pilot plant testing of Grum ores has been carried out in the facilities of Lakefield Research Ltd. since October 4, 1977. Test work will end on December 15, 1977. Sufficient data have been collected for a feasibility study.

A composite sample has been tested. The composite was blended on the advice of Kerr Addison and NML geologists and mineralogists from twelve bulk samples which represented different ore types. Over sixty-five per cent of the pilot plant sample consisted of massive sulphidic ores of high base metal content. Such ores are more difficult to treat than "average" Grum ore because of very fine dissemination of base metals. The conservative composition of the pilot plant sample was chosen to assure functional circuit design.

Forecasted results for this type of mill feed are:

	Analyses % or oz./t				Recoveries %			
	Au	Ag	Pb	Zn	Au	Ag	Pb	Zn
Mill Feed	.03	2.7	5.8	10				
Lead Conc.	.14	27	62	10	33	72	77	
Zinc Conc.			2.5	56				81
Tailings			1.3	1.5				

A truly "average" composite of Grum ores will assay lower in lead and zinc and should contain a lower percentage of iron sulphides, its grain size distribution would be more favourable and somewhat better results should be attainable. Metallurgical results for average ores are estimated at:

	Analyses						Recoveries			
	Au	Ag	Pb	Zn	Hg	As	Au	Ag	Pb	Zn
Mill Feed	.025	2	4	8	100	0.3				
Lead Conc.	.15	28	62	8	90	0.1	33	72	80	
Zinc Conc.			2.0	56	650	<0.1				84
Tailings			0.7	1.0						

The Grum ores vary in hardness. The work index for fine grinding ranges from 6 to 15 KWH/T. It is estimated that the average work input in primary grinding will be 15 KWH/T. For the highly sulphidic ores, which are soft, this produces a primary grind of 90 percent passing 200 mesh. For the harder ores, a somewhat coarser grind can be accepted since they are generally coarser grained. However, the concentrator throughput would also fluctuate moderately as ores of different hardness are treated but the fineness of grind of the flotation feed must be a closely controlled variable.

.../4

Regrinding of the lead and zinc rougher concentrates is indispensable. The combined power requirement for both regrind mills is estimated at 2.4 KWH/T of mill feed.

Concentrates are very finely ground at 95 per cent passing 20 micron for the lead and 85 to 90 per cent passing 20 micron for the zinc concentrate. Such fineness influences strongly the capacity of thickeners, filters and dryers.

The flotation of all products is reasonably fast. The capacity provided in the initial lay-out - 3.2 cubic feet per ton of mill feed - appears adequate.

Tailings pond effluents have been recycled in the pilot plant but it was not possible to use effluents in all circuits. In the lead cleaner circuits, use of effluents led to uncontrollable foaminess so that fresh water had to be substituted. A maximum of 75 per cent of mill water requirements can be supplied by recycled effluents. Management of the tailings pond and recycle facilities will have to be carefully planned to attain such high usage of effluents.

.../5

The Pilot Plant Composite

Twelve bulk samples were taken from the Grum deposit in July 1977. They were shipped to Lakefield, Ontario and the different types of ore were blended for pilot plant testing in the following proportions.

Sample No.	% of Composite
A-2	5%*
B-5	10%*
C-4	10%
D-4	5%
FV-4	5%*
FQ-4	5%*
G-4	10%
H-4	10%
J-76-1	15%*
K-68-1	10%*
K-76-1	5%*
K-80-1	10%*

(*) massive disseminated sulphide

This composite contains a high percentage of finely disseminated sulphides. It was deliberately blended in such a ratio that a conservative and realistic approach to metallurgical evaluation and plant design would ensue.

The agreement between the results of the laboratory cycle tests and the pilot plant continuous runs has been excellent. Therefore, the metallurgical results when treating ores from all the individual sections of the Grum deposit may be predicted with confidence from careful analyses of the laboratory testing.

The last pilot plant tests were completed by mid-December, some five months after the samples had been mined and three months after fine crushing. There have been indications of slow oxidation, the most noticeable being a gradual increase in soda ash consumption from 3 lbs/ton in October to 5 lbs/ton in December to maintain the same pH value (9.0) in the grinding circuit. Fortunately, this change had no undue influence on metallurgical results. Oxidation should be a minor problem for the Grum milling operations.

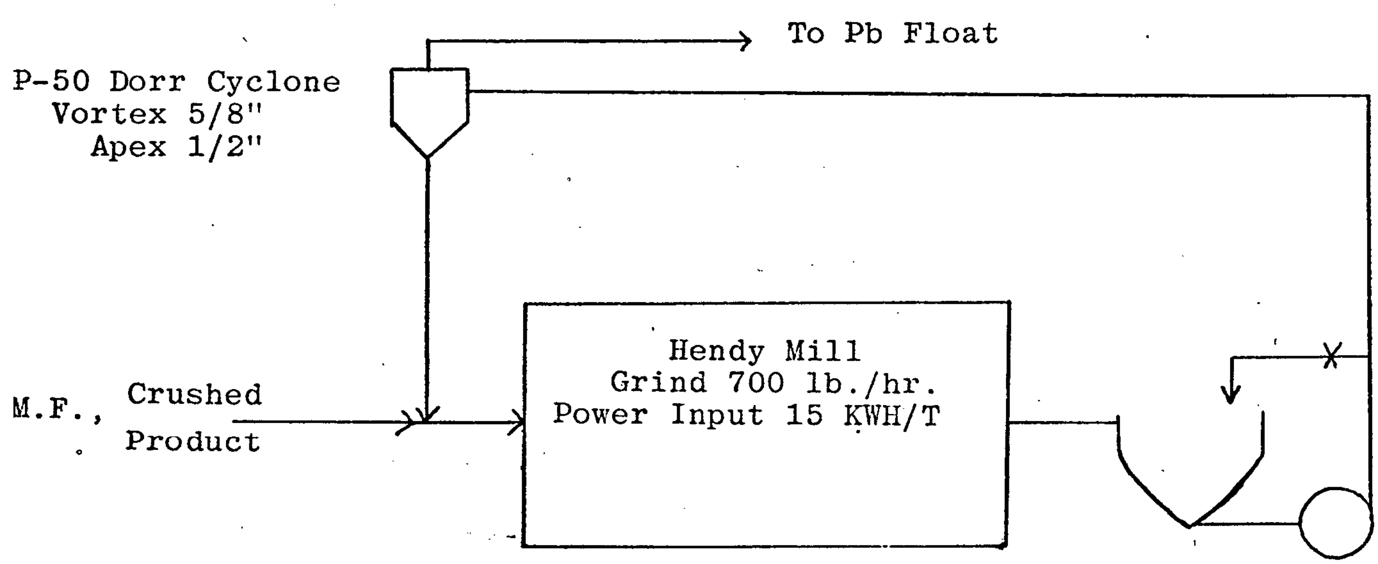
.../6

December 8, 1977

GRUM FLOWSHEET 1

Pilot Plant Testing

Primary Grind



Sizing of Products

Mill Feed

Passing	½ in	3M	8M	200M
	100%	77.6%	45.1%	9.3%

Cyclone Overflow

Passing	100M	200M	270M	400M
	99%	91%	84%	70%

Reagents Added

To Mill Feed:
Soda Ash: 3-5 lbs/T
NaCn 0.2 lbs/T

Collectors 0.09 lbs/T

pH: 9.0 - 9.2
oxygen demand is low

The metal content of the pilot plant composite was:

Au	0.03 oz./t	Cd	0.012%
Ag	2.8 oz./t	Ni	0.003%
		Co	0.007%
Cu	0.13%	CaO	0.85%
Pb	5.8%	MgO	0.27%
Zn	10.1%	As	0.23%
		Hg	82 ppm
Insol	28.2%	Ge	0.001%
SiO_2	25.3%	Mn	0.05%
Fe	20.5%	Ti	0.05%
S	27.0%	Cr	0.01%

Grinding

The hardness of Grum ores varies considerably, but even the hardest can be broken satisfactorily. No difficulties were encountered in crushing any Grum sample. In primary grinding, the work indices vary from less than 6 KWH/T to over 15 KWH/T. The pilot plant composite had a work index of 11.4 KWH/T.

For sulphidic ores (P.P. composite) a fineness of grind is required of 90 per cent passing 200 mesh. At coarser grinds, tailings losses increased rapidly and all circuits became overloaded with middlings products. (See also paragraph on flotation.)

For plant design a power input of 14.5 KWH/T had been estimated prior to pilot plant testing. This design criterion has been modified to be 15 KWH/T from now on. Total installed HP should thus be 6000 HP, 2000 HP in the rod mill and 2000 HP in each of the ball mills.

Regrinding

The lead and zinc rougher concentrates will be of lower grade than normal because they will contain an unusually large quantity of middlings. Regrinding is definitely required in both circuits for production of saleable products at acceptable recoveries. The lead concentrate will have a fineness of 95 per cent passing 20 micron, the zinc concentrate 85 to 90 per cent passing 20 micron. Classification efficiency must be very high for both circuits to prevent slime losses.

For the initial lay-out, prior to pilot plant testing, it had been assumed that both circuits would be equipped with a 400 HP regrind mill. The total power consumption of 800 HP will be maintained but the distribution of regrind power will be altered to allow about 300 HP for lead and 450 HP for zinc regrinding, final choice depending perhaps on availability of used mills.

.../7

Autogenous Grinding

We do not recommend pilot plant autogenous grinding tests at this time. Therefore, we cannot recommend layouts for any form of autogenous grinding for feasibility purposes during the present design phase. Our reasons for making these statements are enumerated below:

Bench scale semi-autogenous grinding tests have been conducted at Aerofall Mills on two types of the Grum ores. One type showed work indices of approximately 5.80 and the other 11.20 indicating a soft ore and a medium hardness ore respectively. It is the opinion of three consultants that these ores could be ground semi-autogenously but that pilot plant tests in a larger grinding mill of at least 6 ft. diam. would be mandatory to obtain adequate data for scale-up purposes.

Such a pilot plant test would consume a minimum of 30 tons of minus 12 inch ore for the autogenous analyses alone. While flotation could and should proceed simultaneously, the metallurgy is so complex that a minimum of 50 tons would be required - FOR ONE ORE TYPE. As demonstrated to date, there will be at least six types of ore and therefore it is quite conceivable that at least 300 tons of ore would be required to obtain adequate data for meaningful predictions.

Fully autogenous ore grinding means grinding ore with ore and due to the extreme variations in hardness in the Grum orebody, it could be predicted that there would be periods when no hard ore could be delivered from the open pit and hence, there would be no grinding media and therefore no grinding.

The first alternate route to this is semi-autogenous grinding which means grinding with coarse ore lumps plus steel media (2 to 10% by volume). The consumption of steel grinding media in these primary mills is at least 0.5 to 1.0 lbs./ton and frequently is over 1.0 lb/ton. The operators of primary semi-autogenous mills must feed the mills at the ore feed rate which the mill will take to minimize liner maintenance. Therefore, with an ore such as the Grum with a minimum differential in hardness of 2:1 the tonnage rate would vary at least in the same proportion.

These probable variations have two serious implications for the Grum operation. Twice the equipment capacity in all units from flotation feed to concentrate dispatch or tailing disposal would have to be provided at appreciable capital cost. The most serious feature would be the effect on metallurgy because the ore is very sensitive to any changes - quantity of ore and reagents including water - and therefore a very stable operation will be essential.

When one hears the term autogenous grinding, one might expect that little or no steel media would be required. With the Grum ores, this will not be the case. The primary semi-autogenous mill might be feasible but the subsequent finer grinding steps require grinding media (pebbles) which can be produced in the primary unit or in the crushing plant. With steel in the primary unit, the main source of pebbles will be the crushing plant. This means more complex crushing plant design and the quantity of pebbles is dependent on the competency and the hardness of the ore.

It might be possible to obtain adequate pebbles frequently for secondary grinding but even if the quantity and size were available for tertiary and regrinding steps, the quality (specifically as to unit weight) would not be suitable. Therefore, regardless of other advantages earlier in the flowsheet, finer grinding can only be accomplished with steel media. Consumption of steel in these areas might be 2 to 4 lbs. per ton milled.

The presence of abraded iron from media which enters the slurry can have a beneficial or a detrimental effect on metallurgy. The current pilot plant program with steel produces assessable results which would not necessarily compare with those from autogenous tests and therefore the pilot plant metallurgy would have to be re-tested.

It is guesstimated at this point in time that the capital costs for a conventional grinding system vs. an autogenous system would not be significantly different. The autogenous units are appreciably larger for the same horse-power input. Since it is also probable that the power costs will be similar and since the overall grinding steel consumption will be between 2 and 5 pounds per ton with autogenous grinding, the operating cost advantages of autogenous grinding may not be as appreciable as one would hope. ?

Aeration or Conditioning

Laboratory investigations had given some indication that aeration might be beneficial to lead flotation. This could not be confirmed in the pilot plant. Furthermore, careful readings were taken (by Noranda Research) of the oxygen demand of circuit feeds. The oxygen demands with Grum ore were significantly lower than those for other sulphide ores treated in concentrators of the Noranda Group. It has therefore been decided to delete aerators from the mill design.

.../9

December 8, 1977

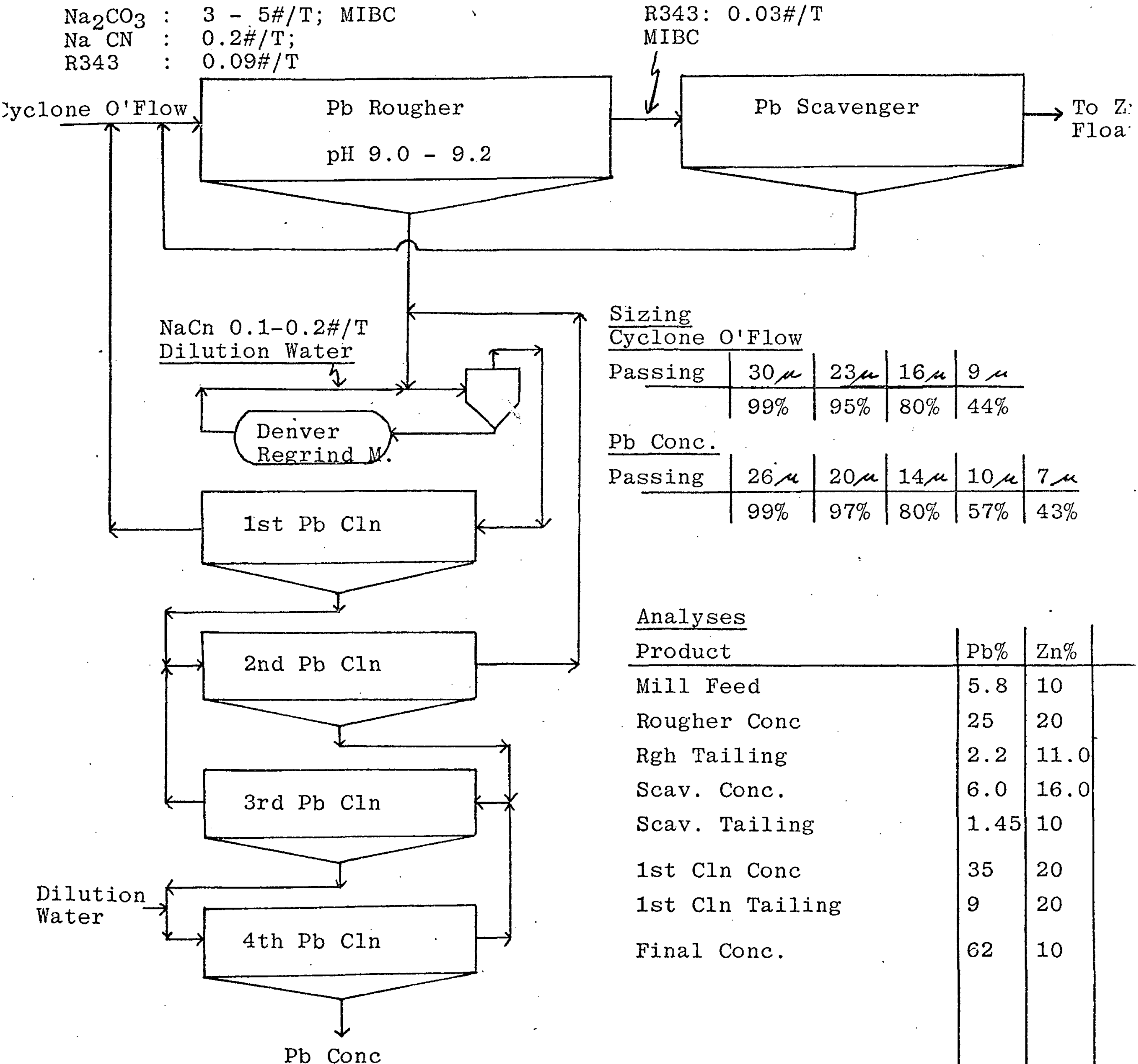
Grum Flowsheet 2

Pilot Plant Testing

Lead Circuit

Reagents added to Grinding Circuit

Na_2CO_3 : 3 - 5#/T; MIBC
Na CN : 0.2#/T;
R343 : 0.09#/T



Sizing
Cyclone O'Flow

Passing	30 μ	23 μ	16 μ	9 μ
	99%	95%	80%	44%

Pb Conc.

Passing	26 μ	20 μ	14 μ	10 μ	7 μ
	99%	97%	80%	57%	43%

Analyses

Product	Pb%	Zn%
Mill Feed	5.8	10
Rougher Conc	25	20
Rgh Tailing	2.2	11.0
Scav. Conc.	6.0	16.0
Scav. Tailing	1.45	10
1st Cln Conc	35	20
1st Cln Tailing	9	20
Final Conc.	62	10

FLOWSHEET 2

Flotation

The following remarks are based on observation of operations with the pilot plant composite. The comments do not necessarily apply to all other ore types, several of which should be easier to treat than the above.

The approach to flotation in the Grum concentrator will be dictated by the very fine intergrowth of base metals, iron sulphides and silicates. The lead rougher and the subsequent zinc rougher flotation stages are in reality two successive bulk flotations. In the "lead rougher" flotation lead-zinc and lead-zinc-pyrite middling predominate over free lead particles. Therefore, a very low grade rougher concentrate is produced. (See flowsheet #2.)

Similarly, acceptable recoveries in zinc rougher flotation can only be attained by floating middlings, and again low grade rougher concentrates have to be produced. (See flowsheet #3.)

Both rougher concentrates can be upgraded to products of good quality but very close control of circuits is mandatory.

Speed of flotation in all circuits is fast. The cell volumes chosen in the preliminary lay-out appear adequate. (3.2 cu. ft. per ton of daily capacity.)

Lead Flotation

The operating conditions are sketched in flowsheet 2 on the opposite page. Close control is required for the following variables:

- Fineness of grind for the lead circuit feed (90 percent passing 200 mesh)
- Regrind cyclone efficiency, pulp level in the pump box feeding cyclones, density.
- Pulp density in all lead cleaners, particularly the final lead cleaner. (It will be below 10 per cent solids.)
- Circulating load between cleaner and rougher circuits.
- Analyses of lead circuit feed
  lead rougher concentrate
  lead scavenger tailings
  lead first cleaner tailings
  final lead concentrate.

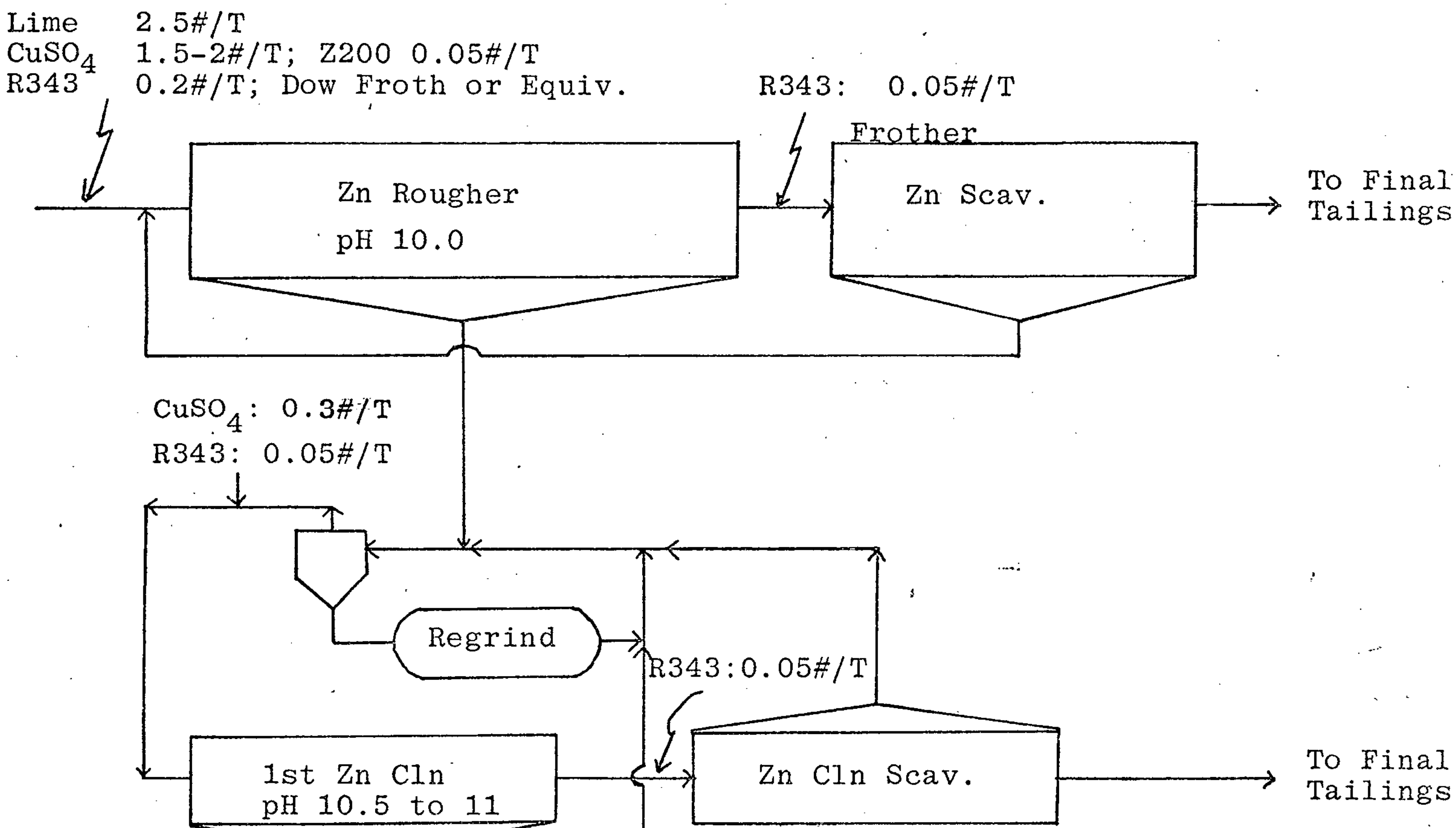
.../10

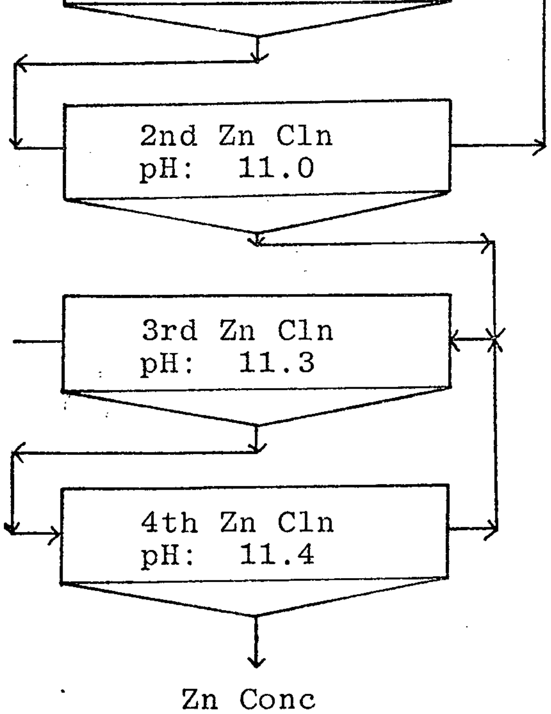
December 11, 1977

Grum Flowsheet 3

Pilot Plant Testing

Zinc Circuit





Fineness or Zn Conc:
85-90% passing 20

Analyses

Product	Pb%	Zn%
Zn Circuit Feed	1.4	10
Zn Rgh Conc	1.5	25
Zn Scav. Tailing	1.2	1.6
Zn Scav. Conc	1.1	3-8
1st Cln Conc	2.5	40-45
Zn Cln Scav. Conc	3	10-15
Zn Cln Scav. Tailings	1	1-1.5
Final Tailings	1.3	1.5
Zn Concentrate	2.3	56

Flowsheet 3

Zinc Flotation

The significant operating parameters are shown in flowsheet 3. Close control is required for:

- pH in the zinc rougher circuit

- pH levels in the zinc cleaner circuit. This control is critical. At pH values above 11.5 zinc minerals become depressed and it appears that prolonged contact with lime alkalinity reduces the floatability of zinc. However, as one would expect, low pH values in the cleaner circuit lead to high circulating loads of pyrite.

- An efficient classification and regrinding circuit is mandatory. Zinc concentrates will have a fineness of 85 - 90 per cent passing 20 micron.

- Analyses of the following circuit flows

  zinc circuit feed (lead scavenger tailings)
  zinc rougher concentrate
  zinc scavenger tailings
  first zinc cleaner tailings
  final zinc concentrate
  final tailings.

Reagent Balance

A great variety of reagents have been tested with Grum ores and some fairly exotic schemes have been tested.

Example: acidification of the lead tailings prior to zinc activation in an attempt to reduce tailings losses. Fortunately, standard reagent combinations produced the best results. Lead flotation requires soda ash alkalinity and cyanide as a zinc depressant. Sodium isopropyl xanthate was the most efficient collector and MIBC the frother. Zinc sulphate produced no benefits. Collectors of the dithiophosphate family were of little value.

Zinc flotation, in lime alkalinity, works well with the same xanthate as lead flotation. There appears some advantage in froth formation from the use of small quantities of Z-200. MIBC appears too weak a frother for zinc flotation, and a stronger frother of the Dow Froth variety will have to be used.

Copper sulphate consumption will be around 1.5 pounds per ton. For reagent quantities, see flowsheets 2 and 3.

Experimental

GRUM TAILINGS POND

Lakefield, Ontario

Oct. - Dec. 1977

Above: The Lined Pond being filled in early November.

Centre: The well for the Recycle Pump.

Below: Snow covered pond during flotation test with recycle water.

Process Control

The operating strategies in the Grum concentrator will have to be very flexible since change in the composition and the characteristics of the mill feed will be great, even with good grade control by the mine. Control on the basis of operator visual inspection and after-the-fact-analysis(2 hours to 24 hours) would fail.

Circuit control has to be designed with all available well-proven instruments, such as:

- pH measurement and control
- particle size determination
- froth level and pulp level control
- density control
- methods for quick analyses, on-stream analysis included.

All instrumentation should be compatible with computer control. Computer control of reagent additions should be aimed for within the early years of operation. Details on instrumentation will be the subject of a separate memo.

Recirculation of Tailings Dam Effluents

pond.

A special tailings dam was constructed at the Lakefield facilities for the Grum pilot plant run - see photographs opposite.

Tailings were collected from the first test run onwards. Effluents were pumped back into the plant by early December and replaced fresh water in test No. 45 on December 2, 1977 and subsequently. Effluents have been used successfully in:
the grinding circuit and lead rougher circuit
the zinc rougher circuit
the zinc cleaner circuit.

They could not be used in the lead cleaner circuit. Uncontrollable foaminess reduced lead concentrate grades to 45% Pb when effluents were added.

In other circuits, the "frothing effect" of effluents was also felt, but it was controllable. It is estimated that 75 per cent of the mill water requirement can be supplied by effluents. A prerequisite for utilization of such high percentage of effluents is aging or retention time in the tailing lake and careful management of the effluent return system.

- Ample storage capacity will have to be provided to avoid sudden changes in effluent characteristics (3 months storage).

- The tailings pond cannot receive waste oils, lubricants or similar foaming agents. Road salt or equivalent.

- Collecting and frothing reagents which dissipate quickly have to be used - for example, MIBC frother - or collectors such as xanthates which are likely to absorb completely onto the surfaces of the pyrite contained in tailings.

When operating with effluents in three circuits, pilot plant results were equal to those obtained with fresh water after appropriate circuit adjustments were made, example:

	Fresh water throughout		Effluent in 3 circuits	
Test No.	#41		#47	
	Pb	Zn	Pb	Zn
Lead Concentrate	62.7	10.4	64.6	9.3
Zinc Concentrate	2.4	57.4	2.2	55.5
Final Tailing	1.2	1.6	1.2	1.5

The tests from #47 onwards were all conducted with effluents in three circuits and conditions remained stable. Forecasts of metallurgical performance in the initial summary assume flotation using recycle waters.

The effluents returned from the Lakefield pond had a surprisingly low thiosalt content of under 50 ppm, their alkalinity remained between a pH value of 8 to 9. Acidification of the tailings pond at Grum may be less likely than had previously been feared.

Dewatering

Lead and zinc concentrates were thickened and filtered at Lakefield for the collection of large samples. In the thickening, the clarity of overflow left much to be desired, no flocculants or lime was used to assist settling. Filtering at Lakefield produced a wet filter cake.

Such observations confirm the validity of equipment selection for thickeners, filters and dryers in the initial lay-outs.

Detailed results on all pilot plant work will be submitted by Lakefield early in 1978.