CONTINUOUS
DIFFERENTIAL FLOTATION
OF COPPER NICKEL IRON
SULPHIDE ORES
OF SUDBURY DISTRICT

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CONTINUOUS DIFFERENTIAL FLOTATION OF THE COPPER NICKEL IRON SULPHIDE ORES OF THE SUDBURY DISTRICT.

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By

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"Continuous Differential Flotation of the Copper, Nickel, Iron, Sulphide Ores of the Sudbury District."

INTRODUCTION.

The Copper Nickel Ore deposits of the Sudbury district, Ontario, are much larger than any other known nickel-bearing ore bodies in the world, and their richness, relatively uniform character and favorable location as regards markets, warrants the conclusion that the Ontario Nickel industry has little to fear from outside competition.

The chief uses of Nickel at present are:-

1. As a component of alloys.
2. As a surface coating for other metals.
3. As a chemical or catalytic agent.
4. As a pure metal.

During the war the demand for nickel was much greater than the supply, due to the fact that nickel steel combines strength and toughness to an extent unequalled by any other available metal, and was thus needed in enormous quantities for battle-ship armor and similar uses.

This demand ceased with the coming of peace, and left the three great Canadian nickel producing companies with such large stocks that operations had to be severely curtailed and prices lowered to an unprofitable figure, and, as the demand for armor plate is likely to remain small, the producers have, for several years, been engaged in intensive research in the hope of developing new uses for nickel and of cheapening its production sufficiently to make it available for industrial use on a far larger scale than heretofore.

The first stage in the existing system of treating the Ontario ores consists in smelting them in the blast furnace, either raw or after a preliminary roasting. This produces a matte running approximately 15% to 18% copper plus nickel.

The matte from the blast furnace is then Bessermerized in a basic lined converter, and the resulting matte contains about 80% of the total copper and nickel of the ore. The further metallurgical treatment need not be discussed.

The blast furnace operation is wasteful and troublesome to the nickel companies, since the finer or dust particles of ore are very hard to treat, and extensive losses result, and an improvement in method or an alternative method of treatment at this point, which would lessen these difficulties and lower the cost would indeed be welcome.

The fact that Flotation has entered other concentrating fields with such great success in the last few years, leads one to hope that it will prove applicable to the troubles of the nickel companies. The question therefore is this. Are the Ontario Nickel Copper Ores amenable to Flotation to such an extent that a concentrate containing, say, 18% copper plus nickel can be secured, thus eliminating the first stage of the present treatment, - that of the blast furnace?

Such a substitute would enormously decrease the cost of smelting, giving a correspondingly lower cost of the pure metal.

No operating costs of the nickel companies could be obtained, but, since copper smelting almost parallels their treatment, a comparison of costs will be made on that basis.

At the smelter of a large copper company in Canada, the blast furnace costs average $2.50 to $2.60 per ton of ore treated, with straight pyritic smelting.

The cost of the coke alone is 55% of this figure, and their coke is secured at a much cheaper rate than it can be acquired by the nickel companies, due to their higher freight expense. The charges on coke delivered at the Ontario smelters probably amount to $8.00 per ton.

A safe figure for flotation would be $1.25 per ton, and with several large companies the actual cost is far below this price.

Hence, the saving effected; if flotation could be applied to the nickel ores would amount to $1.25 per ton or equal to the cost of the coke in the blast furnace operation. This calculation does not include the difference in cost of coke for the two smelters.

Under present conditions of restricted output, there is little incentive to employ concentration methods for the nickel copper ores of Sudbury. Only high grade ores are treated at the present time and these require little but hand sorting. Lean ores are left in the mines, but, as the cost of obtaining them is small, they could probably stand the additional expense of flotation. At some future date, when the lower grades of ore are reached, the interested companies will, no doubt, turn more seriously to flotation as a means of treatment.

A positive gain of this kind would be as beneficial as an improvement in metallurgical processes for the prevention of actual smelting and refining losses, and is quite in keeping with the tendency of modern metallurgical methods.

This paper involves a discussion of flotation experiments carried out on the copper nickel ores of Sudbury in the laboratory of McGill University with such an end in view, - the elimination of the blast furnace and the substitution of flotation treatment.

Part II.

1. Historical Summary of Flotation Development.

2. Theoretical Considerations.

I. Historical Summary of Flotation Development.

The most ancient method used for separating sulphides from gangue, was to crush the ore to a suitable degree of fineness in order to free the sulphide particles from the adhering waste material. The crushed mass was then subjected to mechanical operations to separate sulphide from gangue, and the values were recovered by smelting operations. This method was in use for hundreds of years.

An advance in the treatment of certain ores made use of their magnetic qualities.

Both of these methods had limitations in usefulness and served as a constant spur to metallurgists towards perfecting new processes of treatment.

The knowledge that substances heavier than water would, under suitable conditions, float on its surface was not at all new. It was also known that some heavy substances would float on the surface of water with more certainty than others. The principles involved in this fact formed the basis of a third method of separating mineral sulphides from gangue as soon as it was recognized that the sulphides would float with greater ease than gangue. From that time on, the word flotation was used to designate the art and practice of separating gangue and mineral by floating one away from the other, and its greatest application is in the separation of sulphide minerals from the waste material.

The actual history of the development of flotation step by step is not of great immediate interest.

The process developed from the affinity of oils and fatty substances for metals and metallic minerals.

The first record of any attempt to float minerals was in the year 1860 in England, and since that time the practice has advanced with increasing success, and ideas on the principles of flotation have changed several times.

At first, oil alone was used, then air bubbles were introduced, followed later by agitation. Thus the modern methods were gradually evolved more by experimentation than by any scientific aid, and it was only after Flotation was an acknowledged and commercial success that theories were advanced which seemed to give legitimate clues to the phenomena.

If, in one patent, namely the Everson, the agitation had been continued longer or had been a little more violent, together with a slight reduction in the amount of oil used, froth flotation would have been discovered in 1885, giving proof of the experimental advance of the process.

II. General Outline of Theoretical Considerations.

It has been deemed advisable to make this paper as complete in itself as possible, within reasonable limits, and since the word flotation, and its practice, is discussed freely throughout, a concise resume of the generally accepted theory without any great detail, might prove appropriate.

The paper of H. Livingstone Sulman and the thesis of W. Erlenborn are used freely in the following discussion.

Surface Tension. -

The most important phenomenon on which the flotation process is based and which therefore demands the closest study is that of surface tension.

The presence of a force on the surface of a liquid can be clearly demonstrated by such experiments as floating a needle on water or by sprinkling finely ground particles of a sulphide mineral on the surface of water. The fine particles remain on the surface.

In both instances the solids involved are of greater specific gravity than water, thus showing that the force or surface tension of the liquid is of real and perceptible consequence.

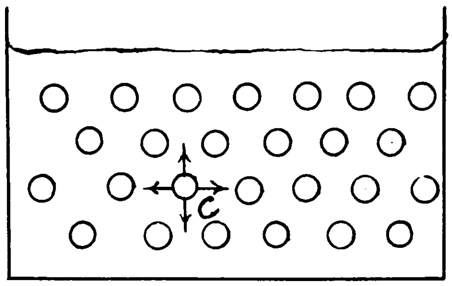
Kinetic Molecular Hypothesis. -

The generally accepted theory of surface tension is based on the Kinetic Molecular Hypothesis which states, "That gases, liquids and solids are made up of physically indivisible particles called molecules separated from one another by distances which are comparatively small in solids, somewhat larger in liquids, and very large in gases, depending on the conditions under which they exist. All are in rapid motion, increasing or decreasing with rise or fall of temperature.

Practical flotation deals mainly with liquids. In these the mean free path of the molecule is very small, probably not more than the diameter of a molecule, but at the same time they are able to move freely amongst each other, giving the fluid its mobile qualities.

These molecules have a mutual attraction for one another which is very intense but is manifested over very small distances only.

The attractive forces exerted in the interior of a liquid on a molecule, by its neighbors, are therefore without a permanent resultant which would tend to move it in any direction.



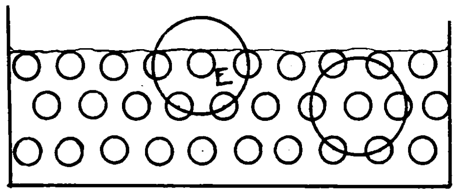
Referring to the above figure the forces attracting the molecule "C" can be resolved into six general directions - four in the plane of the paper and two at right angles to this plane. These forces are perfectly balanced, assuming of course that the molecule is in the interior of the liquid.

Cohesion. -

If an imaginary plane is traced through the body of a liquid, the molecules immediately on one side of the plane will attract those immediately on the other side, with the same force as they attract their neighbors. This attraction which they mutually exert across the imaginary plane is called COHESION.

Surface Energy. -

The above molecule was taken in the body of the liquid. Now, if it is assumed in the surface layer, the thickness of which depends on the distance over which the molecular attraction manifests itself, there is a permanent resultant force attracting the molecule toward the interior.



Referring to the above figure let "E" be a molecule in a layer near the surface and let the circle represent its radius of molecular attraction.

The molecule "E" will attract all other molecules within this range. But its radius of attraction cuts the surface at "ST".

Hence above the surface "ST" there are no more molecules to attract "E". The force, therefore, is unbalanced in this direction by an amount equal to the shaded portion "LM" of the circle, producing a downward resultant tending to draw "E" towards the interior. If we take another molecule a little further from the surface the unbalanced resultant will be less, hence surface tension is not entirely concentrated at the surface but grades off towards the interior.

The foregoing is the simplest possible statement of the molecular theory accounting for surface energy.

Interfacial tension. -

Total surface energy is only manifested in a vacuum. In all practical work the water surface is in contact with air and very often with solids, other liquids and gases. Thus there are other molecules near the surface, or at the surface, which may or may not have attraction for the molecules of the liquid. This will influence the surface tension. If there is attraction between the foreign substance and the liquid, strain is decreased, if repulsion an increase of strain.

Hence the practical surface tension depends on the nature of the substance or substances with which it is in contact, and this is known as "Interfacial tension."

Wetting. -

It was an early discovery in flotation that minerals which could be floated were not wetted by the liquid to any considerable extent.

To make this point of wetting clearer, - A piece of glass is heated in a flame so that the surface is absolutely clean. Now let us dip the glass into water. On withdrawing, it is observed that the water adheres closely to every part of the submerged surface, or in other words the glass is "wetted" by the water. If now a thin film of grease is smeared on the glass and the operation repeated, wetting will not take place. This phenomenon is explained by Interfacial tension.

If a foreign body is suspended in a liquid, there is an area of strain surrounding that body, because at the contact there are no molecules to satisfy the forces of attraction of the molecules of the liquid, except those of the solid.

If the molecular forces of the solid are such that their unbalanced resultant will tend to relieve the strain of the liquid at the contact then the liquid will be attracted toward the solid or in other words will wet it. But, if there should be an increase in the strained area due to the contact of the two substances then the liquid will be repelled.

Now, in the latter case, if a gas is present whose contact with the solid in preference to the liquid would tend to relieve this increase of strain, then the gas will replace the liquid at the contact with solid.

Those minerals which are not wetted by water show a great adhesion or attraction for oils, indicating again a reduction of the forces at work at the surface of either sulphide or oil.

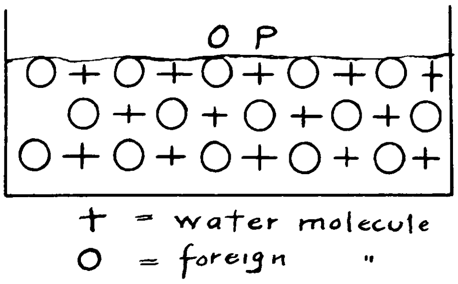
Certain conclusions can be drawn from the above discussion.

Every substance shows a preference for certain other substances. Under ordinary circumstances, sulphides, metals, and certain elements, show a preference in their contact with oil and air over that with water. Under favorable conditions, therefore, air and oil will replace water at their surfaces. Also, water will replace air and oil at the surface of gangue minerals such as quartz, calcite, etc.

The theory of surface tension in the discussion so far has dealt solely with pure liquids. There are several factors which may change the surface energy. A change in temperature of the liquid will cause a corresponding difference in the surface tension, and it is found that it varies inversely as the temperature. If the temperature of a liquid is raised the surface tension is decreased.

Adsorption. -

But the factor affecting the greatest change, is known as Adsorption. This brings forward the discussion of solutions, or a liquid in which foreign molecules are present.



As previously explained, there is a tendency at the free surface, for the molecules of the liquid to be pulled to the interior. Consider the two molecules "O" and "P". Let the attraction between "O" and a water molecule "P" be less than the attraction between two water molecules; hence, there is a greater force in the interiof of the liquid pulling "P" molecules down, than there is on "O". Therefore "O" will be virtually pushed to the surface. Such foreign molecules will concentrate at the surface of the liquid, and this is known as positive adsorption.

As less work is done in bringing the molecule "O" to the surface than upon a water molecule, it will there possess less energy; and, since the foreign molecules displace those of water, the presence of the former in a surface layer will diminish its total surface energy, i.e. its tension.

Hence, it is seen that positive adsorption of a foreign substance in a liquid will lower the surface tension of that liquid, a most important phenomenon in flotation work.

Negative adsorption occurs when the foreign molecule has a greater attraction for the molecules of the liquid than these have with each other, and we have the reverse effect. Few foreign particles will remain in the surface layer and most will concentrate in the interior of the liquid. Negative adsorption increases surface tension.

What is true for molecules applies to groups of molecules or small particles, and it is found that finely ground ore tends to be positively or negatively adsorbed.

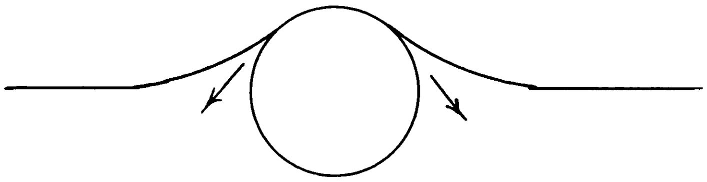
Stability of froths. -

Positive adsorption finds its greatest use in stabilizing a froth.

It is a well known fact that a pure liquid will not produce or sustain a froth. If bubbles of air are introduced into a pure liquid they immediately break on reaching the surface.

Let an air bubble be immersed in a pure liquid. A strained layer is formed around the bubble and when it rises to the surface this strained area is carried along. When the bubble emerges, it does so under a definite set of conditions. There is a force acting towards the centre of the bubble produced by the surface tension of the liquid around the bubble. This is opposed and balanced by the pressure due to the air expansion in the bubble. But when it emerges this equilibrium is upset due to external conditions and the bubble breaks because there is no latitude within which the forces can adjust themselves.

Now if an air bubble is introduced into a solution in which a substance is positively adsorbed, it carries the area of strain surrounding it, to the surface as in the case of the pure liquid, but at the surface a different set of conditions exist. As the bubble tends to expand it pushes up the surface layer as shown in the diagram.



The force of gravity drains away the liquid between the two films, thus draining away foreign molecules which were concentrated there, and increasing the tension on the bubble, keeping it from expanding to the breaking point.

If the opposite effect exists, i.e. external conditions are such that the bubble tends to be compressed on emerging, there is a greater concentration of foreign molecules due to the contraction of the bubble, decreasing the strain. Hence, there is a variable limit between which the energies of the bubble can adjust itself. On one side is the surface tension of the liquid if no foreign molecules were at the surface, and on the other side that tension existing if all foreign molecules were concentrated at the surface. If the bubble can adjust itself between these two limits it will persist, and a multitude of bubbles would form a stable froth holding at the surface any particles to which they were attached.

The foreign substance capable of adsorption necessary for the production of a stable froth need not always be dissolved in the liquid. Small solid particles may be adsorbed at a surface with the consequent reduction of surface tension.

So far, the conditions necessary for flotation of a mineral have been discussed. To summarize these, we must have -

(1) A mineral that does not tend to be wetted by water.

(2) The introduction of air to float these minerals to the surface.

(3) A substance present which will be positively adsorbed, thus stabilizing the froth.

Most sulphides come under the first essential. Air is easily introduced mechanically giving the necessary bubbles and also increasing the capacity of a machine due to the greater liquid-air surface produced.

The substance used for the third essential is oil.

Oils. -

Every oil consists to a greater or less degree of a soluble portion and an insoluble portion.

The soluble portion of an oil is positively adsorbed, stabilizing the froth. The insoluble portion has two uses. A small part coats the bubble film and the remainder coats the sulphides, further increasing their tendency not to be wetted, and since oil molecules have a great attraction for one another the bubble of air and the sulphide will be drawn together with a greater force than if each were unoiled.

Oils are divided into two general classes:-

1. Those obtained from the distillation of various hard and soft woods.
2. Those obtained from the distillation of coal.

Pine and eucalyptus oils are examples of the first class. These constitute the soluble oils.

As examples of the second class we have coal tar and coal tar products, which are almost completely insoluble oils.

In commercial practice these two types of oils are mixed in varying proportions.

Flotation Reagents. -

Air is undoubtedly the prime factor in froth flotation. Various reagents assisting the air in its work are, - oils, organic salts and acids, inorganic salts and acids, and electrolytes.

Oils have been already dealt with. It might be added here that the soluble portion is the "frother", and the insoluble portion the "collector".

With respect to the other reagents mentioned, their use is determined by experimentation.

The principal reagents used are - Sulphuric acid, Caustic Soda, Sodium Carbonate, Lime, Sodium Sulphide, Sodium Silicate and Copper Sulphate. Their effect on the ore pulp is either physical or chemical, depending primarily on the type of ore.

Colloids. -

In general, the presence of colloids in an ore pulp have proven detrimental to flotation.

One of the factors affecting surface tension is the size and character of the mineral particle. If the ore is ground so fine that a portion enters the colloidal state, i.e., a very fine suspension in the solution, an enormous surface of ore particles is exposed to the water.

Surface energy is the product of surface tension and area, and colloids, because of their enormous proportion of surface area, would probably have a greater effect on the surface quilibrium than any other substances present. The soluble particles and the oil would be adsorbed on the colloid surfaces, and retained, preventing them from aiding the flotation of sulphide particles.

PART III.

Commercial Aspects of Flotation.

1. Position of Flotation in Ore Dressing.
2. Requirements for Flotation.
3. Flotation Machines.
4. Differential Flotation.
5. Application of Flotation to Ores Other Than Sulphides.
6. Handling of Froth Concentrate.

With the basic principles and fundamental ideas in mind the commercial applications of the process may be more clearly understood.

1. Position of Flotation in Ore Dressing.

Water concentration is eminently satisfactory in the treatment of ore containing relatively coarse and granular material and a light gangue.

Chemical treatment is equally satisfactory when the valuable mineral crushes to powder and + is soluble when the gangue is not soluble.

Between these two, lies the field for flotation, this method of concentration being effective both in the presence of a heavy gangue and with fine mineral.

The modern mill flow-sheet brings flotation into use in varying degrees, giving:-

1. All-flotation treatment.
2. Primary flotation with secondary water concentration.
3. Primary water concentration with secondary flotation.
4. Primary water concentration; secondary flotation; final water concentration.

All flotation is practised only where water concentration is impossible. Such an ore would have a heavy gangue or flaky minerals. Possibly the treatment of sand and slime would come under this type.

As a general rule flotation with water concentration is used in most plants and the sequence of the two is determined by the type of ore.

Flotation has its limits in the size and types of ore it can treat and probably will never displace water concentration or chemical methods entirely.

It is not effective on material coarser than 40 mesh and is not very satisfactory for material which approaches the colloidal size.

*Types of Commercial Processes.

In considering processes which have been commercially applied, four main types are noticed:-

1. Oil-flotation, such as the Elmore Bulk oil process.
2. Gas-froth flotation, exemplified by the Potter-Delprat process.
3. Film or skin flotation, such as the McQuisten tube.
4. Air froth flotation, M.S. and Elmore vacuum.

Mill practice today deals wholly with air-froth flotation.

2. Requirements for Flotation.

Mineral froth flotation is carried into effect by the following series of operations.

1. Reduction of the material to the necessary small size and the preparation of the aqueous pulp.

Flotation is not successful on particles larger than about 40 mesh, and in particular is good for the recovery of material which must had been be ground to 80 - 120 mesh for their its release from gangue.

Flotation also requires a definite mobility of the particles in the aqueous pulp in which they are born,e experience indicating that with sandy material a liquid solid ratio of 3.5 : 1 and with slime a ratio of 7 : 1 are suitable dilutions.

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*Truscott's Text-Book of Ore Dressing.

2. Mixing with the contaminating agents.
3. Introduction and sub-division of the air.
4. Collection and handling of the resultant froth.

3. Flotation machines.

The apparatus in which air is introduced and sub-divided and the mineral laden froth is formed and collected, is the flotation machine.

Mixing with contaminants takes place either in this machine, or previously in a separate apparatus.

There are three main types of flotation machines -

The first, that in which mixing and aeration take place together and by means of a fast revolving impeller; these being known as mechanical machines.

The second, in which the fine division of the air is accomplished by forcing air through a porous bottom, the mixing having taken place previously in a separate vessel; these being pneumatic machines.

Thirdly, a machine in which, after separate mixing, aeration takes place by the entrainment of air as the pulp falls from one separating vessel to another; these being Cascade machines.

Mechanical machines. -

This type is the most widely applied of the three described above, and was also the first type introduced, the most common example being the Minerals Separation (M.S.) standard machine. A discussion of this machine will be omitted here since it is described later in this paper. The commercial machines have an agitation box 18" - 42" square and 24" - 60" in height and having in front a frothing chamber rectangular in plan but triangular in side elevation. The impeller is 12" - 14" in diameter and is rotated at 250 - 350 revolutions per minute, or an average peripheral speed of 1500 feet. A machine of 15 cells will treat about 400 tons per day.

In the Minerals-Separation sub-aeration cell the agitation box is, itself, in its upper portions, the frothing chamber, the necessary quiet conditions being secured by introducing the air through a pipe far below.

Another mechanical machine, the Janney, has a frothing chamber on either side of a central agitation compartment wherein two impellers on the sane spindle are directly driven by a motor above sucking pulp equally from the bottoms of the two frothing chambers and throwing it into them again from the top.

Other mechanical machines are modifications of these types, and we have such cells as the Ruth, Groch, K & K machine, and Rork, the last two named being horizontal shaft machines as opposed to the vertical shafts of the other types.

Pneumatic machines. -

The principal type of this class is the Callow cell, which consists of a rectangular box about 2' wide and 8' long with a sloping bottom, the depth being about 20" at one end and 45" at the other. This sloping bottom is not solid but of a porous material, generally of closely stitched canvas held between wire netting. This porous bottom is the cover to an air box into which a blower delivers air at about 5 pounds pressure. In consequence of greater depth, the hydraulic head under which the air issues at the deep end is greater than at the shallow end. To equalize the flow of the air under these conditions, the air box is divided into compartments, each separately served from the air main, the amount of air passing into each being regulated by a separate valve. The shallow end of the box is the feed end; upon entry the feed is directed downward to the air mat by a baffle, passing below which it meets the flood of rising bubbles, the sulphides attaching themselves and rising to form a voluminous froth, the gangue particles continuing down the slope to pass out at the deep end through an automatically controlled discharge. The froth so formed, building itself up from below, eventually overflows, a discharge lip running the greater portion of one side, falling into a launder.

In this machine the water level and depth of froth are matters of more than ordinary moment. The bubbles which rise to the underside of the froth always carry some gangue; being relatively weak and brittle many break, but the rate of arrival being greater than the rate of breakage the froth as a whole rises. At each break, a load is shed, the mineral particles attaching themselves to other bubbles and rising again, the gangue particles losing hold. Accordingly the higher the bubble, the cleaner the load.

The capacity of the machine described would be about 50 tons per day.

The Inspiration machine consists of the division of the pneumatic machine into many separate cells.

Cascade Machines. -

Cascade machines make use of the power of a moving stream or jet of one fluid, to carry forward by friction an amount of a surrounding fluid. Thus a stream or jet of water entering quiet water takes air with it, introducing and distributing this air by virtue of its kinetic energy.

Comparison of Machines.

Flotation machines must secure the following conditions to operate successfully.

1. Mechanical emulsification of the insoluble contaminant if any be used.
2. Distribution of the soluble contaminant.
3. Entry and minute sub-division of the air.
4. Contact between the contaminated mineral particles and minute air bubbles.
5. Ready flotation of the loaded bubbles and quiet formation of froth.

With respect to these conditions, the mechanical machines secure the complete emulsification of the insoluble contaminant, bringing into solution at the same time any soluble fraction associated with it; they also attribute the soluble contaminant rapidly.

The minute division of air is accomplished perfectly and the violent agitation multiplies also the opportunities for the essential contact of mineral and air bubble, hence the bubble efficiency is high. With the sub-aeration type, the supply of air is more abundant, the froth in consequence more voluminous, and the bubble efficiency lower.

With contaminants suitable to each of the above types, the standard machine taking in air at the top produces a less voluminous but stronger froth capable of retaining relatively large and heavy particles, while the sub-aeration type produces a froth which in abundance and frailty is more suited to a fine material.

With pneumatic machines, aeration takes place after previous mixing in some pneumatic apparatus such as a Pachuca tank which is unequal to the adequate emulsification of thick insoluble contaminants. The froth is voluminous and frail in character, hence favours the flotation of fine mineral.

Compared with the two previous types, Cascade machines are gentle in operation and are only equal to raising mineral which is readily floatable.

4. Differential Flotation.

Differential flotation takes advantage of the different floatabilities of minerals, floating one mineral ahead of another and subsequently floating the second mineral. Differential work differs little from ordinary "Collective" flotation except that the differences in flotation are finer, and the operation more delicate.

Differential flotation may be applied either to an undressed ore pulp or to a collective concentrate obtained from a previous flotation and may be secured in two ways, -

By (1) Normal Differential flotation.

(2) Inverted Differential flotation.

Normal Differential Flotation.

The idea of floating sulphides successively in the order of their floatability was first used at Broken Hill in 1913.

Galena and sphalerite have been floated differentially in the Coeur d'Alene district by using a small amount of effervescing agent to float the galena, and then in another machine a selective agent and copper sulphate to raise the sphalerite.

Differential flotation effects the separation of chalopyrite from pyrite and pyrrhotite.

Water concentration is not of much use in separating these three minerals since their specific gravities are very near one another.

Inverted Differential Flotation.

Differential flotation is also possible by so altering the surface of the more floatable sulphide that it, and not the less floatable sulphide, will sink. Such a reversal of normal procedure may be brought about either by (1) fractional roasting, or (2) fractional hydro-chemical action.

Fractional roasting is the basis of the Horwood process which makes use of the fact that some sulphides are more readily oxidized by roasting than others. Galena can be roasted more readily than sphalerite.

The great bulk of the lead when roasted is changed to lead sulphate, the zinc remaining unaltered.

The roasted mass after cooling is treated in flotation cells, the sulphatized galena sinking.

In general the fractional roasting processes depend upon very careful roasting and cooling in which the temperature range and the rate of feed are all important factors.

With respect to hydro-chemical differential processes, it has been shown that ferric chloride in solution, and under conditions which left the blende unaffected, was capable of so altering galena that subsequently it would sink while the blende floated. The idea has never been commercially applied.

It has been proposed to deaden galena in the presence of sphalerite by digesting at a temperature of about 140° F. with a 0.2% or 0.5% solution of Potassium Dichromate, a chemical which will also deaden pyrite to make it separable from copper pyrite.

The cost of chemicals prevents the commercial adoption of these chemical differential processes.

5. Application of Flotation to Ore Other Than Sulphides.

Oxidized Ore.

Ores in this class are copper silicate, copper carbonate, lead carbonate, cassiterite, etc.

Oxidized ores have never been readily floated, and in most cases they will not float. Research has been carried out to some extent on these ores and it was found that by "sulphidizing" the surfaces to a degree approaching their original sulphide state, they could be floated more or less easily.

This was accomplished by using Hydrogen sulphide as a sulphidizing agent and was quite successful in procuring a good grade of concentrate with good extraction, but the use of H_2S was unpleasant and dangerous.

Sodium Sulphide was used as a substitute for H_2S and has been commercially applied at Bisbee, Arizona, in the treatment of Lead Carbonate.

Gold Ores.

The Minerals Separation Co. have investigated the feasibility of applying flotation in the treatment of gold on the Rand in South Africa. They have demonstrated the efficiency of the process with ordinary milling conditions and the ore ground through an 80 mesh screen, and treated in a 4 : 1 pulp. Special reagents were necessary. (Min. Journal, Jan. 21, 1922)

Coal.

Flotation has been used to separate ash from low grade coals. A number of tests were carried out, resulting in the following conclusions.

1. Coal slime does not concentrate well and the process is limited to the treatment of more granular material.
2. Pure coal is easily floated.
3. Cleaner flotation is obtained when coal is in angular fragments.
4. In the grading of coal into clean coal, bone, bituminous shale, and free ash, careful control and the use of differential methods is necessary. (Chem. & Metall. Eng. 1922)

6. Handling of Froth Concentrate.

The froth as it overflows from the flotation machines is sticky and voluminous, and either brittle or tough, depending on the type of flotation cell.

Water jets playing on the launders serve to break up the froth as well as carry it away.

Since smelters penalize concentrates which contain much moisture (more than 10%) it must be dewatered. This is accomplished by intermittent settling and decantation, or thickening followed by filtration.

Intermittent settling is carried out in large tanks where the concentrate is allowed to settle for some length of time.

Continuous settlement is accomplished by Dorr Thickeners which bring the settled material to the discharge as fast as it settles.

Filtration is effected by such mechanical appliances as the Oliver, American and Portland filters.

PART IV.

1. The Ore.
    (a) Microscopic Examination.
2. M.S. 10-Cell Continuous Machine.
3. Accessory Laboratory Apparatus.
4. Chemical Analysis.
5. Discussion of Experimental Work.
6. Conclusion.

1. The Ore.

The ore used in the experimental work came from the Worthington Mine, in Ontario, and was very raw in metal contents, averaging approximately 1½% Copper, 1% Nickel and 15% Iron.

The ore minerals are chalcopyrite, pentlandite, pyrrhotite and pyrite with norite as the gangue. Chalcopyrite is the copper bearing sulphide, containing 34.5% Cu. Pentlandite is the nickel sulphide containing 22% Ni., and pyrite and pyrrhotite are the iron sulphides.

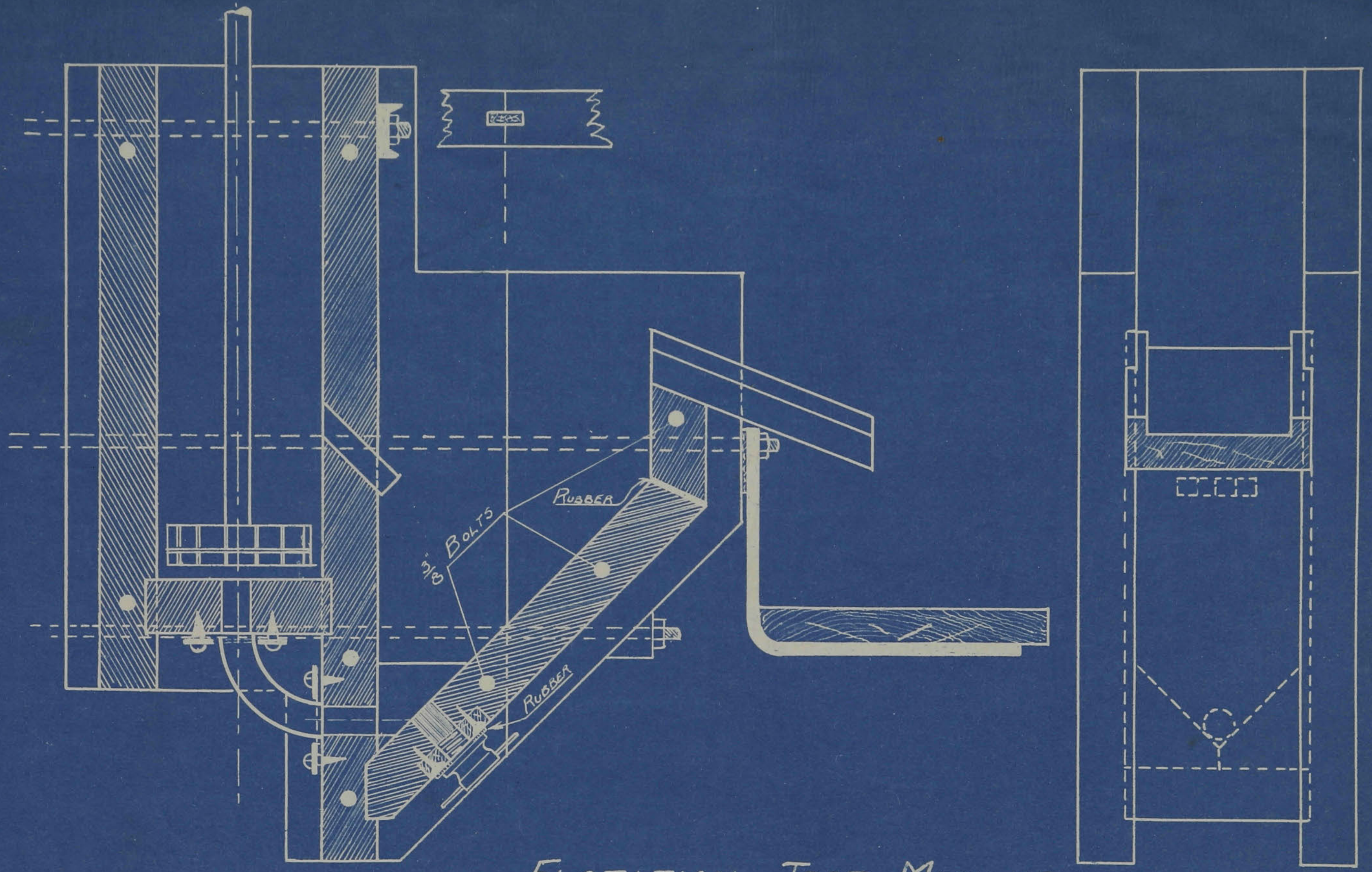
The character of the ore may be described as more or less rocky, being always accompanied by fragments consisting of norite, greenstone, quartzite and granite. Hand sorting of the ore eliminates a great deal of this waste material.

1. (a) Microscopic Examination. -

A study of thin sections of the ore showed that the sulphide minerals were scattered throughout the norite. Pyrite and pyrrhotite were nearly always in contact and the chalcopyrite was always associated with more or less pyrrhotite.

The ore was low in grade hence the chalcopyrite was scarce and the pentlandite even more so. In fact, only one piece of the nickel sulphide was spotted and it was in association with pyrrhatite.

It was noticed that the sulphides and the norite were not so intimately mixed that grinding would not separate them. The rock did not penetrate all through the ore minerals, which would

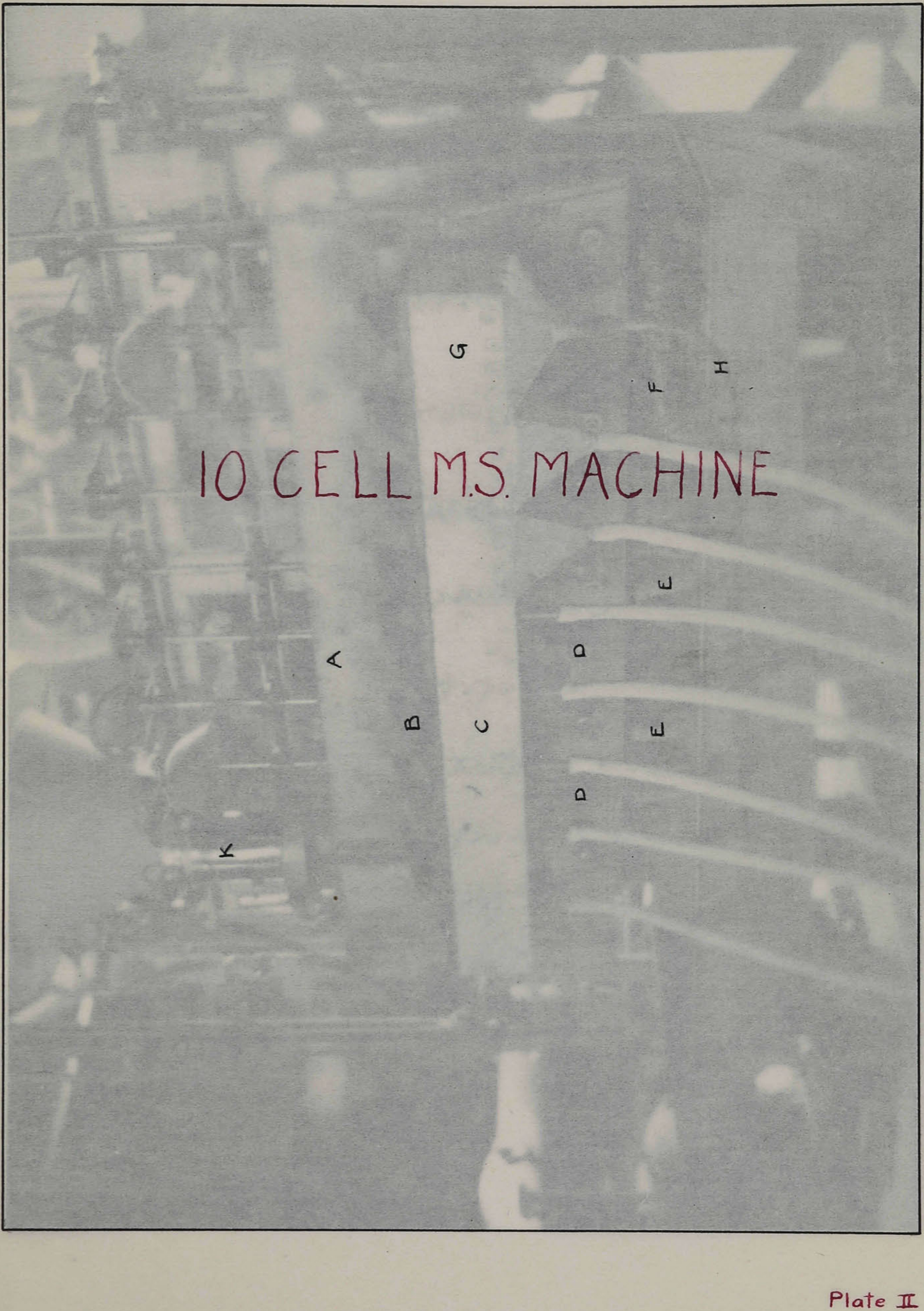


FLOTATION TEST MACHINE

MINERALS SEPARATION TYPE

ORE DRESSING LAB McGILL UNIVERSITY.

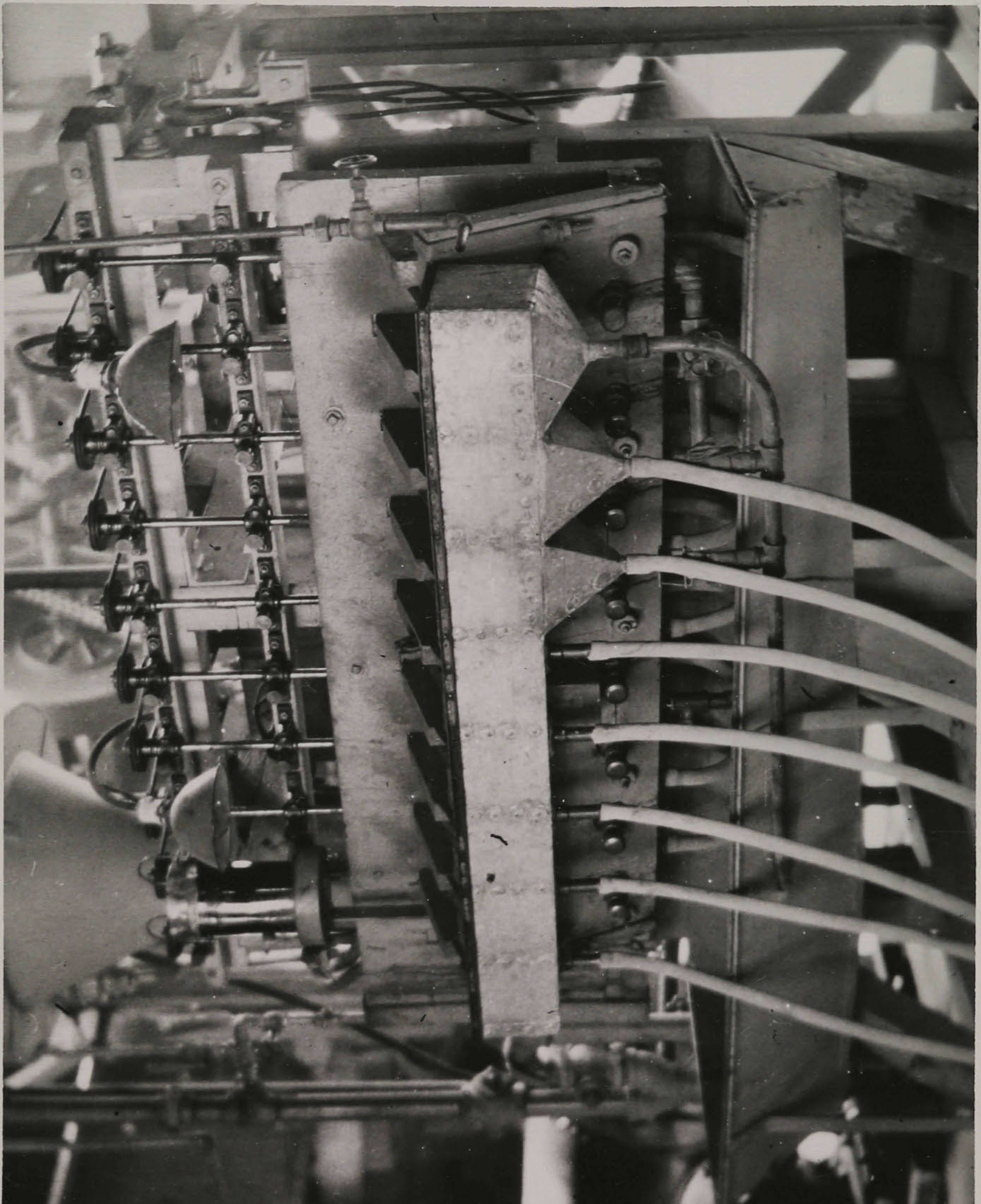
Scale - 3in. = 1 Foot.



10 CELL M.S. MACHINE

Plate II

P. 33



render very fine grading necessary for their separation, but rather, each was separate from the other and it was estimated that by grinding the ore through 60 mesh most of the sulphide would be separated from the gangue. From this knowledge a 60 mesh screen was used in the Huntingdon Mill.

2. M.S. 10-Cell Machine.

The continuous M.S. machine was built in the laboratory of McGill University. Each cell is of the standard M.S. type, consisting, as shown in the accompanying cross-section (Plate 1), of an agitation box 4½" square and 13½" deep, with a 4" Howard impeller revolving in this box ½" from the bottom. The spitzkasten is built on the front of the agitation chamber, and is 4½" wide at the top and is narrowed in size at the bottom on three sides, the side next to the agitation chamber being vertical.

The discharge from the agitation box to the spitzkasten consists of 3 one-half inch holes bored at an angle of 45° and sloping towards the front of the spitzkasten. These holes are bored close together and in the centre of the chamber.

The bottom of the spitzkasten is 2" lower than the bottom of the agitation box and, in the one cell type, the two are connected by a ¾" lead pipe as shown.

In the one cell machine the impeller revolving at 1000 R.P.M. (approx.) beats air into the ore pulp in the agitation chamber by forming a vortex and cascade effect, in which air is drawn from the surface and entrapped by the liquid. The necessary oil and reagents are added in the agitation chamber.

Due to the centrifugal force caused by the rapidly revolving impeller, the pulp is forced through the slots into the spitzkasten. The slots are bored in a downward direction which allows the bubbles of air with their attached sulphides to rise to a quiet surface where the froth can be skimmed off. Any particles that sink to the bottom of the spitzkasten are drawn into the agitation chamber again through the connecting pipe, by the suction of the impellers, and retreated. Thus there is a continuous circuit of the ore pulp from the agitation box to spitzkasten and return.

In the ten-cell continuous machine the operation is the same as described above, with the exception that the pipe from the bottome of one spitzkasten leads to the bottom of the adjoining agitation box, and so on, causing the pulp to travel from the first box, through each cell to the other end. The discharge from the last spitzkasten constitutes the tailings and is run to waste.

A front view of the laboratory machine is shown in Plate 2. The front wall of the 10 agitation chambers is shown at "A". The impeller driving rods can be seen in their respective agitation chambers.

The spitzkastens shown at "B" are eight in number and jointed to "A". No spitzkastens are affixed to the first two boxes since they are used solely for agitation.

The froth collecting launder "C" is attached to the front of the spitzkasten and is divided into a water-tight compartment for each cell. The froth may be collected from each box by the several hose pipes, or all run into one tub. The last compartment "G" of the launder is connected by pipe "4" to the bottom of the second agitation cell. The last spitzkasten is allowed to overflow and the suction of the impeller in agitation box "2" draws the overflow through "G" and "H" into that chamber. The height of the liquid in "G" regulates the level of the first spitzkasten, and this overflow into "G" is controlled by the tailings valve "F".

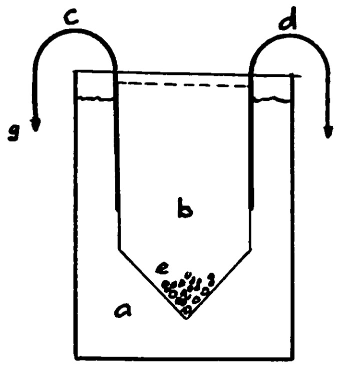
For example, if the froth is low in the first spitzkasten, the level can be raised by shutting off the tailing valve a small amount, and causing more water to overflow in "G". Any pulp that comes over is drawn back to cell "2" and retreated. If desired the product of the last three spitzkastens can be retreated by making the necessary pipe connections.

The continuous feed enters the first agitation cell where the oil is also added from the oil feeder "K". It is drawn by suction to the next chamber where it is further agitated, and in the third cell the first froth is skimmed. The pulp passes on through the machine, being treated in each cell, and the tailings discharged at "F".

The 10-cell machine is 5'4" long, 5' high and 2' wide at the top, increasing to 4' at the bottom. The impellers are driven by a 3 H.P. motor.

3. Accessory apparatus.

1. Oil Feeder.



The oil feeder ("K" in Plate 4) works on the siphon principle. A glass jar (a) holds the oil. A cylinder made of tin and having a conical water tight bottom, floats in the oil. Two tubes (c) and (d) made of small copper tubing are attached to the outside of this cylinder and on opposite sides. Both tubes terminate in needle sized openings. Lead shot or other similar material is placed in the bottom of cylinder to weight it down.

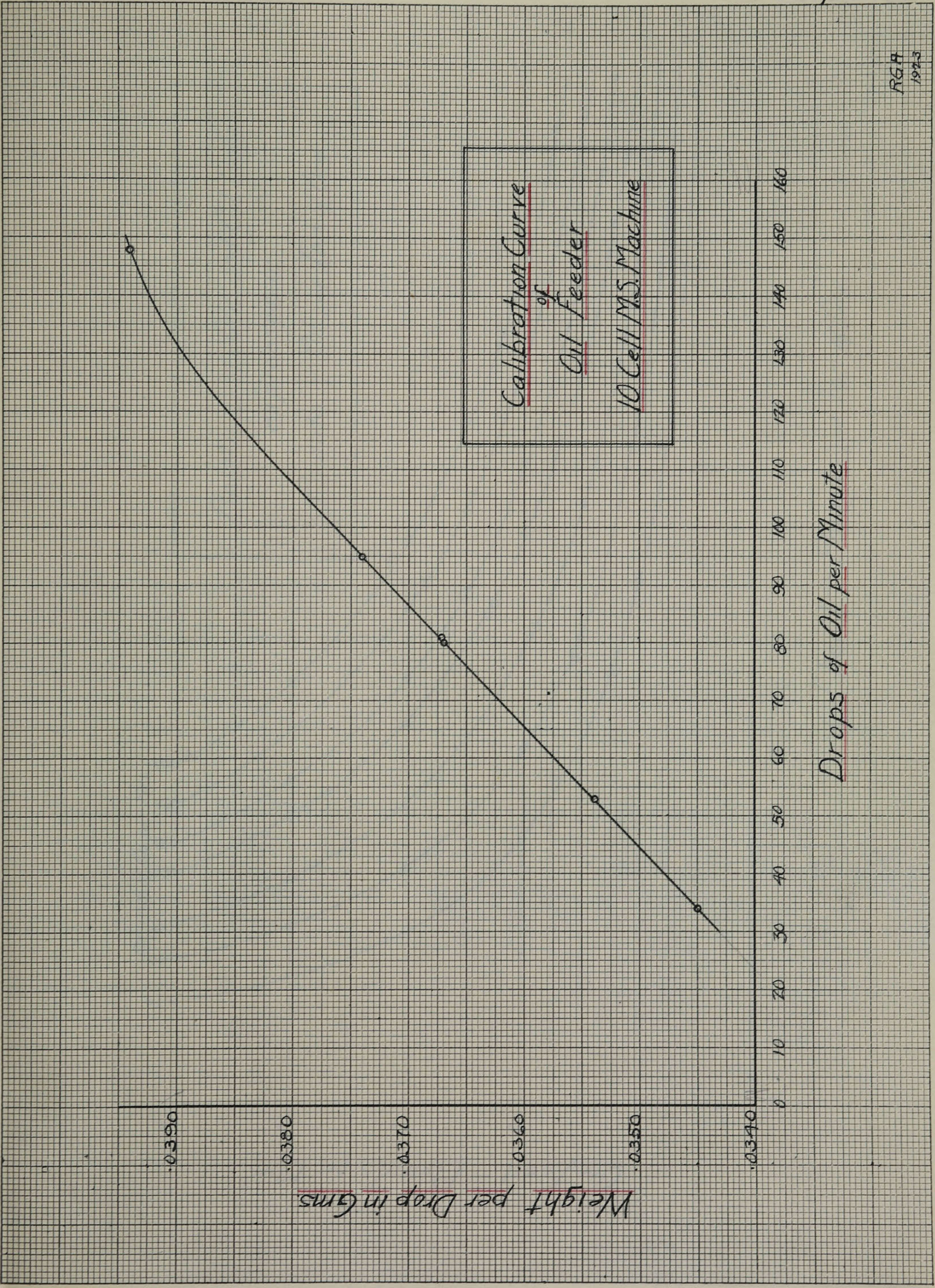
Oil is added to (a) until the surface is higher than the end of the tubes (c) and (d).

By causing suction at (g), oil is drawn through the tube (c) and will continue to run so long as there is a difference in head. By moving the shot (e) from one side to the other the head is changed and thus the flow can be regulated. One tube only is used to add oil to the machine. The other may be used if desired but it serves mainly to balance the feeding tube (c) .

The connections between one spitzkasten and the next agitation chamber are shown at "E".

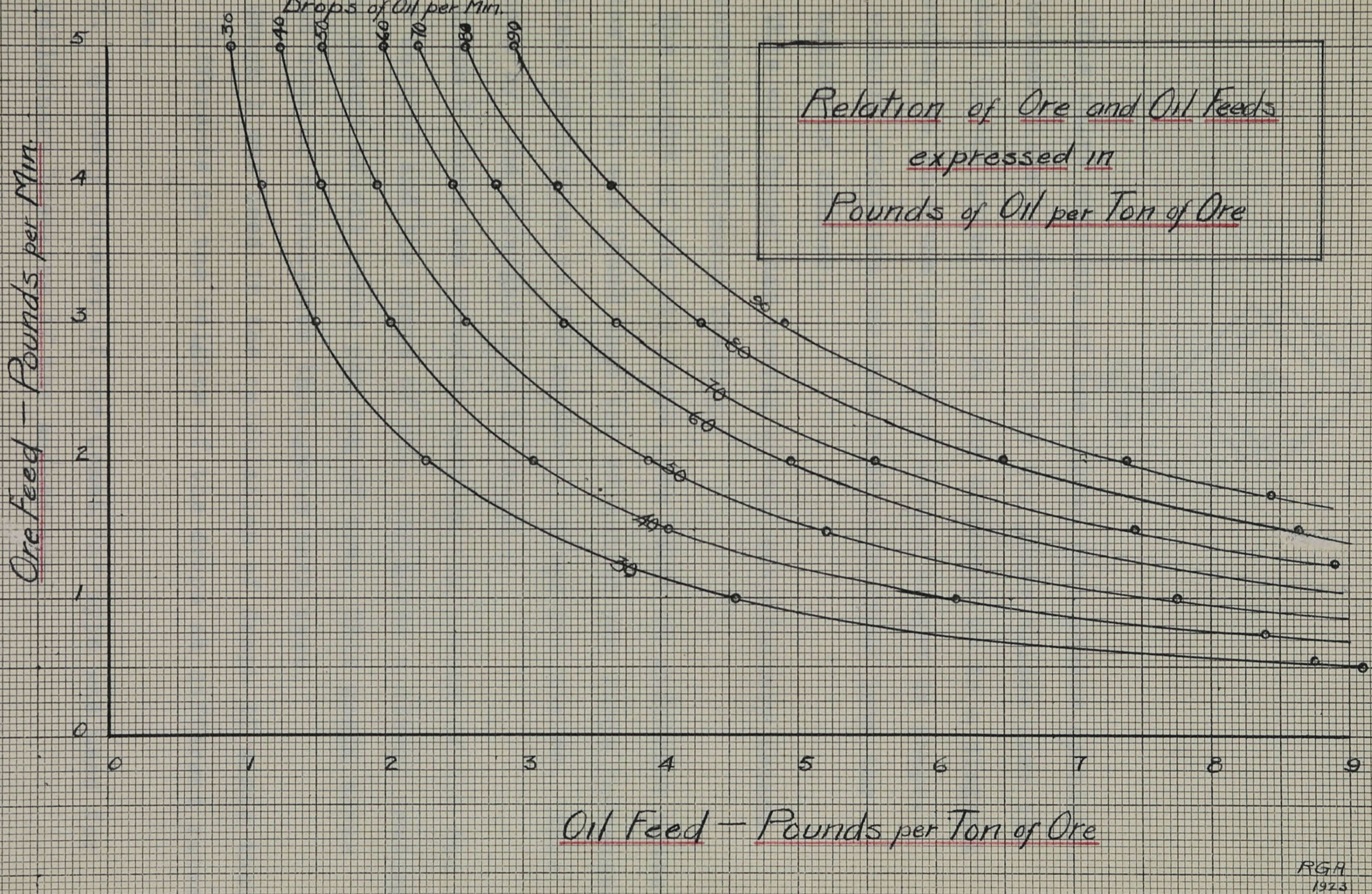
The level of the pulp surface in each spitzkasten may be adjusted by the screw valves "D".

Graph I

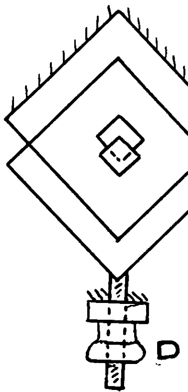


Calibration Curve of Oil Feeder 10 Cell M.S. Machine

Graph II



Relation of Ore and Oil Feeds
expressed in
Pounds of Oil per Ton of Ore



This valve consists of two plates with square openings. The bottom plate is fixed and the top plate slides over it, operated by the screw head D. The movement is in a diagonal direction, so that the opening is always square in shape. This opening regulates the amount of pulp drawn into the next agitation chamber.

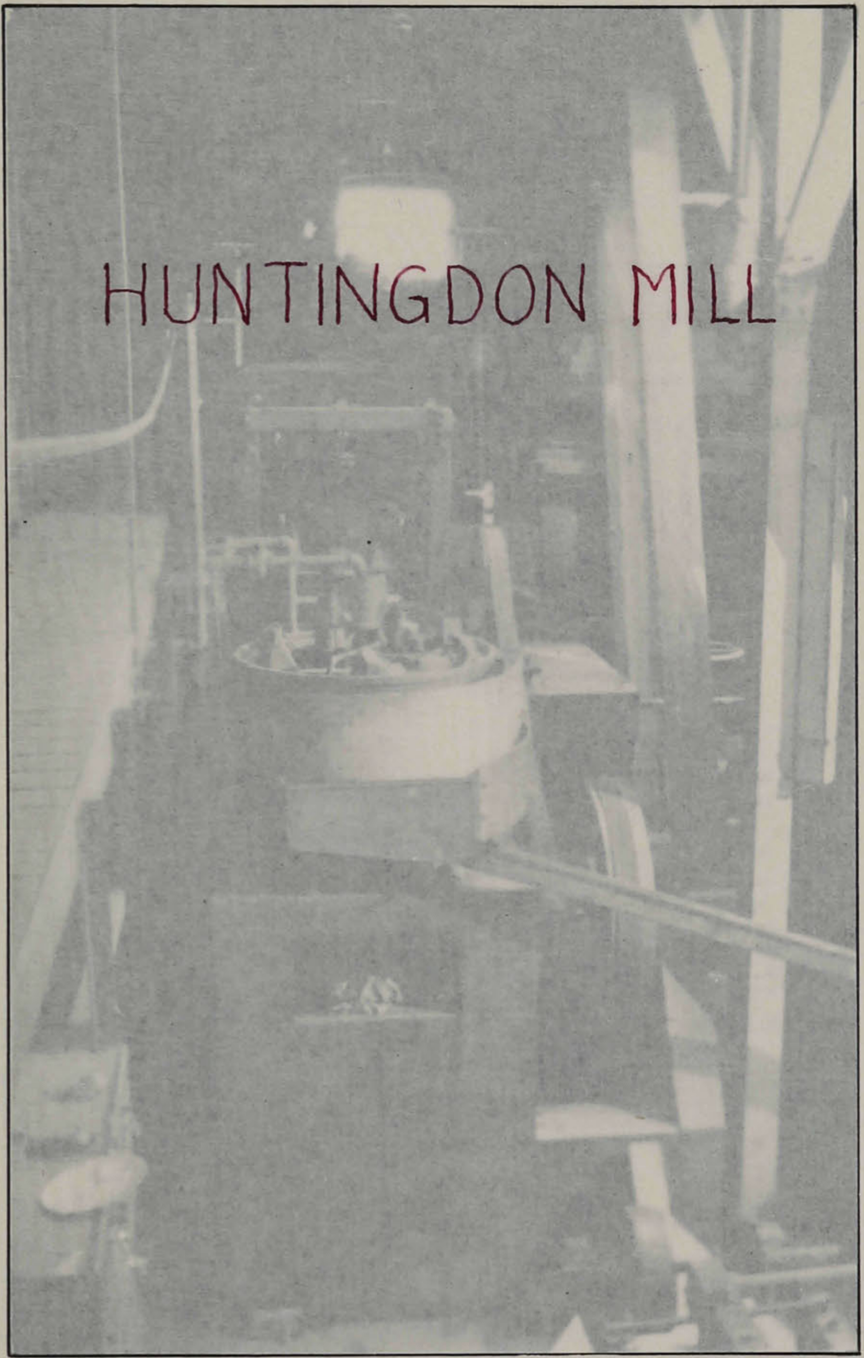
This oil feeder has proved a very satisfactory method for constant continuous feeding.

The wieght of the oil drops were taken at different rates of flow and it was found that the weight of the drops increased in direct proportion to the number of drops per minute. This is shown by the straight line in Graph 1.

Graph 2 shows the relation between the amount of ore fed to the machine and the drops of oil, and gives a direct reading on the amount of oil added per ton of ore. This graph saves a great deal of calculation throughout each test.

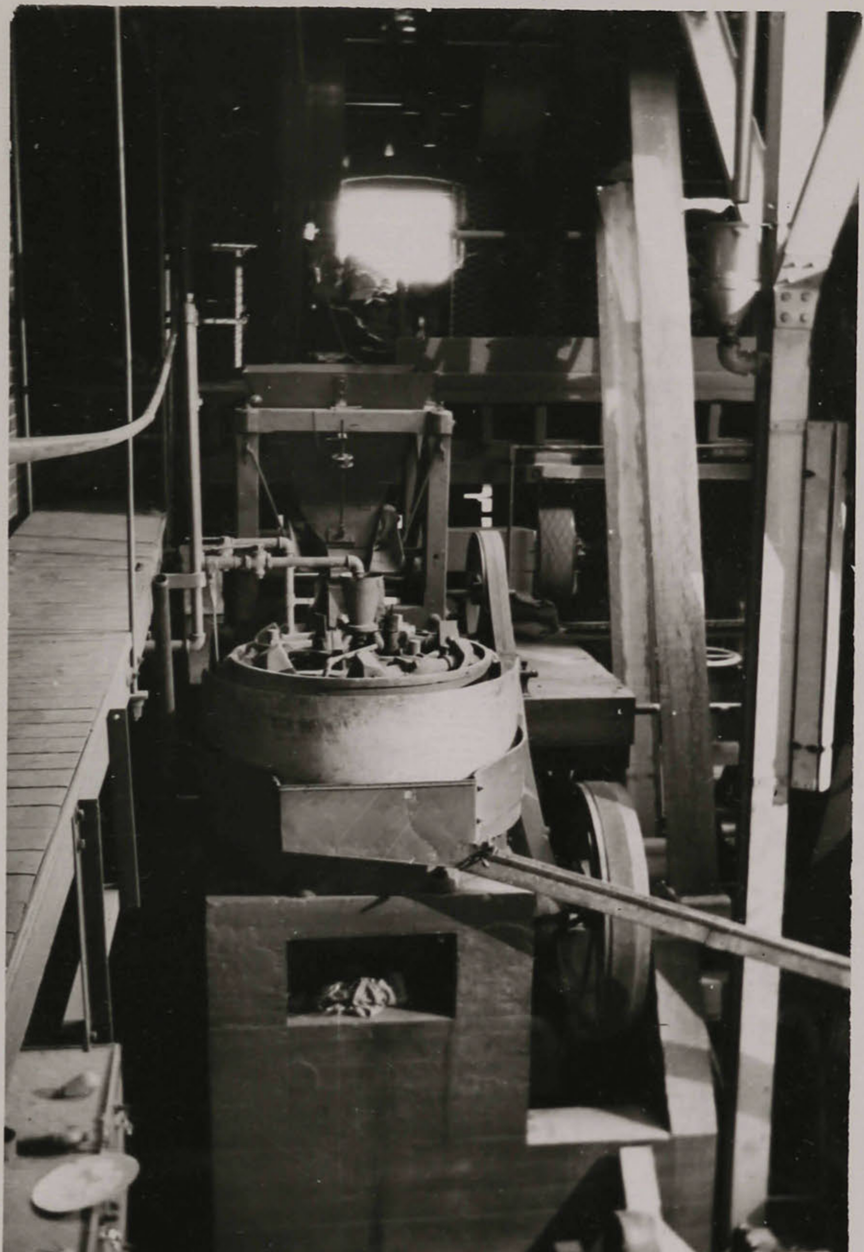
Graph 1 was used in the calculation of Graph II since there was a difference in the weights of the drops at different rates of flow.

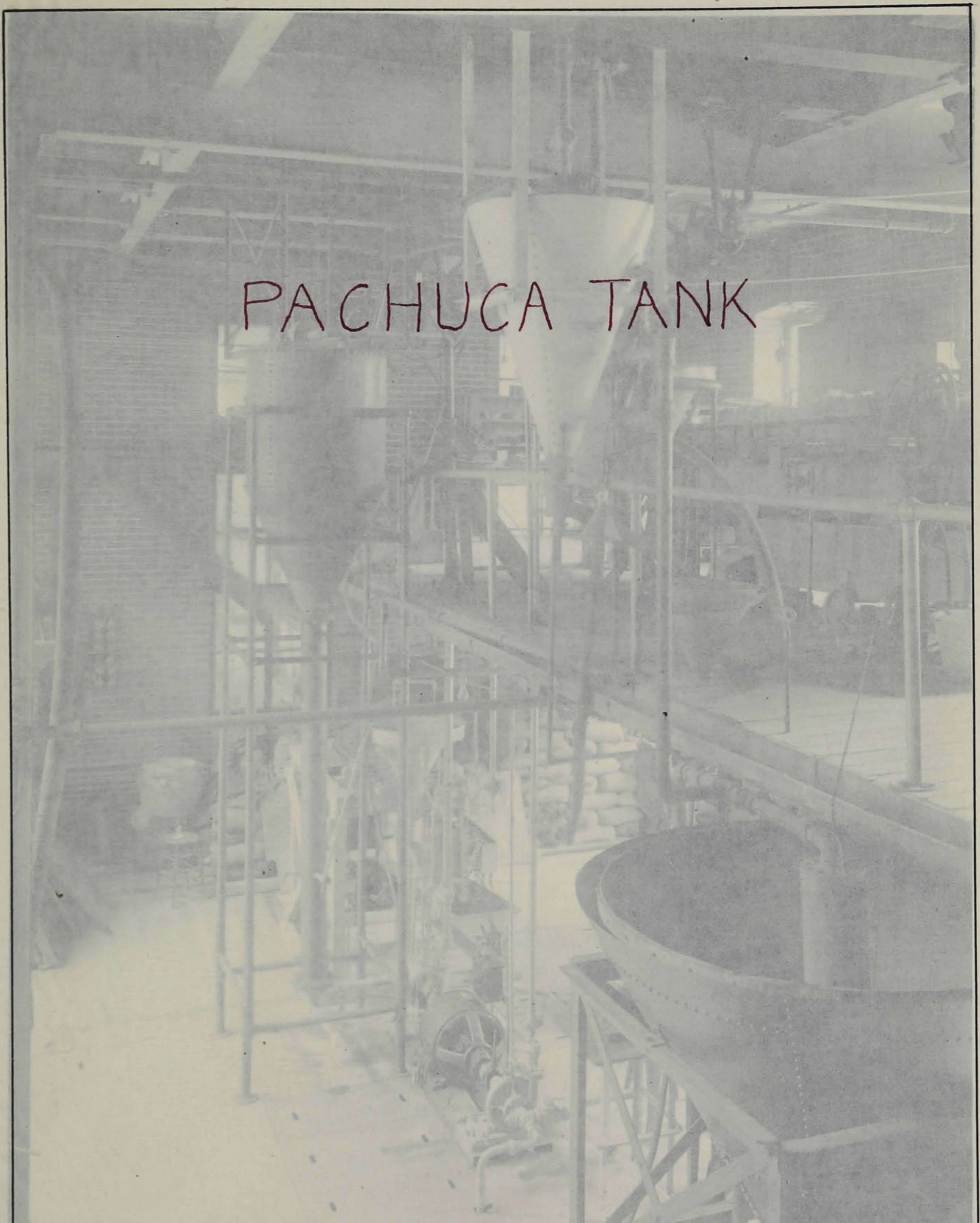
2. Gyratory Crusher of the Comet "A" type was used for the preliminary breaking of the sacked ore.



HUNTINGDON MILL

Plate VI
P. 37

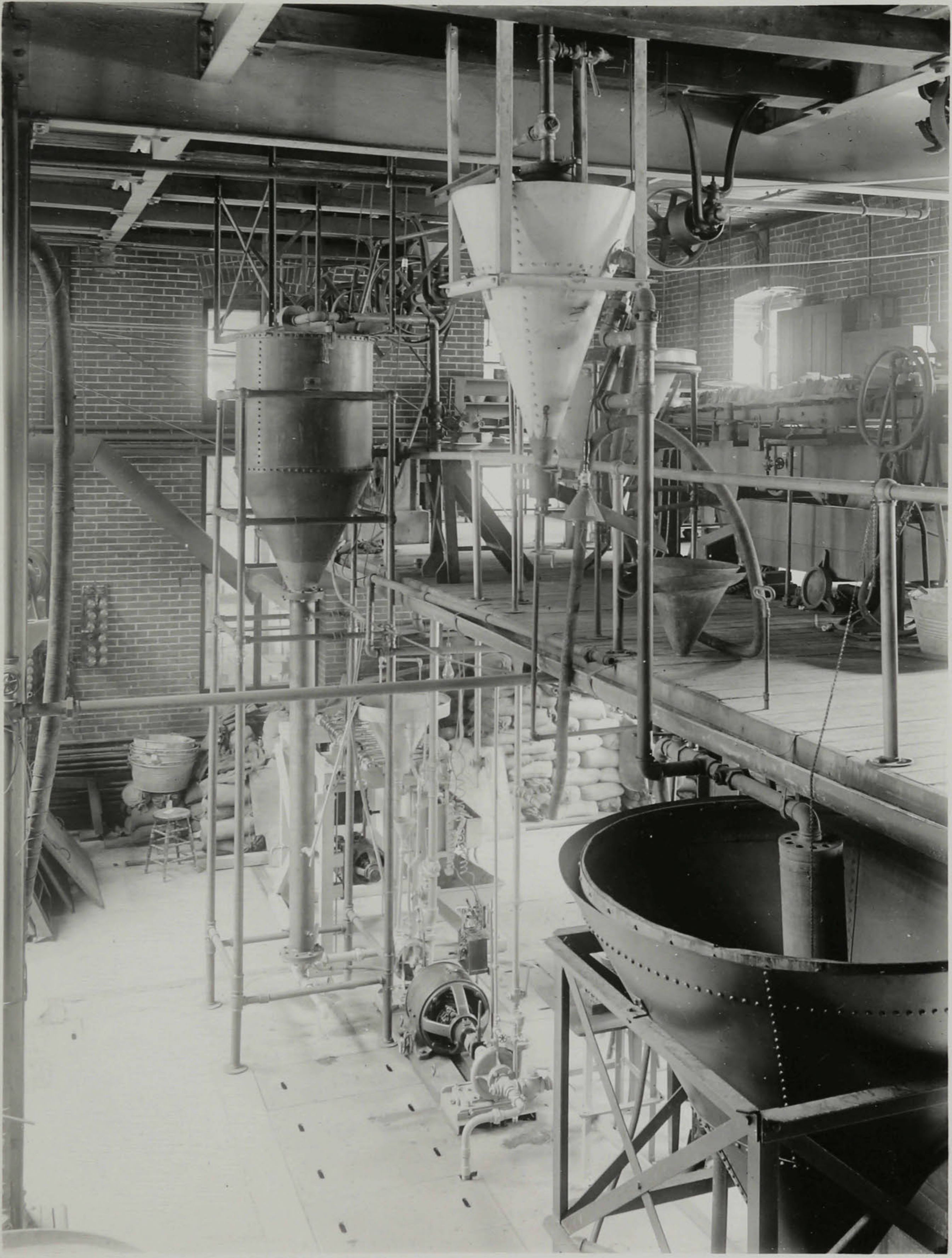




PACHUCA TANK

Plate V

P. 37



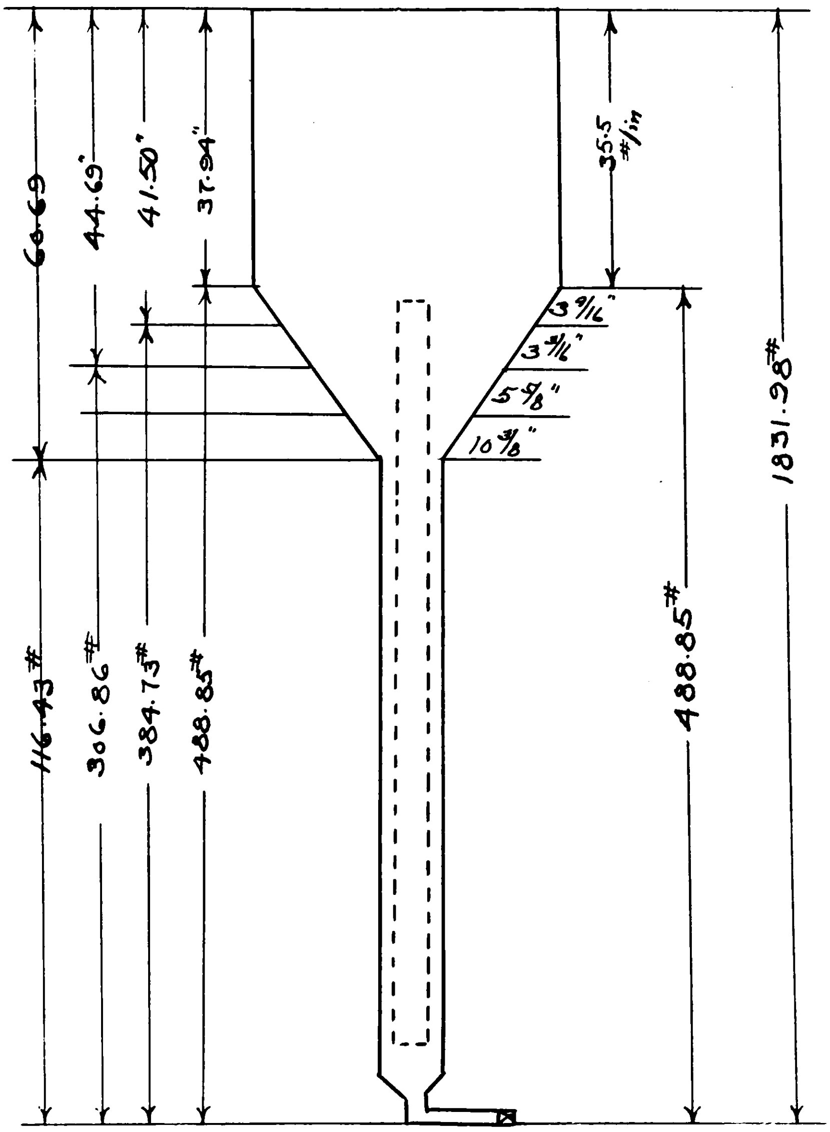
3. Rolls, size 10" x 16" were used to crush the ore after it had passed through the Gyratory crusher.

4. A Huntingdon mill capable of grinding approximately 1000 #/ hr. through 60 mesh ground the ore after it had passed the rolls.

5. Settling canes were used in order to decant the excess water in the pulp after grinding.

6. A centrifugal pump driven by a 5 H.P. motor transferred the pulp from one point to another.

7. <u>Pachuca tank</u>.



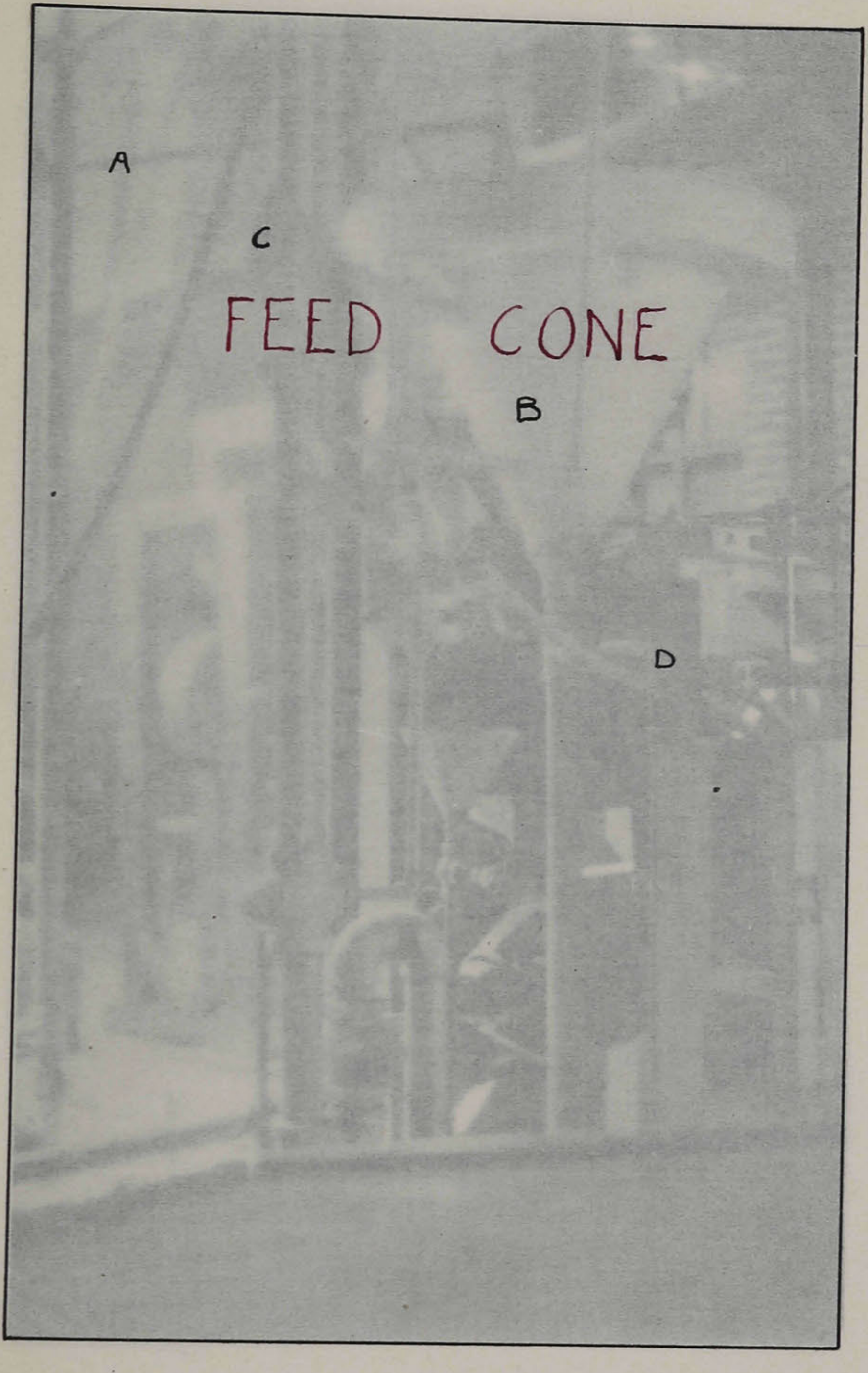
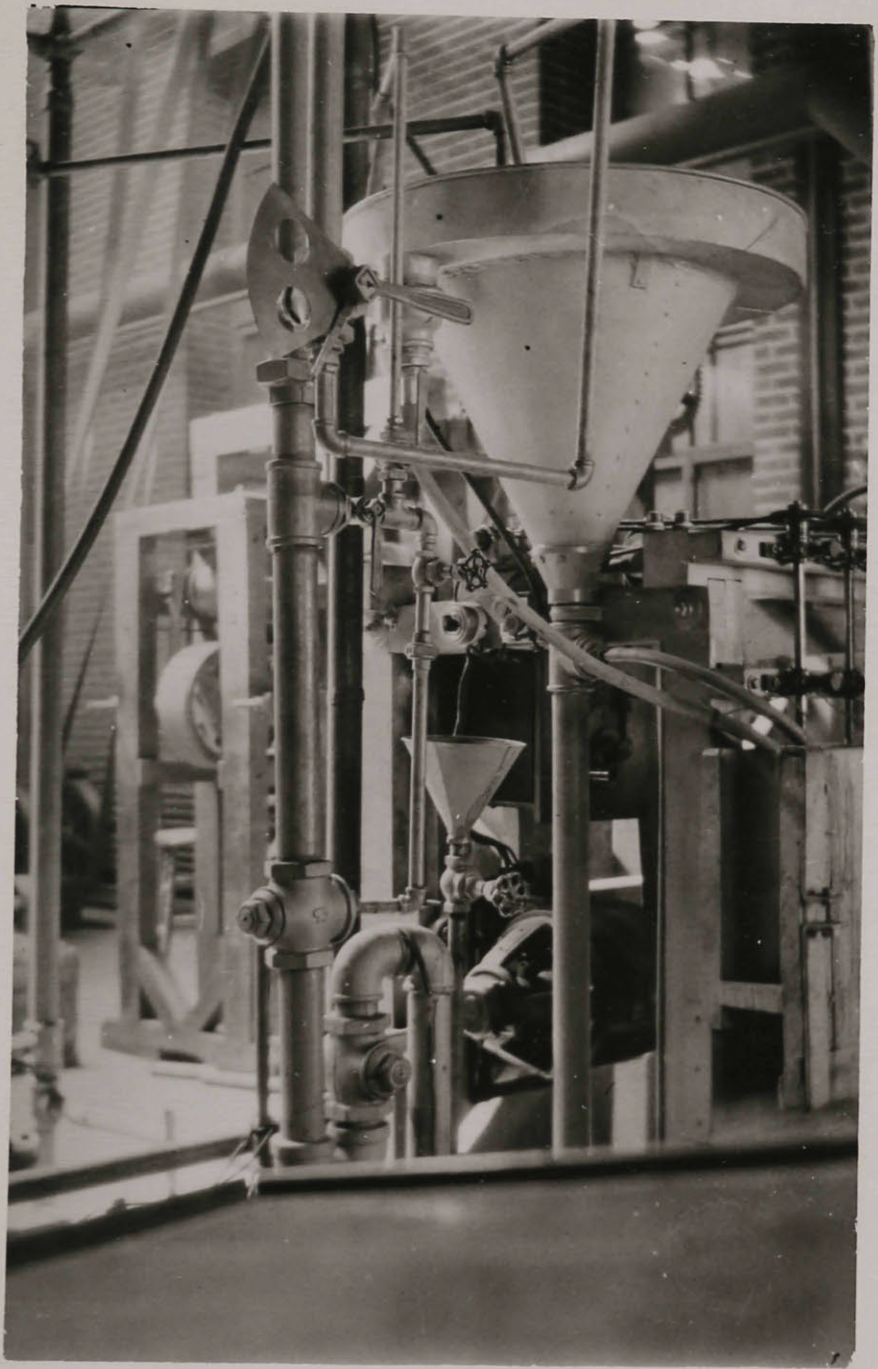
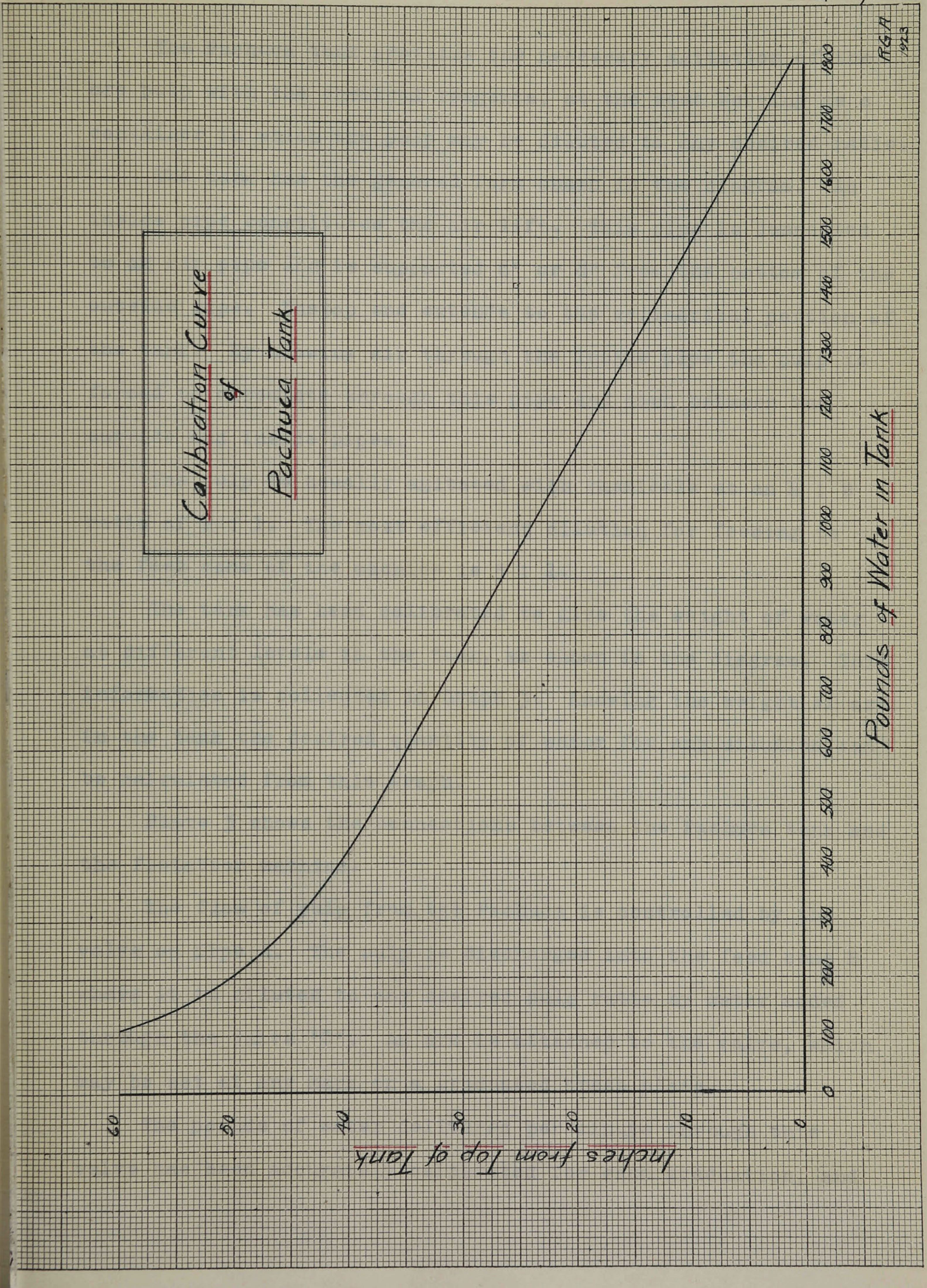


Plate III

P. 38



Graph III



Calibration Curve of Pachuca Tank

The Pachuca tank provides the necessary agitation of the ore pulp with the chemical reagents, at the same serving as a container in which the pulp may be diluted to any desired ratio.

The tank has the general form shown in the diagram. An inside pipe constitutes the air lift. This pipe is connected to an air pipe and is supported 6" or 8" from the bottom of the outside pipe, Thetop end extends to the cylindrical portion of the tank. By blowing air through the inside pipe the pulp is forced to circulate through this pipe and down between the outside and inside pipes.

The pulp is usually agitated with chemicals at an L : S ratio of 2 : 1. The most efficient dilution for feeding to the feed cone of the machine is 5 : 1.

The tank has been calibrated to give the weight of water at different levels in the tank, as shown in the diagram. This information is collected in Graph 3. Knowing the weight of ore in the tank the desired quantity of water for any dilution can be calculated from this graph.

Plate 3 shows the connections between the Pachuca tank and the flotation machine.

The flow of pulp from the Pachuca is controlled by the valve on pipe A. The pulp is discharged into the feed cone B where it is diluted to any desired pulp ratio by water added through the valve "C". An arm is attached to the valve, which may be set at any mark on a graduated brass plate.

The pounds of water delivered per minute through this valve has been accurately calibrated for each graduation, and

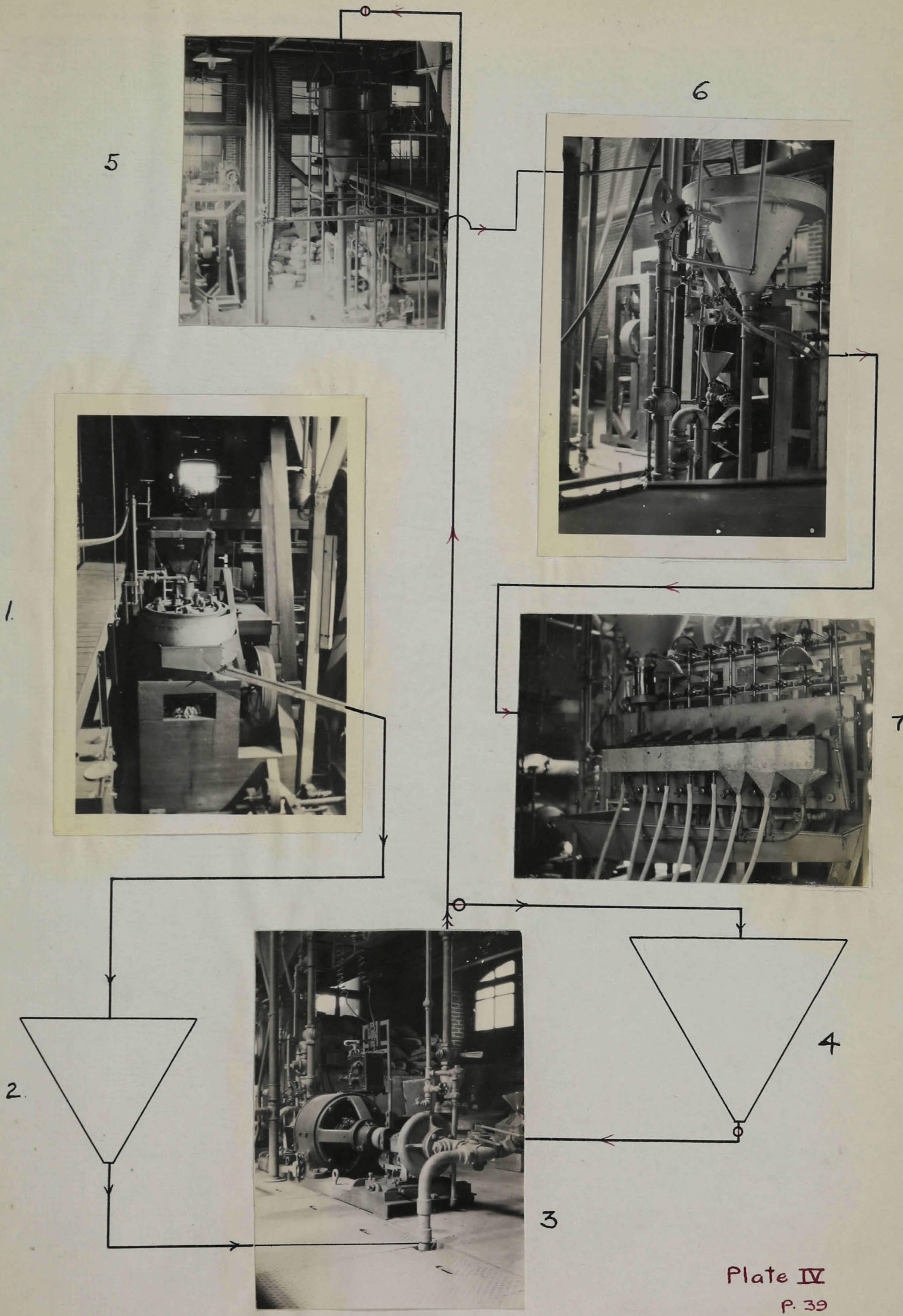
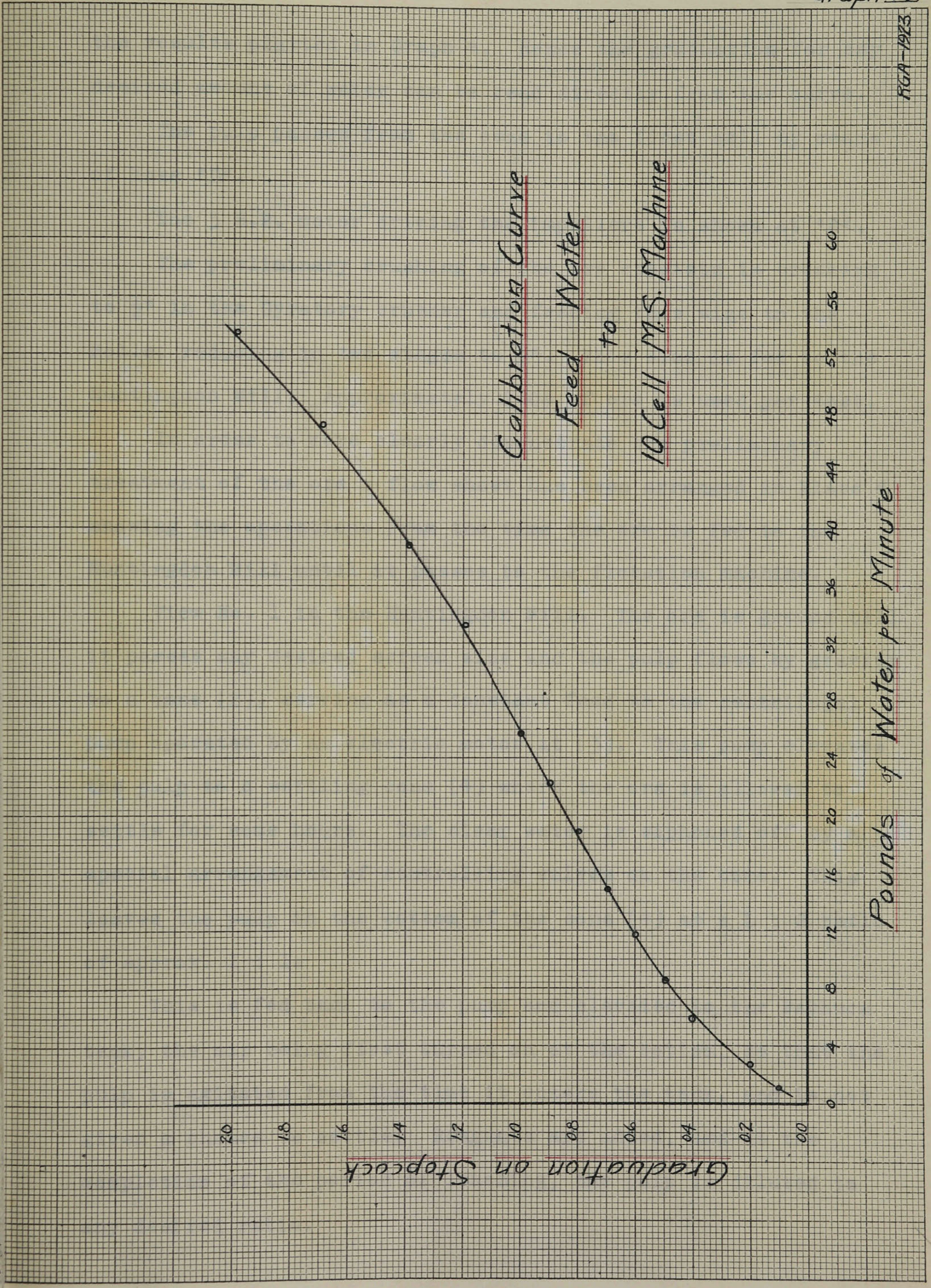


Plate IV

P. 39

Graph IV


Calibration Curve
Feed Water
to
10 Cell M.S. Machine
RGA-1923
Pounds of Water per Minute
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
Graduation on Stopcock
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

the results platted in Graph 4. Hence the graduation for any desired amount of water can be read directly from the curve.

The pulp passes from the cone to the first cell by means of hose "D".

The 3 H.P. motor driving the impellers is shown at "E".

The preliminary crushing of the ore consists in breaking to ½" in the Gyratory crusher and feeding this size to the Rolls, reducing in two stages to ⅛". This size is fed to the Huntingdon Mill. Approximately 200# of ore is used per test.

In order to more clearly demonstrate the preliminary treatment of the ore a flow sheet has been arranged in Plate 4 showing the operations from the time the ore is fed to the Huntingdon Mill until it passes to the flotation machine.

View No. 1 is the Huntingdon Mill. The ore is ground till it passes any desired screen size and the pulp flows by gravity to a cone (2), serving as a constant feed to the centrifugal pump operated by an electric motor at (3). This pump elevates the pulp to a settling cone (4) where the ore is allowed to settle for some hours. The clear water is siphoned off by a special arrangement of controlling valves on the cone. This leaves the pulp in the bottom of the cone (4) at a L : S ratio of approx. 1 : 1.

This is fed back to the pump and elevated to the Pachuca tank, the air being first turned on at the bottom, so that the pulp is agitated from the time it enters the tank, and is not given a chance to settle. Reagents are added, and at the completion of the period of leaching, the pulp is diluted to any desired ratio.

A pipe and controlling valve, shown in (6) allows the pulp to flow into the feed cone of the Flotation machine from whence it is fed into the first cell.

Operation of the Machine.

The cells are first filled with water, and the motor started, the impellers revolving at approximately 1000 R.P.M.

The feed cone is filled with water to a certain point determined by a float, the feed water added in the desired amount through the calibrated valve, and the pulp from the Pachuca added to the feed cone in such an amount that the float is kept constantly at a certain mark.

After the pulp is fed to the first cell, the oil feeding is commenced. (The oil must not be added before the feed is started, since this would cause the Raw oil effect and would kill the froth for some time.)

While the pulp is progressing to each cell in turn, the overflow is regulated to keep the pulp surface in the first spitzkasten at the proper level, and adjustments relating to the level of the froth in each spitzkasten are made by the thumbscrews D (Plate 2).

When froth appears on all the spitzkastens and the surface of feed-cone pulp is at a constant level, the froth is skimmed from all cells, the time taken, and the test started. The froth is collected in tubs. Ten second feed and tails samples are taken at five minute intervals.

When the test is finished the time is again taken, the froth skimmed off, and the launders washed down. The feed sample is dried and weighed. From the two weights, the pulp ratio of the feed can be calculated, and also the dry ore fed per minute to the machine.

The products are dried and the concentrate weighed in order to compute extraction. The feed tails and concentrates are assayed by the method described later in the paper.

In order to show the various computations and the method of taking notes during a run, test #43 will be taken as an example.

Test # 43.

170# of ore through 100 mesh in Huntingdon Mill.

Time

2.30 Transferred from cone to Pachuca tank.

2.40 Added 193 gms. (5 #/ton) Na_2CO_3 to Pachuca.

525 425 1.235

549 445 1.235 27.7 2.6 : 1

3.10 Added 410# water to Pachuca.

23" from top of tank gives 5 : 1 pulp ratio.

429 399 1.075

507 475 1.070 10.1 8.9 : 1

Added feed water at 0.1 or 1.2# per min.

Oil - 10% GNS #5, 90% FPL #24.

3.18 Feed started - oil 62 drops per min.

3.25 Beginning of test.

3.30 1st feed sample (10 sec.)

3.35 2nd " " " "

3.40 3rd " " " "

3.45 4th " " " "

3.50 5th " " " "

3.55 6th " " " " End of test.

Feed Sample:-	Gross.	Tare.	Net.
	30.44#	9.44#	21.00#
Weight of feed sample, dry -			1.79#
Weight of water in pulp -			19.21#

Pulp ratio of feed is $\frac{19.21}{1.79} = 10.7 : 1$

Weight of dry feed sample = 1.79#

Therefore feed to machine = 1.79# per min.

Calculation of Pulp Ratio.

The pulp ratio in the Pachuca tank is found from a formulae in Hamilton's Book of Cyanidation.

Let S = specific gravity of the ore.

P = " " " " pulp.

Then the % solids = $\frac{S(P - 1)}{P(S - 1)} \times 100$.

The specific gravity of the ore = 3.20.

P is found by allowing the pulp to run from a small cock in the side of the Pachuca into a 500 c.c. graduate.

Let W = weight of pulp.

Y = c.c. " "

Then $\frac{W}{Y} = P$.

In the foregoing example -

W = 525

Y = 425

$\frac{W}{Y} = 1.235$.

Applying this information in the formula:-

$$\frac{3.2\ (1.235 - 1)}{1.235\ (3.2 - 1)} = 27.7\%\ \text{solids.}$$

$$\text{Pulp ratio} = \frac{100 - 27.7}{27.7} = 2.6 : 1.$$

In this test 170# of ore was fed to the Huntingdon Mill, so it must be assumed that 170# of ore is delivered to the Pachuca tank.

The desired ratio is 5 parts of water to one of ore, by weight.

Therefore, in all, 6 parts of pulp by weight are required in the tank.

6 X 170 = 1020# pulp.

From the calibration curve of the Pachuca tank (Graph 3) it is found that the surface of the liquid is 23" below the top of the tank with 1020# of water present.

Hence water is added until the surface is this distance below the top, which should give a pulp ratio of 5 : 1. This is equivalent to adding 410# water.

The pulp was already at a ratio of 2.6 : 1 when agitating with Na_2CO_3.

Hence 3.6 x 170 = 612# of pulp present before diluting to 5 : 1. Therefore 1020 - 612 = 410# of water actually added.

Note:- It is well to notice here that when the actual pulp ratio was measured it was found to be 8.9 : 1 instead of 5 : 1, showing that less than 170# of ore was delivered to the Pachuca tank. The loss occurred in the Huntingdon Mill and also in transferring. This loss is more or less of an uncontrollable factor.

Calculation of Feed Water.

By measurement, it was found that the hose, connecting feed cone to flotation machine, delivered 21# of water per minute.

By experiment the running capacity of the machine was rated at 2# of dry ore per minute.

In the example the pulp ratio in the Pachuca is 8.9 : 1 or 9.9# of pulp per pound of dry ore.

If 2# of dry ore is the capacity of the machine, then 2 x 9.9 or 19.8# of pulp per minute must be delivered to the feed cone from the Pachuca.

But, the feed hose delivers 21# per minute to the flotation cell.

Hence the difference 21 - 19.8 or 1.2# per minute must be added to the feed cone. This is accomplished by means of the graduated feed-water cock.

Referring to Graph (4) it is found that 1.2# of water per minute are delivered when the pointer is at 0.1 on the deal.

The feed water is constant, and to maintain the surface in the feed cone at a constant level the valve controlling the flow from the Pachuca must be watched closely since frequent clogging occurs.

It was pointed out above that the actual amount of ore delivered to the Pachuca was always in doubt. It occurred to the writer, when explaining this, that the settling cone might be calibrated in the following manner.

Let 50# of ore be ground in the Huntingdon Mill and allowed to settle, say, for 12 hours in the cone. At the end of this time the distance of the surface of the settled pulp from the top of the cone could be measured, and then the ore removed in some way and weighed. A relation would at once be established between depth and weight, and from the mathematics pertaining to the volume of a cone, various relations of depth to weight could be calculated.

No great quantity of ore is lost in transferring from the cone to the Pachuca;, hence, by this calibration, the actual weight of ore present could be determined with a fair degree of accuracy.

4. Chemical Analysis.

The chemical analysis of the ore was identical with that developed last year by Messrs. Saunders and Dewar.

The same trouble was experienced with the low grade copper, but it seemed impossible to avoid. this point.

Extremely careful manipulation is necessary to get accurate analysis. To obviate this, a definite amount of copper was added to the assays. This made manipulation a little easier but it introduces other errors. The average result obtained is, however, a little better than without the addition of the copper.

The iodide method for copper depends on the fact that in a solution made slightly acid with acetic acid, cupric compounds oxidize potassium iodide with the liberation of iodine. This is then titrated with standard triosulphate solution. The equations for the reactions are:

$$Cu\,(No_3) + 2\,KI = Cn\,I + 2\,KNo_3 + I$$

$$2\,I + 2\,No_2\,S_2O_3 = 2\,Na\,I + Na_2\,S_4O_6$$

The permanganate method for iron depends on the fact that metallic aluminum, in a boiling slightly acid solution, will reduce ferric to ferrous sulphate. The ferrous sulphate is then oxidized to the ferric state again with standard permanganate solution. The equations are:-

$$2\ Al + 3\ Fe_2(SO_4)_3 = Al_2(SO_4)_3 + 6\ Fe\ So_4$$

$$2\ K\ M\ N\ O_4 + 10\ Fe\ So_4 + 8\ H_2SO_4 = K_2SO_4 + 2\ MNSO_4 + 5\ Fe_2(SO_4)_3 + 8\ H_2O.$$

The method for nickel depends upon the following reactions:

$$Ni(NH_3)_6\ SO_4 + 4\ KCN = K_2\ Ni(CN)_4 + K_2SO_4 + 6NH_3$$

This reaction takes place in a solution alkaline with ammonia and a large amount of ferrous iron may be present without interfering, if before making alkaline, a considerable quantity of sodium citrate is added. The citrate combines with the iron to form unionized iron citrate which does not allow the iron to precipitate as ferric hydroxide when ammonia is added.

The end point of the reaction between the nickel and the cyanide is shown by the disappearance of a turbidity due to the presence of silver iodide. The reaction is:-

$$AgI + 2\ KCN = K\ Ag(CN)_2 + KI$$

Procedure:- Take a 1 gram sample ($\frac{1}{2}$ gram of a rich concentrate). Add 20 cc of aqua regia (equal parts of hydro chloric and nitric acids) and evaporate to dryness. Bake for a few minutes. Cool and add 10 cc. of 1 : 1 sulphuric acid. Evaporate to sulphuric acid fume. Cool and take up with about 25 cc. of water. Heat until all the soluble salts are in solution. Then filter off the insoluble. Add 10 cc. of standard copper solution to the tailings. Precipitate the copper by boiling with aluminum strips. When the copper is all precipitated the iron is reduced to the ferrous condition. This can be determined by the presence of a white stable froth on the surface of the liquid.

Decant the hot solution through a filter. Wash the precipitated copper several times with hot water adding the washings to the liquid in the filter. This liquid contains the iron and nickel.

Place the beaker containing the copper and the aluminum strip under the drained filter. Wash the filter with a few ccs. of boiling 1 : 1 nitric acid. As little acid as possible should be used, enough must be added to insure complete solution of the copper. Wash the filter with a little hot water. Place the beaker on the hot plate and heat until any copper adhering to the aluminum strips is dissolved. Wash and remove the strips. Add 10-20 ccs. of bromine water and evaporate almost to dryness. Cool and take up with water. Neutralize the assay with a solution of sodium carbonate. The neutralization is complete when a permanent precipitate of copper carbonate is formed.

Dissolve this precipitate with acetic acid and add two or three ccs. in excess.

Add from 1-3 gms. of potassium iodide, depending on the amount of copper in the solution. Titrate with standard thiosulphate solution until the yellow color of free iodine is almost gone. Then add 5 ccs. of starch solution and titrate until the blue color disappears.

The filtrate from the copper precipitation is ready to be titrated for iron. Run in standard permanganate solution until the last drop turns the assay a pink color.

To this solution add 30-40 cc. of saturated solution of sodium citrate. Make alkaline with ammonia. Cool to below 20°C. Add 5 cc. potassium iodide solution and 5 cc. standard silver nitrate solution. Titrate until the fine suspended precipitate of silver iodide has disappeared and the solution is clear with standard potassium cyanide.

Notes, - The object of baking and then fuming the assay with sulphuric acid is to drive off the excess of hydro chloric and nitric acids. These interfere with copper precipitation and also with the iron titration.

In the copper assay, free bromine, nitrous oxides, ferric ions, trivalent arsenic and antimony will liberate or absorb iodine. The addition of bromine oxidizes the arsenic and antimony to the pentavalent state, in this condition they are not active towards iodine. The bromine is driven off by evaporation along with any excess of nitric acid.

It sometimes happens that the blue color of the starch iodine indicator returns. This is due to the presence of iron or an excess of sodium carbonate. These can be eliminated by careful manipulation. The excess of sodium carbonate when neutralized to sodium acetate by acetic acid tends to prevent the action of the copper on potassium iodide by lowering the ionization of the acetic acid.

In any case take the appearance of the first end point as being correct.

It is necessary to have a large excess of potassium iodide in order to hold the liberated iodine in solution and make the reaction rapid.

Lead and bismuth having yellow iodides cause trouble by obscuring the end point.

The point requiring the most careful manipulation in the copper assay is the precipitation and filtering of the precipitated copper. It is obvious that the precipitation of the copper must be complete. Finely divided copper is very liable to be oxidized to copper oxide which may be colloidal in fineness. This will go through the filter paper and hence is lost. Rapid filtering and hot water for washing is hence essential for the success of this operation.

The only precaution necessary in the iron analysis is to make sure that the amount of nitric and hydro-chloric acid in the solution is very small. The fuming of the sulphuric acid, if done correctly, is the best safeguard against this difficulty.

In the nickel assay, the reaction between the cyanide and the nickel salt goes on first, then the cyanide acts on the silver iodide. The silver iodide acts as an indicator and uses up a fixed amount of the indicator which must be subtracted from the total cyanide used.

The solution must be ammoniacal before titration as both potassium and potassium nickel cyanides are broken up by acids. The excess of ammonia must be small owing to its dissolving influence on the silver halogen salts.

The solution must be dilute. If it is not there is great danger of a turbid solution due to the undissolved nickel cyanide causing over titration.

Considerable amounts of iron and alumina make the titration difficult. This may be overcome by increasing the amount of sodium citrate. In such cases the solution should stand about 5 or 10 minutes after titrating and if the precipitate comes back in this time, potassium cyanide should be added until the liquid is clear again. If the precipitate comes back again after 15 minutes it is of no consequence.

Cobalt shows its presence by a dark color in the solution. It reacts with potassium cyanide but does not form the double cyanide, but salts similar to potassium ferro-cyanide.

In general the titration gives the total amount of nickel plus about three quarters the amount of cobalt in the assay. As the amounts of cobalt present are generally very small compared with the nickel the results referred to plan an unimportant part.

There is no other method of determining whether the solution is alkaline or not except by the sense of smell. There is a color change but it depends on the amount of iron, litmus is of little use as it cannot be distinguished in the darker color of the solution.

The titration is best carried out over a black plate and with an electric light playing directly on the surface of the liquid. The titration if carried on slowly, gives a definite final end point, but for concentrates this is too tedious a procedure. The solution is titrated to an end point rapidly, set aside, and after 10-15 minutes retitrated slowly. This second titration usually takes less than 1 cc. and the time involved is not very long.

5. Experimental Work.

The laboratory tests were carried out in collaboration with Mr. J.E. Saunders who conducted research on the same ore in a one cell M.S. machine the previous session.

It was stated earlier in the paper that a 10-cell continuous M.S. machine was used in the following tests, and the machine itself, as well as the accessory apparatus used in connection with the tests,have been explained.

The first consideration in treating this ore was to find if all the sulphides could be floated.

The second consideration was based on the first. If all the sulphides could be floated it might be possible to differentiate them; that is, float one particular sulphide before the others.

Before entering into the discussion of the tests the writer has taken the liberty of extracting certain conclusions from the Thesis of J.E. Saunders.

Theae are:

1. That sodium hydroxide as a leach has only a slight effect on the pyrrhotite of this ore.

2. Salt is a much more effective chemical to keep pyrrhatite down.

3. A mixture of salt and alkali gives a better extraction of copper and has the same effect on iron than either reagent separately.

4. Ferric chloride was the most effective agent for keeping down the iron, but it also acts on the chalcopyrite.

These conclusions served as a basis in conducting the present work.

The first few tests were mainly of an experimental character. The machine had not been thoroughly tested and no definite method of conducting a test had been devised, hence it was first necessary to learn the manipulation of the machine; and secondly, the best method of carrying out a run.

Data sheets giving full particulars will be found at the end of this paper.

Test #1.

The compressor supplying air to the Pachuca tank was being repaired so the agitation was carried on by means of the electrically operated pump. It did not prove very satisfactory as shown by the varying pulp ratios. A settling of the ore seemed to occur in the stand pipe of the Pachuca tank.

The pulp ratio of the feed in this test and in a few following, was taken from the feed hose at constant intervals throughout the test. Here also there was a variation in the pulp ratio which was to be expected since the ratio in the Pachuca tank was also varying. The pipe leading from the Pachuca to the feed cone plugged at intervals, which game an intermittent feed through the machine.

The pipes leading from one spitzkasten to the next agitation box also clogged due to the intermittent feed, causing the spitzkastens to overflow.

The data obtained was so erratic that no computations for extraction were attempted.

Test #2.

Much the same difficulties were encountered in this run.. The compressor kept the pulp in more uniform agitation but trouble was experienced in the feed from the Pachuca. The valve was not of the right type to give a uniform flow of pulp.

It was found that the method of taking specific gravities of the pulp was not of much use at ratios greater than 6 : 1.

The tests following met with greater success as the skill of the operators increased. In order to give the reader a clearer conception of the results a tabulation of each series will be given, followed by a discussion of each run.

Test	Oil Ore	Reagent	Grade.			Extraction.		
			% Cu.	% Ni.	% Fe.	% Cu.	% Ni.	% Fe.
#3	FPL #24	NaOH	20.8	0.76	26.0	41.5	3.4	6.9
#4	"	"	12.7	2.90	29.4	86.6	39.2	23.6
#5	"	"	7.77	3.08	22.4	73.8	40.8	22.8
#7	"	"	10.30	3.41	24.8	78.5	59.0	48.2

Test #3.

A good grade of concentrate was obtained but the extraction was of no consequence and it was thought that by increasing the pulp ratio a higher extraction might be obtained.

Test #4.

The liquid solid ratio (hereafter L.S. ratio) was increased from 7.3 : 1 to 3.8 : 1 and the immediate increase in extraction was noticed though accompanied by a lower grade of concentrate. The better result is due solely to the increase in the ore feed since the other conditions were the same.

Test #5.

The proper amount of oil was a doubtful factor and test #5 was carried out to see if an increase in the oil would prove beneficial. Such was not the case. The grade and extraction were lower than in the preceding case, proving that too much oil was detrimental.

Test #6.

This test had to be rejected due to a mishap during the run.

Test #7.

It was thought advisable, before the completion of the series with oil, to run a test in a neutral circuit and thus to see if the use of NaOH as a leach was beneficial or otherwise. The L.S. ratio was decreased to 11.9 : 1 and 9.5# of oil per ton of ore were added.

The results proved almost parallel to test #4 and probably if the oil had been reduced to 4 or 5#/ ton the grade and extraction would have been even better. No approximation of the relations between quantity of ore and oil could be made because the feed was rather variable and the oil feeder had not been calibrated. Hence, at the completion of this test the weight of a drop of oil at different rates of flow was determined and plotted as shown in Graph 11.

Summary.

This series of tests showed that, with FPL #24, the change in L.S. Ratio had not much effect, and that a neutral circuit gave better indications than when using NaOH as a leach. This reagent produced a very good froth but evidently the collecting power was poor.

In the above tests the feed sample was taken at the beginning of the run by allowing the feed pipe to discharge into a tub for a period of one minute.

This method was not very successful since the feed varied within small limits, and, unless the pulp ratio remained constant throughout the test a good average was not obtained. Hence it was decided to take a feed sample for a period of 10 seconds, at five minute intervals, giving a very good average of the run and at the same time eliminating the necessity of constantly taking pulp ratios of the feed throughout the run. This latter could now be calculated from the weight of the feed sample.

A change was effected in the feed from the Pachuca tank. Formerly the controlling cock was situated some distance below the top of the feed cone and the pipe between the two had quite an upward grade and depended on the head in the Pachuca for its discharge. Consequently, when the feed cock was shut off, any pulp in this pipe would settle and was only removed with the greatest difficulty.

The change consisted in connecting the feed pipe with the Pachuca at a point slightly higher than the top of the feed cone. Thus when the feed was shut off the pipe would drain of its own accord.

One other point was discovered as a result of these tests. If the surface of the pulp in the Pachuca tank reached a level near that of the inside pipe, a settling out of the ore occurred due to improper agitation, and was the cause of the fluctuating pulp ratios of the feed.

In all of the following tests the run was started and completed while the pulp surface was still in the cylindrical part of the tank, and as a result the pulp ratio was constant throughout the run.

The following series of tests were run using an oil mixture consisting of 5% GNS #5 and 95% FPL #24.

The discharge nipple of the feed cone was changed to one of smaller size, in order to give some approximation of the capacity of the machine.

Series II.

Test	Oil	Reagent	Grade.			Extraction.		
			Cu.%	Ni. %	Fe. %	Cu. %	Ni.%	Fe. %
8	5% GNS#5 95% FPL#24	NaOH	7.85	3.51	24.5	78.5	50.0	48.2
9	"	"	7.38	4.48	33.2	81.9	75.8	37.8
10	"	"	14.8	5.74	28.1	61.0	33.2	9.1
11	"	Na_2S	(14.7	3.43	28.7	(61.8	18.2	8.7
			) 7.8	5.85	29.1	) 20.8	20.2	6.5

Test #8.

This test was a comparison with #5 to determine the effect of NaOH as a leach with a different oil. Very little difference was noticed with the exception that more ore was floated in #8. The grade of concentrate and the extraction of the copper and nickel was almost identical with #5.

Test #9.

Since the neutral circuit of Series I showed the best result,,a similar test carried out with a different oil would serve as a comparison of the two oils.

Test #9 gave a fair grade of copper and nickel and a greater extraction than #7, proving that the oil used in test # was better than that in #7.

Test #10.

It was thought that too much oil was used in the previous test, and since it was inferred in the first test that a preponderance of oil was detrimental, a better grade and extraction might be procured with less oil.

Test #11.

Accordingly the oil was reduced from 5.1# / ton to 3.0# /ton. The results show that the assumption was incorrect.

The results of these two tests seemed to indicate that a decrease in the amount of oil gave a better grade of concentrate but a reduced extraction.

Good results had been obtained in the M.S. one-cell machine at this time in the flotation of lead-zinc ores using sodium sulphide as a reagent. Mr. Bell suggested that it might prove interesting to see the effect on Cu. Ni. ore.

Consequently test #11 served as the last of the series with the same oil, using Na_2S as a leach.

The first concentrate was taken from boxes 1 and 2, and the second concentrate from 3, 4 and 5.

The results were encouraging in the fact that a total of 83.6% Cu. was floated, with 38.4% Ni. A great deal of the iron was kept down.

Na_2S showed a distinct differential action in the first concentrate and would bear further investigation.

Summary of Series II.

1. NaOH as a leach was of no use with this oil.
2. A neutral circuit again proved one of the best of the series.

3. Na_2S as a leach produced a differential action, floating the Cu. and keeping down the nickel and iron.

From this it appeared that the nickel occurred with the pyrrhotite and not the chalcapyrite.

Series III.

An oil mixture consisting of 1% GNS #5 and FPL #24 was used with various reagents in the following series in order to determine the relative values of each.

			Grade.			Extraction.		
Test	Oil	Reagent.	Cu. %	Ni. %	Fe. %	Cu.%	Ni. %	Fe. %
12	1%GNS#5 99% FPL#24	Na_2S	22.6	3.28	29.1	44.2	8.0	5.4
13	"	Na_2CO_3	8.6	2.77	32.3	86.0	58.1	38.2
14	"	NaCL	16.0	4.26	29.9	46.2	13.6	6.6
15	"	NaOH) NaCl (	16.0	2.84	27.7	50.1	15.2	9.8
16	"	NaOH ($CuSO_4$)	8.5	3.88	33.4	15.1	12.4	5.3

Test #12.

The feed from the feed cone fell off appreciably in #11, and on investigating the cause it was found that the discharge nipple had clogged.

The machine seemed to be running under capacity, hence a larger nipple was inserted, giving a flow of approximately 34# of pulp per min. This gave a feed of 3.44# of dry ore per minute, and proved to be greater than the capacity of the machine, since with the tailings valve wide open the spitzkastens still overflowed.

As a result the test was not of much value, the extraction being very poor.

A smaller nipple was inserted in the feed cone at the completion of the test. The discharge was 21# per minute. A mean value of 2# of dry ore per min. was taken as the capacity of the machine. These figures were used in the remainder of the tests.

Test #13.

Na_2CO_3 produced a very favorable extraction of the copper but the nickel was low. The grade of the concentrate is also very poor.

Test #14.

NaCl had a distinct tendency to keep all the sulphides down, and especially the iron, bearing out one of the conclusions of Mr. Saunders' thesis.

Test #15.

NaOH and NaCl together seemed to have a differential action on the Copper. The froth in the previous test had been very poor and NaOH was added to form a voluminous froth to see if an increased extraction resulted. It proved of little value.

Test #16.

CuSO4 is a common reagent in Lead-Zinc ores but the effect on Cu. Ni. ores was not known. The results indicated clearly that $Cu\ SO_4$ was of no use since it kept everything down.

Summary of Series III.

The main purpose of this series was to experiment with different reagents. These were not chosen promiscuously but in keeping with the results on the one-cell machine.

Na_2S and Na_2Co_3 were clearly the better reagents. It would be useless to experiment further with the remainder.

So far the results have demonstrated that the best oil mixtures were 1% GNS #5 with 99% FPL #24, and 5% GNS #5 with 95% FPL #24.

The best reagent was Na_2CO_3. The neutral circuit proved better than the alkaline circuit.

Two series of tests frollowed from the above information. One with 1% GNS #5 and 99% FPL #24 in alkaline and neutral circuits and the other with 5% and 95% mixtures in similar circuits.

Series IV.

			Grade.			Extraction.		
Test	Oil	Reagent	Cu.%	Ni. %	Fe. %	Cu. %	Ni. %	Fe. %
17	5% 95%	-	5.25	3.33	33.7	86.9	79.1	57.0
18	"	-	6.76	4.00	35.7	86.0	63.8	38.5
19	"	Na_2CO_3	5.17	3.21	36.0	70.8	58.5	39.0
20	"	Na_2CO_3	7.85	3.36	34.45	62.5	62.5	47.6
21	"	Na_2CO_3	5.55	3.26	33.7	78.0	64.2	38.7
22	"	Na_2CO_3	4.70	2.57	28.7	74.0	54.0	34.5

Test #17.

Since test #9 had showed such promise, test #17 was more or less a duplicate to check up the assays which had not agreed very closely.

The grade was not as good as test #9, but the extraction was very much better. Approximately the same amount of oil was used but a slightly greater amount of feed. The increased extraction was no doubt the result of the more expert manipulation of the machine, obtained by the experience in the previous tests.

Test #18.

The pulp left in the Pachuca tank at the completion of test #17 was diluted to 8 : 1 and another test carried out to determine if the extraction was increased with less feed per minute through the machine. At the same time the oil per ton of ore was increased.

The effect of increasing the oil per ton in the neutral circuit showed no better result. The grade was a little higher but the extraction of the nickel fell off considerably, accompanied by a decrease in the iron extraction. Again the relation of the nickel to the pyrrhatite was clearly shown. The floating of one resulted in the flotation of the other.

Test #19.

The ore was agitated for 30 minutes with 5# /ton Na_2CO_3 and floated with an oil feed of 6.8# per ton. The results were not comparable to the previous two tests, both grade and extraction being lower.

Test #20.

The residual pulp from test #19 was diluted to 9 : 1. The test was similar to that preceding with the exception that the oil per ton was doubled. The extraction was poorer; evidently too much oil had been used.

It was thought that not enough Na_2CO_3 was added to have any effect; hence, in the next two tests 10# of $Na2CO_3$ per ton were added.

Test #21.

10# of Na_2CO_3 with 4.7# of oil per ton gave much the same result as in the preceding tests. Increasing the amount of Na_2CO_3 had no beneficial effect.

Test #22.

The residual ore from test #21 was diluted to 10 : 1 L.S. ratio, cutting down the feed of dry ore to 0.88# per min. The oil was increased to 13.1# per ton. No better result was obtained.

Summary of Series IV.

1. Na_2CO_3 as a leach was not effective in causing complete or differential flotation of the sulphides.
2. The neutral circuit produced the best results with this oil.
3. Five pounds of oil per ton appeared to be a sufficient quantity to effect the flotation of the sulphides.

Series V.

To determine the effect of 1% GNS #5 with 99% FPL #24 using Na_2CO_3 as a leach.

Test	Reagent	Grade.			Extraction.		
		Cu. %	Ni. %	Fe. %	Cu. %	Ni. %	Fe. %
#23	Na_2CO_3	6.8	3.49	24.4	43.5	26.6	15.5
#24	Na_2CO_3	17.4	3.80	29.5	51.5	18.3	9.5
#25	Na_2CO_3	8.15	5.0	35.4	66.9	53.5	26.7

This oil produced no better results with Na_2CO_3. Test #23 was not equal to test #13, due probably to the smaller quantity of oil used.

The residual pulp from test #23 was retreated, giving the effect of a high L:S. ratio with a greater quantity of oil. The result was of no value.

Test #25.

Increasing the Na_2CO_3 to 10# per ton produced a result similar to that when using 5% GNS #5 with 95% FPL #24. These tests show clearly that the use of Na_2CO_3 was not as promising as indicated in test #13.

The results, as far as they had gone, were of rather a disappointing character. It was noticed in many cases that considerable mineral was being floated in the last two or three boxes. The launder permitted of only two products being taken, a concentrate and a middling. Hence, it was impossible to determine the grade of each cell separately throughout a whole run, or to see if the last cell was producing a froth free from copper and nickel.

Consequently it was thought advisable to construct a launder in which the froth of each cell could be collected separately throughout a run, and the extraction and grade of each determined. Plate I. shows the new launder with a separate discharge for each froth.

Tests #26 and #27 served to complete series IV with GNS #5 and FPL #24 as well as to find just how each cell was functioning.

Test #26.

Referring to the data sheet for test #26, the first two cells produced a good grade of Cu. and the succeeding cells were all approximately of the same grade. The last cell ran 9.4% in Copper, showing that a great deal of the copper was going out in the tailings. The grade of nickel and iron was similar in each box.

Test #27.

The results of the test are very similar to test #26. The grade of each box was higher in copper. NaCl was added to see if a differential float of the copper could be obtained but was not successful.

Summary of Series V.

1. Na_2CO_3 had no beneficial effect in the treatment of ore with 1% GNS #5 and 99% FPL #24.
2. The results of #26 and #27 showed that the ore did not have sufficient treatment before being discharged. A longer machine would be necessary, or the connections so changed that the ore would remain in the machine for a longer period.

Time was not at our disposal to effect any such radical changes in the machine and it was decided to carry on as before in the hope of finding reagents and oils which would produce better results than heretofore.

The following series consisted largely of retreating the tailings in order to secure the effect of a longer treatment. The tailings were collected in tubs, and pumped back to the settling cone.

Series VI. - Retreatment of Tailings, and the use of "XY" mixture.

Test	Oil	Reagent	Grade. Cu.	Ni.	Fe.	Extraction. Cu.	Ni.	Fe.
#28	XY	Na2CO$_3$	20.7	4.52	26.8	71.9	27.4	13.6
#29	XY	Na2CO$_3$	20.9	4.52	23.7	77.2	36.5	14.2
#30	XY	-	5.50	3.53	29.9	43.9	17.9	12.9
#31	1% CNS#5 99% FPL#24	Na$_2$CO$_3$	10.7	3.61	25.2	76.2	45.3	30.2
#32	"	NaOH	1.56	1.05	13.3	65.0	42.7	32.9
#33	XY	Na2CO$_3$	16.1	5.77	27.6	83.5	61.3	23.0
#34	XY	Na2CO$_3$	16.9	6.74	25.2	86.0	56.5	19.7
#35	XY	-	18.15	5.60	27.0	74.0	39.8	16.7
#36	5%GNS#5 95% FPL#24	Na$_2$CO$_3$	12.6	3.96	24.7	59.8	39.8	19.2
						18.4	24.5	13.2

"XY" mixture consists of xylidin and alphanapthylamene in varying proportions, and is used very extensively in the flotation of some ores.

Test #28.

A preliminary test was carried out using "XY" mixture and leaching with 5# /ton of Na$_2$CO$_3$. The result was sufficiently satisfactory to warrant further investigation. A good grade of copper was obtained (20.7%) with a differential float, the extraction of copper being 71.9% and the nickel 27.4% while the iron was limited to 13.6%.

It was decided to run another test similar to #28 with slightly more "XY" mixture and to collect the tailings for retreatment.

Test #29.

The addition of further oil served only to increase the extraction of both copper and nickel slightly, the grade remaining the same.

Test #30.

The tails from test #29 were collected in tubs and pumped back into a settling cone and the excess water was siphoned off after the pulp had settled.

The tailings were pumped back to the Pachuca tank and agitated. A difficulty was experienced at this point, due to the froth that collected on the surface of the pulp. The tailings were already mixed with oil, and the air supplied to the Pachuca tank formed a voluminous froth which was sufficient to upset any calculations based on the extraction. As much of the froth as possible was recovered and added to the concentrates.

The concentrate was fair, showing that a retreatment was advantageous.

The combined extraction of test #29 and #30 was Cu. 80.4%, Ni. 36.6%, Fe. 14.9%, with a grade of Cu. 26.40%, Ni. 8.05%, and Fe. 53.6%.

Test #31.

Since test #13 was one of the best results it was decided to duplicate it as far as possible and re-run the tailings.

The first extraction was lower than test #13, but the grade was better.

The treatment of the tailings produced a very low grade concentrate and fair extraction.

The combined extraction was very disappointing, amounting to 72.2% Cu., 47.3% Ni., and 27.5% Fe.

The next three tests determined the relative advantages of XY mixture with varying amounts of Na_2CO_3, and also with a neutral circuit.

Test #33.

Treating with 5# Na_2CO_3 a good grade of concentrate was obtained with good extraction of copper. This proved one of the best tests up to the present. The grade and extraction of copper was very good and the nickel was also floated to a greater degree than before.

Test #34.

Na_2CC_3 was increased to 10# per ton, but with no better result, as the table shows. 5# /ton of Na_2CO_3 was sufficient.

Test #35.

XY mixture in a neutral circuit did not prove as successful as previous tests in a similar circuit. The grade of Cu. was excellent but the extraction was not up to the mark of preceding experiments.

Test #36.

The retreatment of tailings in the 10 cell machine had not been very successful, so it was decided to collect the tailings from a test carried out with 5% GNS #5 and FPL #24 and Na_2CO_3, and retreat them in approximately 1000 gram lots in the one cell M.S. machine.

The grade and extraction of the copper was good but the nickel was poor, in the preliminary test in the 10 cell machine.

36, A, B, C, D.

The retreatment tests in the small machine did not prove of any value. Scarcely any froth was formed. The oil already in the pulp may have been the cause, but the results were too poor to give a reasonable extraction.

Summary of Series VI.

1. XY mixture produced the best all-round test.
2. Na_2CO_3 and XY mixture were more effective than the XY mixture in a neutral circuit.
3. The retreatment of tailings was not very successful due to the froth on the top of the Pachuca.
4. In the retreatment of tailings, the oil already present had a detrimental effect in the formation of a froth in the spitzkastens.

Series VII.

No experimentation had been carried out in an acid circuit and before any conclusions could be drawn with respect to the best treatment, it was necessary to include this phase.

Consequently three tests were carried out, using H_2SO_4 as a leach..

			Grade.			Extraction.		
Test.	Oil	Reagent.	Cu.%	Ni.%	Fe.%	Cu.%	Ni.%	Fe.%
#38	5% G.N.S.#5 95% FPL #24	H_2SO_4 10#/ton	9.65	2.22	35.9	76.0	35.0	26.3
						24.0	65.0	73.7
#39	1% GNS #5 95% FPL #24	H_2SO_4 10#/ton	11.6	2.46	37.1	79.0	40.1	31.8
#40	10% GNS #5 90% FPL #24	H_2SO_4 10#/ton	6.87	3.42	38.2	86.2	73.9	61.2
#41	ditto	Na_2CO_3 5#/ton	7.8	2.58	28.1	85.5	70.0	47.2

Test #38.

The results of this test showed that H_2SO_4 with this oil was no better than when using Na_2CO_3, and certainly not as good as a neutral circuit. The copper was fair but the nickel very poor. The reagents seemed to have the effect of keeping down the nickel but having no effect on the copper.

Test #39.

The use of 1% GNS #5 and 99% FPL #24 gave approximately the same result. The flotation of copper was a little better both in grade and extraction, but the difference was not sufficiently marked to determine which was the better oil mixture.

Test #40.

Oil GNS #5 was increased to 10% in this run and the pulp was leached with 10# /ton of H_2SO_4.

The result was noteworthy in comparison with previous tests. The extraction of copper and nickel was 86.2% and 73.9% respectively. The iron extraction amounted to 61.2%, bearing out the conclusion that the nickel and chalcopyrite were closely related.

The grade of concentrate was low but the original aim of floating all the sulphides was approaching realization.

Test #41.

It was thought advisable to run one test using this oil and leaching with $Na2CO3$ to prove beyond all doubt whether the oil or the Na_2CO_3 increased or decreased extraction.

The results were almost identical with the previous test, showing that the change in oil, and not the reagents used, gave the sudden increase in extraction.

Summary of Series VII.

1. H_2SO4 as a leach showed no improvement over the results obtained with any other reagent.
2. Increasing GNS #5 to 10% greatly increased the extraction.

Screen Analysis.

The ore treated thus far had been crushed through 60 mesh in the Huntingdon Mill.

The results of the last two tests had been very encouraging, hence it was decided to carry out a complete screen analysis on the feed, tails and concentrates of a test before progressing further.

The analysis was carried out on test #33 and the procedure was as follows:-

Approximately 80 gms. of the feed sample was weighed accurately and placed in a pan. Enough water was added to cover the sample and the mixture was then boiled for about five minutes. The pulp was next washed through a 200 mesh screen and the products, both through and on the screen, were dried and weighed.

The product on 200 mesh was placed on the 65 mesh screen of the screening machine, and a careful analysis carried out. The products on each screen were weighed carefully, and prepared for assaying.

The tails and concentrates of test #33 were treated in the same manner.

Referring to the accompanying table, the first column is the screen mesh. The second column is the per cent of material on each screen. The figure 89.1 refers to the per cent of tails in the feed, the remainder being concentrate. The fourth column is obtained by the product of columns 2 and 3. The sixth column is the assay of Cu. for each screen size. The seventh column is the product of 4 and 6. The eighth column is the

SCREEN ANALYSIS

	Screen	% on Screen	% Tails	Product		% Cu	Product	% Extraction		% Ni	Product	% Extraction		% Fe	Product	Extraction
Tails	+65	5·4	89·1	48·1		0·49	236	49·2		0·26	125	91·0		9·1	4370	93·5
	+100	16·4		1460		·29	424	18·5		·55	804	61·2		11·5	16800	86·7
	+150	17·1	"	1521		·19	290	9·1		·40	608	35·3		11·9	18190	80·0
	+200	9·1	"	810		·30	243	12·3		·26	211	29·0		11·8	9600	76·0
	-200	52·0		4630		·44	2040	18·0		·94	2720	32·8		10·7	49650	73·3
			% Conc		A		3283				4468				98610	
Concs.	+65	1·35	10·9	14·8		16·5	244	50·8		1·60	23·7	9·0		21·5	318	6·5
	+100	10·60		116·0		16·1	1870	81·5		4·40	510·0	38·8		22·5	2610	13·3
	+150	18·20	"	199·0		14·6	2905	90·9		5·63	1120·0	64·7		23·5	4675	20·0
	+200	10·75	"	117·5		15·1	1725	87·7		6·05	712·0	71·0		24·5	7990	24·0
	-200	59·10	"	646·5		14·4	9300	82·0		6·34	409·0	67·2		28·0	18075	26·7
					B		16044				6455				28668	
					A		3283				4468				98610	
			% Feed		D		19327				10923				127278	
Feed	+65	4·8	100·0	480		1·02	490			0·55	264			10·8	518	
	+100	15·75	"	1575		1·46	2225			1·25	1910			12·0	1829	
	+150	17·10	"	1710		2·04	3490			1·14	1950			13·4	2290	
	+200	8·90	"	890		2·20	1958			1·16	1030			15·0	1335	
	-200	53·95		5395		2·44	13150			1·30	7020			12·7	6850	
					C		21313				12174				128220	
							2·13				1·22				12·8	
							1·93				1·09				12·7	

extraction on each screen. The nickel and iron are carried out in the same way.

When all these figures have been obtained the summation of the tails and concentrate should equal the feed, for Cu., Ni. and Fe.

This is shown in the table. "D" is the summation of "A" and "B" and is very nearly equal to "C".

A check of this kind proves that no large error is present.

It will be noticed from the table that the greatest proportion of values was obtained in the finer sizes. The greatest loss of nickel occurred in 200 mesh.

Since the values appeared to be in the finer sizes, it was decided to carry out a few tests, using a 100 mesh screen in the Huntingdon Mill. It was thought that the finer grinding would cause a greater separation of gangue and mineral and a better grade of concentrate could be obtained.

Series VIII.

			Grade.			Extraction.		
Test	Oil	Reagent	Cu.%	Ni.%	Fe.%	Cu.%	Ni.%	Fe.%
#42	10%GNS #5 90 %FPL #24	-	6.62	3.26	29.5	85.0	88.4	54.2
#43	"	Na2CO3	7.40	3.25	25.8	81.2	72.3	48.7
#44	"	H_2SO_4	9.70	4.18	34.9	84.4	75.0	52.3

Test #42.

Since #40 was such a success with 10% GNS #5 and 90% FPL #24, the same oil was used in this test. The ore was ground through

100 mesh and the run was carried out in a neutral circuit.

The extraction was indeed startling, 85% of the Cu. being recovered and 88.4% of the nickel. The grade was very poor, but a great deal had been accomplished in floating the sulphides, and it served as a starting point for differential work.

Test #43.

The use of Na_2CO_3 in this run cut down the extraction appreciably, though the result was still good. The addition of the Na_2CO_3 here served again to show that the oil and not the reagent was responsible for the increased extraction.

Test #44.

The addition of H_2SO_4 produced a higher grade of concentrate than in #40. The extraction was almost identical with that test. The inference was that the finer grinding produced a greater % of free mineral particles, and the H_2SO_4 had a better chance to assist in their flotation.

Summary of Series VIII.

1. A neutral circuit proved the best of the series.
2. Finer grinding appeared to have a beneficial effect.
3. H_2SO_4 proved a better reagent than Na_2CO_3, giving a cleaner concentrate.

In the comparison of this series with others, it was necessary to modify statement two above. At first glance it had appeared that finer grinding was the clue to the better separation of sulphides, but test #17 proved to be almost an equal of #42, both in grade and extraction.

Test #42 gave a higher extraction of nickel, which placed it slightly ahead of test #17, and it is doubtful whether this was due to the change in oil or the finer grinding.

			Grade.			Extraction.			
Test	Oil	Reagent.	Cu.%	Ni.%	Fe.%	Cu.%	Ni.%	Fe.%	Screen
#17	5% GNS #5 95% FPL #24	-	5.25	3.33	33.7	86.9	79.1	57.0	- 60
#40	10% GNS #5 90% FPL #24	-	6,62	3.26	29.5	85.0	88.4	54.2	-100

The above table shows clearly the similarity between tests #17 and #40.

The end of the session was approaching and it was impossible to continue experimental work. The next series of tests would have proved very interesting due to the promising character of series VIII.

Mr. Saunders carried on further experimental work but the writer did not obtain his final results.

CONCLUSION.

The experimental work has not been successful from the viewpoint of differential flotation. Considerable success, however, was attained in the total flotation of the sulphides.

The extraction of nickel was advanced from 60% to 88%. The copper from 60% to 85%. Further experimentation would be necessary to discover if the iron could be kept down while upholding this high extraction.

The nearest approach to the solution of the problem stated in the forepart of this paper was obtained from Test #33.

"XY" mixture with a leach of 5# /ton Na_2CO_3 produced a concentrate running 21.87% copper plus nickel with an 83.5% extraction of copper and 61.3% nickel, with only 23% iron.

Test #42 produced the best extraction of copper and nickel but the combined grade amounted to only 9.88%.

However, certain conclusions may be drawn from the information obtained.

1. A neutral circuit is better than an alkaline or acid circuit in the treatment of this ore.
2. H_2SO_4 has a slight advantage over Na_2CO_3 as a leach.
3. NaCl seemed to keep all sulphides down.
4. A mixture of 10% GNS #5 and FPL #24 gives the highest extraction of the sulphides.
5. XY mixture produces the highest grade of concentrate accompanied by good extraction.

6. Grinding finer than 60 mesh is not advantageous to any great extent.
7. The 10-cell Continueus M.S. Machine does not permit of the ore being treated for a sufficient length of time.

The copper nickel ores have proved to be amenable to concentration by flotation.

The replacement of the Blast furnace by this process does not seem to be an impossibility. The introduction of rougher cells and cleaner cells would no doubt give the required grade and extraction of sulphides.

The interest being shown in flotation treatment by the nickel companies is the surest indication that it is a desirable substitution.

In conclusion, the writer wishes to express his appreciation of the advice and ideas tendered by Prof. Bell and Mr. Erlenborn towards the subject matter of this paper.

R. G. Anderson

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 1

DATE Oct. 19, 1922. 19

ORE NO. 158

PULP RATIO 7 : 1

R.P.M. IMPELLER

PULP TEMP.	
START	°
FINISH	°
MEAN	°

NOTES:

289.5 # of ore crushed through 60 meshin Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.10						Transferred		
16.15	NaOH			270 g		Pulp Ratio 3:1		
10.55	Water					" " 6:1		
11.50						Feed started		
	Oil 30 drops/min. Feed water @ 0.5							
12.05						Beginning of test.		
12.31						End of test		
	Feed too erratic-dropping from 25.13# of pulp/min. to							21.8#
	Pipes clogged.							
						Feed	502	
	This test a trial run only.					Tails	501	
						Concs.	500	

REAGENT	%	LBS. P.T.
Oil:-		
FPL #24		5.0
NaOH		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	%	WEIGHT	%	WEIGHT	%	WEIGHT	%	WEIGHT	PERCENT OF TOTAL			

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FLOTATION TEST NO. 2

NOTES: 287.2 # of ore crushed through 60 mesh in Huntingdon Mill.

DATE Oct. 23, 1922 19

ORE NO. 158

PULP RATIO : 1

R.P.M. IMPELLER

PULP TEMP.	
START	°
FINISH	°
MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.00						Transferred		
10.20	~~Water~~	NaOH		266 g		Pulp Ratio 1:1		
10.30	Water							
		Compressor belt broke.						
3.25						Feed started		
	Oil 60 drops/min.			feed water - 0.85				
						Feed	505	
						Tails	503	
						Conc.	506	
	Variation in feed and pulp ratio too great to compute extraction							

REAGENT	%	LBS. P.T.
Oil:-		
FPL #24		

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	506		21.6		0.91		25.0			
	503		0.53		0.51		12.3			
	505		1.29		0.63		12.9			

PERCENT OF TOTAL			

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FLOTATION TEST NO. 3

NOTES:

239.8# of ore - 60 mesh in Huntingdon Mill.

DATE October 26,1929

ORE NO. 158

PULP RATIO : 1

R.P.M. IMPELLER

PULP TEMP.		
START		°
FINISH		°
MEAN		°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.00						Transferred		
10.15	NaOH			224g		Pulp Ratio 1.2:1		
10.45	Water			370#		" " 3.3:1		
11.25						Feed started.		
	Oil 60 drops/min. Feed water @ 0.70							
11.26						Start of test		
12.45						End of test		
						Feed	507	2.7 #
						Tails	508	
						Concs.	509	1.73 #
						Feed 2.7 #/min.		
						Total feed 51.3#		

REAGENT	%	LBS. P.T.
Oil:-		
FPL #24		3.5
NaOH		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	509	3.3	20.8	68.5	0.76	2.5	26.0	85.8			41.5	3.4	6.9	
	508	96.7	1.0	96.7	0.73	70.5	11.9	1150.0			48.5	96.6	93.1	
				165.2		73.0		1235.8			100.0	100.0	100.0	
	507		1.65		0.75		12.3							

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FLOTATION TEST NO. 4

NOTES:

275# ore crushed through 60 mesh in Huntingdon Mill

DATE Nov. 3.1922. 19

ORE NO. 158

PULP RATIO 3.78: 1

R.P.M. IMPELLER

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
9.55						Transferred		
10.15	NaoH			258 g.		Pulp Ratio 1.7:1		
10.45	Water			345 #		" " 3.1:1		
11.05						Feed started		
						Oil 96 drops/min		
11.20						Beginning of test		
11.45						End of test		
						510	Feed	4.37
						511	Tails	
						512	Concs.	11.75
						Feed 4.37#/min		
						Total Feed 109#		

REAGENT	%	LBS. P.T.
Oil:-		
F.P.L.#24		3.6
NaOH		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe.	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	512	10.8	12.7	137.0	2.90	31.4	29.4	317.5			86.6	39.2	23.6	
	511	89.2	0.24	21.4	0.55	49.0	11.6	1032.0			13.4	60.8	76.4	
				158.4		80.4		1348.5			100.0	100.0	100.0	
—														
				1.58		0.80		13.6						
	510		1.67		0.83		13.6							

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FLOTATION TEST NO.	5
DATE	November 5,1929
ORE NO.	158
PULP RATIO	3.58: 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

294 # ore crushed through 60 mesh in Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.25						Transferred		
10.40	NaOH			333 g		Pulp Ratio 1.54:1		
11.10	Water			409#		" " 3.22:1		
11.40						Feed started		
						Oil 114 drops/min		
11.57						Beginning of test		
12.25						End of test		
						Feed aver.A&B	513	4.59#
						Tails		
						1- Conc.	514	19.31#
						2- Conc.	515	4.53
						Feed 4.59#/min		
						Total feed 128.5 #		

REAGENT	%	LBS. P.T.
Oil:-		
FPL # 24		4.2
		-5.0-
NaOH		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe.	
	514	15.0	7.77	116.4	3.08	46.2	22.4	336.0			73.8	48.0	22.8	
	515	3.5	0.58	2.0	0.87	3.0	13.5	47.3			1.3	3.1	3.2	
	Tails	81.5	0.41	39.6	0.57	46.8	13.3	1086.7			24.9	48.9	74.0	
				158.0		96.0		1470.0			100.0	100.0	100.0	
	513		1.58		0.96		14.7							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 7

DATE Nov. 13,1922 19
ORE NO. 158
PULP RATIO 11.9 : 1
R.P.M. IMPELLER 1200

PULP TEMP.	
START	°
FINISH	°
MEAN	°

NOTES:

240 #Ore crushed through 60 Mesh in Huntington Mill.

Neutral Circuit.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
3.05	Water					Pulp Ratio 4.6:1		
						Water feed cock @	0.55	
4.10						Beginning of test		
4.40						End of test.		
						Oil 75 drops/min		
						Feed	516	
						Tails	517	
						Conc	518	
						Feed 1.27#/min		
						Total feed 37.67#		

REAGENT	%	LBS. P.T.
Oil:-		
FPL #24		9.5

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	518	14.3	10.3	147.0	3.41	48.6	24.8	354.0			78.5	43.2	20.6	
	517	85.7	0.47	40.3	0.75	64.2	15.85	1359.0			21.5	56.8	79.4	
				187.3		112.8		1713.0			100.0	100.0	100.0	
				1.87		1.13		17.1						
	516		1.65		0.97		16.8							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 8

DATE Nov 14.1922. 19

ORE NO. 158

PULP RATIO 7.8 : 1

R.P.M. IMPELLER 1200

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

240 # Ore crushed through 60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
11.50						Transferred		
11.55	NaOH					Pulp Ratio 2.95:1		
						Agitated for 30 mins.		
12.35	Water					Feed cock #0.5		
12.38						Beginning of test		
						Oil 60 drops/min		
1.08						End of test.		
	Note:-	10 sec. samples/5 min of feed and tails						
						Feed	519	2.04 #
						Tails	520	
						Conc	521	8.37 #
						Feed 2.04#/min. Total feed 59.16#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	4.7
FPL #24	95%	
NaOH		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	521	14.2	7.85	111.3	3.51	49.8	24.5	348.0			78.5	50.0	48.2	
	520	85.8	0.36	30.8	0.58	49.8	15.5	1330.0			21.5	50.0	51.8	
				142.1		99.6		16.78			100.0	100.0	100.0	
				1.42		1.00		16.78						
	519		1.40		0.95		14.7							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	9
DATE	Nov. 15, 1922, 19
ORE NO.	158
PULP RATIO	7.8 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

240 # ore -60 mesh in Huntingdon Mill

Neutral Circuit

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.15						Transferred.		
	water					Pulp Ratio 4.25:1		
10.25						Feed started		
	Oil 60 drops/min.-Feed water @					0.55		
10.44						Start		
11.19						End		
						Feed	522	2.16
						Tails	523	
						Conc	524	12.57
						Feed 1.85#/min.		
						Total feed 63.14#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 5.1
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	524	20.0	7.38	147.6	4.48	89.6	33.2	661.			81.9	75.8	37.8	
	523	80.0	0.41	32.8	0.36	28.8	13.6	1088.			18.1	24.2	62.2	
				180.4		118.4		1749.			100.0	100.0	100.0	
				1.80		1.18		17.49						
	522		1.81		1.12		18.1							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.	FLOTATION TEST NO. 10

NOTES:

257 # ore -60 mesh in Huntingdon Mill

Neutral Circuit

DATE	Nov 15,1922 19
ORE NO.	158
PULP RATIO	7 : 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
318						Transferred		
3.20	Water					Pulp Ratio 4:1		
						Feed cock @ 0.38		
3.40						Feed started		
						Oil 30 drops/min		
3.45						Beginning of test.		
3.55	Feed plugged, discarded samples.							
4.06						Beginning of test		
4.36						End of test		
						Feed	525	2.02#
						Tails	526	
						Conc	527	3.37#
						Feed 1.96#/min		
						Total feed 59.16#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 3.0
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	527	5.7	14.8	84.5	5.74	32.7	28.1	160.0			61.0	33.2	9.1	
	526	94.3	0.57	53.7	0.70	65.9	16.9	1590.0			39.0	66.8	90.9	
				138.2		98.6		1750.0			100.0	100.0	100.0	
				1.38		0.99		17.5						
	525		1.50		1.14		17.4							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	11
DATE	Nov.17.1922. 19
ORE NO.	158
PULP RATIO	5.5 : 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

240# ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.50						Transferred		
2.55	Na_2S					Pulp Ratio 2.72:1		
						Agitated for 30 mins.		
3.38						Feed started		
		Oil	32 drops/min		Water	feed cock @ 0.32		
3.43						Beginning of test		
4.13						End of test		
						Feed	528	1.96#
						Tails	529	
						1 Conc.	530	3.25
						2 Conc	531	2.16
						Feed 1.96#/min.		
						Total feed 57.15#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 2.48
FPE #24	95%	
Na_2S		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe
	530	5.7	14.9	85.0	3.43	19.5	28.7	164.0			61.8	18.2	8.7
	531	3.7	7.8	28.8	5.85	21.6	29.1	107.5			20.8	20.2	6.5
	529	90.6	0.26	23.5	0.73	66.1	16.5	1495.0			17.4	61.6	84.8
				138.3		107.2		1766.5			100.0	100.0	100.0
				1.38		1.07		17.7					
	528		1.29		1.05		17.5						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 12

DATE Nov 24, 1922. 19

ORE NO. 158

PULP RATIO 8.6 : 1

R.P.M. IMPELLER 1200

PULP TEMP.	
START	°
FINISH	°
MEAN	°

NOTES:

245 # ore crushed through 60 mesh in Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.40						Transferred		
10.45	Na_2S			271 g.		Pulp Ratio 2.02:1		
11.15	Water			320 #		" " 3.81:1		
11.30						Feed started		
						Oil 56 drops/min		
11.45						Beginning of test.		
12.10						End of test		
						Feed	532	2.86#
						Tails	533	
						Conc	534	2.56
						Feed 3.44#/min.		
						Total feed 83.7 #		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 2.5
FPL #24	99%	
Na_2S		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	534	3.0	22.6	67.8	3.28	9.84	29.1	87.3			44.2	8.0	5.4	
	533	97.0	0.88	85.0	1.17	113.6	15.71	516.0			55.8	92.0	94.6	
				152.8		123.3		1603.0			100.0	100.0	100.0	
	532		1.50		0.97		15.7							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 13

DATE Nov. 28,1922. 19

ORE NO. 158

PULP RATIO 14.2 : 1

R.P.M. IMPELLER

PULP TEMP.	
START	°
FINISH	°
MEAN	°

NOTES:

246 # ore -60 mesh in Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.40						Transferred		
2.50	Na_2CO_3			200 g		Pulp Ratio 2.1:1		
3.20	Water			564 #		" " 3.72:1		
3.40						Feed started		
	Oil 48 drops/min.-Feed water @ 0.35							
4.00						Start		
4.40						End		
						Feed	535	1.18
						Tails	536	
						Conc	537	8.05
						Feed 0.89#/min.		
						Total feed 35.4#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 8.4
FPL #24	99%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	537	22.7	8.6	195.0	2.77	64.8	32.3	740.			86.0	58.1	38.2	
	536	77.3	0.41	31.6	0.59	45.2	15.5	1200.			14.0	41.9	61.8	
				226.6		110.0		1940.			100.0	100.0	100.0	
				2.26		1.10		19.4						
	535		1.24		1.07		17.4							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 14

DATE Nov 29.1922 19

ORE NO. 158

PULP RATIO 7.6 : 1

R.P.M. IMPELLER 1200

PULP TEMP. START °

FINISH °

MEAN °

NOTES:

237 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.05						Transferred		
2.20	NaCL			273 g		Pulp Ratio 1.6:1		
2.40	Water			576 #		" " 3.5:1		
3.10						Feed started		
						Oil 47 drops/min.		
3.30						Beginning of test.		
4.15						End of test.		
						Feed	538	2.98#
						Tails	539	
						Conc.	540	3.29
						Feed 1.98#/min.		
						Total Feed 86.85 #		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 3.8
FPL #24	99%	
NaCl		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		— 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% FE	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	 Ni	 Fe	
	540	3.7	16.0	60.7	4.26	15.7	29.9	112.0			46.2	13.6	6.6	
	539	96.3	0.73	70.2	1.07	104.0	18.4	1760.0			53.8	86.4	93.4	
				130.8		119.7		1872.0			100.0	100.0	100.0	
	538		1.55		1.24		18.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 15

DATE	Nov.30,1922. 19
ORE NO.	158
PULP RATIO	9.8 : 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

270 # ore crushed through 60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.05						Transferred		
10.10	NaOH			306 g				
	NaCl			306 g		Pulp Ratio 1.83:1		
10.40	Water			586 #		" " 5.9:1		
11.05						Feed started		
		Oil 60 drops/min. Feed water						
11.28						Beginning of test		
12.58						End of test		
						Feed	541	1.95#
						Tails	542	
						Conc	543	3.48#
						Feed 1.95#/min.		
						Total feed 56.9#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.1
FPL #24	99%	
NaOH		5.0
NaCl		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	543	6.1	16.0	93.0	2.84	17.3	27.7	164.8			50.1	15.2	9.8	
	542	93.9	1.03	96.7	1.03	96.7	16.6	1560.0			49.9	84.8	90.2	
				194.7		114.0		1724.8			100.0	100.0	100.0	
	541		1.92		1.07		16.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	16
DATE	Nov.30,1922 19
ORE NO.	158
PULP RATIO	8.9 : 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

220 # of ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.15						Transferred		
2.25	NaOH			250 g				
	$CuSO_4$			250 g		Pulp Ratio 2.0:1		
2.55	Water			600#		" " 4.45:1		
3.10						Feed started		
	Oil 66 drops/min. Feed water @							
3.21						Beginning of test		
3.51						End of test.		
						Feed	544	2.10#
						Tails	545	
						Conc	546	1.72#
						Feed 2.0 #/min.		
						Total feed 61.25#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.3
FPL #24	99%	
NaOH		5.0
$CuSO_4$		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe
	546	2.80	8.5	23.8	3.88	10.7	33.4	93.5			15.1	12.4	5.3
	545	97.2	1.34	130.0	0.78	75.6	16.3	1585.0			84.9	87.6	94.7
				153.8		86.3		1678.5			100.0	100.0	100.0
					6.73								
	544		1.91		1.17		18.1						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	11
DATE	December 4, 1922
ORE NO.	158
PULP RATIO	9.2 : 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

230 # of ore -60 mesh in Huntingdon Mill

Neutral circuit.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.00						Transferred		
	Water					Pulp Ratio 4.03:1		
2.30						Feed started		
	Oil 75 drops/min. Feed water @ 0.55- 10#/min.							
2.43						Start		
3.13						End		
						Feed	547	2.13#
						Tails	548	
						Conc	549	18.0
						Feed 2.13 #/min		
						Total feed 62.1#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 5.7
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		— 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe	
	549	29.0	5.25	152.0	3.33	96.5	33.7	976.0			86.9	79.1	57.0	
	548	71.0	.33	23.4	.36	25.5	11.8	840.0			13.1	20.9	43.0	
				175.4		122.0		1816.0			100.0	100.0	100.0	
	547		1.76		1.22		18.2							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 18

DATE Dec. 4, 1922. 19

ORE NO. 158

PULP RATIO 18.5: 1

R.P.M. IMPELLER 1200

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

This test was run with ore left in Pachuca tank after finishing test # 17

The pulp was diluted to 8:1 ratio in Pachuca tank before beginning the test.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
3.30						Feed started		
	Oil 75 drops/min. Water feed cock @ 0.55							
3.39						Start of test.		
4.09						End " "		
	Reduced oil but increased it again.							
						Feed	550	1.06#
						Tails	551	
						Conc.	552	5.66#
						Feed 1.06#/min		
						Total feed 29.9#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 11.7
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	552	18.9	6.76	127.8	4.00	75.6	35.7	67.5			86.0	63.8	38.5	
	551	81.1	0.41	20.8	0.53	43.0	13.2	1080.0			14.0	36.2	66.5	
				148.6		118.6		1755.0			100.0	100.0	100.0	
				1.48		1.19		17.5						
	550		1.65		1.16		18.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 19

DATE Dec 6,1922. 19

ORE NO. 158

PULP RATIO 10 : 1

R.P.M. IMPELLER 1200

PULP TEMP. START °

PULP TEMP. FINISH °

PULP TEMP. MEAN °

NOTES:

210 # of ore ↓ through 60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.35						Transferred		
10.40	Na_2CO_3			227 g		Pulp Ratio 1.62:1		
11.10	Water			676 #		" " 4.6:1		
11.40						Feed started		
	Oil 80 drops/min. Feed water @ 0.55-10#/min.							
11.53						Start		
12.23						End		
						Feed	553	1.89#
						Tails	554	
						Conc.	555	10.75#
						Feed 1.89#/min.		
						Total feed 55.1#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 6.8
FPL #24	95%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe	
	555	19.5	5.17	161.0	3.21	62.5	36.0	702.0			70.8	58.5	39.0	
	554	80.5	.52	41.8	0.55	44.3	13.6	1100.0			29.2	41.5	61.0	
				142.8		106.8		1802.0			100.0	100.0	100.0	
				1.42		1.07		18.0						
	553		1.50		1.24		18.9							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	20
DATE	Dec 6, 1922.
ORE NO.	158
PULP RATIO	25.3 : 1 ?
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

Residual Pulp from test #19
Diluted in Pachuca to 9:1 pulp ratio
Feed water @ 0.55

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
12.35						Feed started		
	Oil 60 drops/min.							
12.46						Start		
1.16						End		
						Feed	556	0.78
						Tails	557	
						Conc	558	3.75
						Feed 0.78#/min		
						Total feed 22.7#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 12.1
FPL #24	95%	
Na_2CO_3		Test #19

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe
	558	16.05	7.85	129.5	3.36	55.5	34.45	570.0			62.5	62.5	47.6
	557	83.95	1.06	78.0	0.45	33.2	12.9	946.0			37.5	37.5	52.4
				207.5		88.7		1516.0			100.0	100.0	100.0
				2.07		0.89		15.16					
	556		1.91		1.02		16.85						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	21
DATE	Dec. 6,1922 19
ORE NO. 158	
PULP RATIO	7.9 : 1
R.P.M. IMPELLER	

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

219 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
3.25						Transferred		
3.32	Na_2CO_3			476 g		Pulp Ratio 1.7:1		
4.03	Water			690 #		" " 5.7:1		
4.35						Feed started		
	Oil 72	drops/min.	Feed	water @		0.45		
4.41						Start		
5.11						End		
						Feed	559	2.43
						Tails	560	
						Conc	561	14.68#
						Feed 2.43#/min.		
						Total feed 72.90#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 4.7
FPL #24	95%	)
Na_2CO_3		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	561	20.7	5.55	115.0	3.26	67.65	33.7	698.			78.0	64.3	38.7	
	560	79.3	0.41	32.5	0.48	38.30	13.9	1105.			22.0	35.8	61.3	
				147.5		105.5		1800.			100.0	100.0	100.0	
				1.47		1.05		18.0						
	559		1.45		1.12		17.9							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 22

NOTES:

Residual ore from test 21 used--diluted to 10:1 pulp ratio
in Pachuca tank.Feed water at 0.55

DATE	Dec .6 1922. 19
ORE NO.	158
PULP RATIO	23 : 1 ?
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
5.25						feed started		
						Oil 72 drOps/min		
5.31						Start		
5.51						End		
						Feed	562	0.59#
						Tails	563	
						Conc	564	3.51
						Feed 0.88#/min		
						Total feed 16.9#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 13/1
FPL #24	95%	
Na_2CO_3		Test #21

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% CU	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	564	20.8	4.70	97.6	2.57	53.4	28.7	596.			74.0	54.8	34.5	
	563	79.2	0.41	32.4	0.53	42.0	13.5	1072.			26.0	45.2	65.5	
				130.0		95.4		1668.			100.0	100.0	100.0	
	562		1.18		1.16		17.6							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 23

NOTES:
210# of ore -60 mesh in Huntingdon Mill

DATE Dec. 11, 1922 19
ORE NO. 158
PULP RATIO 8.2 : 1
R.P.M. IMPELLER
PULP TEMP. START °
PULP TEMP. FINISH °
PULP TEMP. MEAN °

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.20						Transferred		
2.25	Na_2CO_3			238 g.		Pulp Ratio 1.54:1		
2.55	Water			720 #		" " 4.2:1		
3.15						Feed started		
	Oil 75 drops/min.			Feed	water	@ 0.55-10#/min.		
3.20						Start		
3.50						End		
						Feed	565	2.29#
						Tails	566	
						Conc.	567	8.25#
						Feed 2.29#/min.		
						Total feed 66.8#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	5.3
FPL #24	99%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe
	567	12.35	6.8	84.0	3.49	43.1	24.4	302.			43.5	26.6	15.5
	566	87.65	1.24	108.7	1.16	101.5	19.3	1690.			56.5	73.4	84.5
				192.7		144.6		1992.			100.0	100.0	100.0
				1.92		1.45		19.9					
	565		1.90		1.30		20.6						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 24

DATE Dec. 11.1922. 19

ORE NO. 158

PULP RATIO 17.1: 1

R.P.M. IMPELLER

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

Pulp Residue in Pachuca Tank from test # 23

Diluted to 8:1 Pukp Ratio.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
4.00						Feed started		
	Oil 48	drops/min.						
4.10						Start of test.		
4.40						End		
						Feed	568	1.14
						Tails	569	
						Conc	570	1.70
						Feed 1.14#/min		
						Total feed 33.50#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.0
FPL #24	99%	
Na_2CO_3		Test #23

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	 Ni	 Fe	
	570	5.1	17.4	88.7	3.80	19.4	29.5	150			51.5	18.3	9.5	
	569	94.9	0.88	83.3	0.92	87.2	15.2	1440.			48.5	81.7	90.5	
				172.0		106.6		1590.			100.0	100.0	100.0	
				1.72		1.07		15.9						
	568		1.90		1.05		16.8							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	25
DATE	Dec.13,1922 19
ORE NO.	158
PULP RATIO	8.93: 1
R.P.M. IMPELLER	1200
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

300 # ore -60 mesh in Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.50						Transferred		
10.55	Na_2CO_3			681 g		Pulp Ratio 1.65:1		
11.25	Water			705 #		" " 4.18:1		
11.38						Feed started.		
	Oil	80 drops/min. Feed water @ 0.55						
11.45						Start of test		
12.15						End		
						Feed	571	2.14#
						Tails	572	
						Conc	573	8.75#
						Feed 2.07#/min.		
						Total feed 62.15#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 6.0
FPL #24	99%	)
Na_2CO_3		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	573	14.1	8.15	115.0	5.00	70.5	35.4	499.		
	572	85.9	0.67	57.5	0.73	62.7	15.9	1365.		
				172.5		133.2		1864.		
				1.72		1.33		18.6		
	571		1.60		1.29		19.4			

PERCENT OF TOTAL

Cu	Ni	Fe	
66.9	53.5	26.7	
33.1	46.5	73.3	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.	FLOTATION TEST NO.	26

NOTES:

187 # ore -60 mesh in Huntingdon Mill.

New launder made for machine allowing a product to be taken from each cell.

DATE	Jan 25,1923 19
ORE NO.	158
PULP RATIO	9.45 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.7
FPL #24	99%	
Na_2CO_3		5.0

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.10						Transferred		
2.18	Na_2CO_3			180 g		Pulp Ratio 1.94:1		
2.48	water			465 #		" " 4.6:1		
2.48	Feed started.	Oil 72 drops/min.				Feed water 9#/min.		
						(1.	574	1.45#
3.12	Start of test					(2.	575	.91
3.52	End of test.					(3.	576	.84
						Concs. (4.	577	.55
						(5.	578	.50
						(6.	579	.34
						7.	580	
						Tails	581	
						Feed	582	2.92#
						Feed 1.95#/min. Total feed 78.0#		

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe
	574	1.86	18.8	34.9	5.30	9.85	26.7	49.6			48.1	32.2	11.0
	575	1.17	15.8	18.5	6.01	7.04	26.5	31.0			51.9	67.8	89.0
	576	1.08	13.6	14.7	5.94	6.55	25.8	27.8					
	577	.71	12.7	9.0	6.75	4.22	25.8	18.3					
	578	.64	12.2	7.8	10/45	4.31	28.8	18.4					
	579	.44	12.7	5.6	4.07	4.59	28.0	12.3					
	580	.54	9.4	5.1		2.19	24.6	13.3					
	581	93.60	1.1	102.0			14.6	1365.0					
	582		2.2		1.08		16.0						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 21

DATE Jan. 17,1923 19

ORE NO. 606

PULP RATIO 8.7 : 1

R.P.M. IMPELLER

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

195 # Ore crushed -60 mesh in Huntingdon Mill.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.10						Transferred		
2.18	Na_2CO_3			220 g				
	NaCl			220 g		Pulp Ratio 2.04:1		
2.48	Water			585 #		" " 5:1	583	1.45
3.00	Feed started-Feed water @ 0.55-Oil 72 drops/min.						584	.85
3.06						Start	585	.62
3.36						End	586	.43
							587	.39
							588	.30
							589	.36
						Tails	590	62.20
						Feed	591	2.22
						Feed 2.2#/min.		
						Total feed 64.7#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.2
FPL #24	99%	
Na_2CO_3		5.0
NaCl		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	583	2.20	19.1	42.	5.86	12.90	25.8	57.0		
	584	1.28	17.1	21.8	6.30	8.08	26.0	33.3		
	585	.93	14.9	13.8	6.83	6.36	26.5	24.6		
	586	.64	14.1	9.0	6.77	4.34	26.9	17.2		
	587	.59	13.6	8.0	6.90	4.07	26.2	15.4		
	588	.45	14.0	6.3	6.96	3.13	25.4	11.4		
	589	.54	9.5	5.1	5.70	3.08	22.4	12.10		
	590	93.40	1.1	103.3	0.85	79.4	12.8	1194		
				209.43		121.36		1365.05		
	591	2.29			0.92		12.6			

PERCENT OF TOTAL

Cu	Ni	Fe	
51.0	36.0	12.5	
49.0	64.0	87.5	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 28

DATE Jan. 24,1923. 19
ORE NO. 606
PULP RATIO 8.5 : 1
R.P.M. IMPELLER

PULP TEMP.		
	START	°
	FINISH	°
	MEAN	°

NOTES:

200# ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.12						Transferred		
10.19	Na_2CO_3			227 g		Pulp Ratio 1.64:1		
10.49	Water			672 #		" " 4.4:1		
11.06						Feed started		
	Feed water @ 0.55-- Oil 56 increased to 84 drops/min.							
11.13						Start of test		
11.43						End of test		
						Feed	592	2.25
						Tails	593	
						Concs	594	4.54
						Feed 2.25#/min.		
						Total feed 65.6#		

REAGENT	%	LBS. P.T.
Oil:-		
X cake		4.2
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	594	6.9	20.7	142.8	4.52	31.2	26.8	185.		
	593	93.1	0.6	55.9	0.89	82.8	12.6	1172.		
				198.7		114.0		13.57		
				1.99		1.14		13.6		
	592		2.09		1.08		13.3			

PERCENT OF TOTAL

Cu	Ni	Fe	
71.9	27.4	13.6	
28.1	72.6	86.4	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 29

DATE Jan. 25 1923 19

ORE NO. 606

PULP RATIO 10.1: 1

R.P.M. IMPELLER

PULP TEMP. START °

PULP TEMP. FINISH °

PULP TEMP. MEAN °

NOTES:

180 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
597						Transferred		
10138	Na_2CO_3			202 g.		Pulp Ratio 1.70:1		
11.08	Water					" " 5.1:1		
11.30						Feed started		
	Oil 72 drops/min.-Feed water @ 0.5							
11.35						Start		
12.35						End		
						Feed	595	3.76
						Tails	598	
						Conc	597	8.43
						Feed 1.88#/min.		
						Total feed 109.3#		

REAGENT	%	LBS. P.T.
Oil:-		
X cake		6.1
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	597	7.7	20.9	106.8	4.52	34.8	23.7	182.5		
	598	92.3	0.5	46.1	0.66	60.8	12.0	1105.		
				206.9		95.6		1287.5		
				2.06		0.95		12.9		
	595		1.95		0.91		12.6			

PERCENT OF TOTAL

Cu	Ni	Fe	
77.2	36.5	14.2	
22.8	73.5	85.8	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.	FLOTATION TEST NO.	30

NOTES:

Retreatment of Tails of test #29

Returned to Pachuca and diluted to 5:1 pulp Ratio.

DATE Jan 27,1923. 19		
ORE NO. 606		
PULP RATIO		7.7: 1
R.P.M. IMPELLER		
PULP TEMP.	START	°
	FINISH	°
	MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.45						Agitation started		
10.55						Feed started		
	Oil 44 drops/min.							
11.01						Start		
11.26						End		
						Feed	598	1.68
						Tails	596	
						Concs.	599	1.64
						Feed 2.02#/min.		
						Total feed 49.2#		

REAGENT	%	LBS. P.T.
Oil:-		
X Cake		3.5

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	 Ni	 Fe	
	599	3.3	5.50	18.1	3.53	11.6	29.9	1500.			43.9	17.9	12.9	
	596	96.7	0.24	23.2	0.55	53.2	10.6	1020.			56.1	82.1	87.1	
				41.3		64.8		1170			100.0	100.0	100.0	
				0.41		.65		11.7						
	598		0.50		0.66		12.0							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	30 A
DATE	19
ORE NO.	
PULP RATIO	: 1
R.P.M. IMPELLER	

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

Combined extraction of tests . 29 & 30.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT

REAGENT	%	LBS. P.T.

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	597	7.7	20.9	160.8	4.52	34.8	23.7	182.5			80.4	36.6	14.9	
	599	3.3	5.5	18.1	3.53	11.6	29.9	98.7			9.0	12.2	8.5	
	596	89.0	0.24	21.4	0.55	49.0	10.6	955.			10.6	51.2	76.6	
				200.3		95.4		1226.			100.0	10010	100.0	
				2.00		0.95		12.26						
	595		1.95		0.91		12.6							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	31
DATE	Feb. 6,1923. 19
ORE NO.	606
PULP RATIO	11.4 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

198 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.20						Transferred		
225	Na_2CO_3			227 g		Pulp Ratio 1.8:1		
2.55	Water			639 #		" " 5.4:1		
3.10						Feed started		
	Oil 92 drops/min.- Feed water @					0.5		
3.19						Start		
4.24						End		
						Feed	600	3.68
						Tails	601	
						Conc	602	14.81
						~~Feed~~ Feed 1.70#/min		
						Total feed 106.8#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 9.3
FPL #24	99%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	602	13.9	10.7	148.5	3.61	50.0	25.2	349.		
	601	86.1	.54	46.4	0.70	60.2	9.4	808.		
				194.9		110.2		1157.		
				1.94		1.10		11.57		
	600		2.1		1.04		12.0			

PERCENT OF TOTAL

Cu	Ni	Fe	
76.2	45.3	30.2	
23.8	54.7	69.8	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 32

DATE Feb 7,1922 19

ORE NO. 606

PULP RATIO 13 : 1

R.P.M. IMPELLER

PULP TEMP. START °

PULP TEMP. FINISH °

PULP TEMP. MEAN °

NOTES:

Tailings from test # 31 settled and decanted
Returned to Pachuca and diluted to 7.8:1 pulp ratio.

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.39						Feed started		
	Oil 120 drops/min - Feed water @ 0.35							
2.45	NaOH			200 g		To produce froth		
2.52						Start		
3.22						End of test		
						Feed	603	1.51
						Tails	604	
						Conc	605	11.19#
						Feed 1.51#/min.		
						Tatal feed 45.3#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 14.0
FPL #24	99%	
NaOH		4.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% NI	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	605	24.9	1.56	38.8	1.05	26.2	13.3	331.		
	604	75.1	0.29	21.8	0.49	36.8	9.3	698.		
				60.6		63.0		1029.		
				0.61		0.63		10.29		
	603		0.54		0.74		9.6			

PERCENT OF TOTAL

Cu	Ni	Fe	
65.0	42.7	32.9	
35.0	57.3	67.1	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	32 A
DATE	19
ORE NO.	
PULP RATIO	: 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

Combined extraction of tests 31 & 32

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT

REAGENT	%	LBS. P.T.

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe	
		13.9	10.7	148.5	3.61	30.0	25.2	349.5			72.2	47.3	27.5	
		24.9	1.56	38.8	1.05	26.2	13.3	33.1			11.9	24.8	26.1	
		61.2	0.29	17.7	0.49	30.6	9.3	569.0			8.9	27.9	46.4	
				206.0		106.2		1249.5			100.0	100.0	100.0	
				2.06		1.06		12.49						
			2.1		1.04		12.0							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	33
DATE Feb 10, 1923. 19	
ORE NO. 606	
PULP RATIO	10 : 1
R.P.M. IMPELLER	

NOTES:

200 # ore -60 mesh in Huntingdon Mill

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.40						Transferred		
.50	Na_2CO_3			270 g		Pulp Ratio 1.65:1		
11.20	Water			870 #		" " 5.75:1		
11.32						Feed started		
	Oil x	cake	84 drops/min.Feed			water @ 0.47		
11.39						start		
12.24						end		
						Feed	606	2.77
						Tails	607	
						Concs	608	8.81
						Feed 1.85#/min		
						Total feed 80.5#		

REAGENT	%	LBS. P.T.
Oil:-		
X cake		7.5
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	608	10.9	16.1	176.0	5.77	63.2	27.6	302		
	607	89.1	0.4	35.6	0.45	40.0	11.4	1015.		
				211.6		103.2		1317.		
				2.11		1.03		13.1		
	606		2.19		1.09		12.8			

PERCENT OF TOTAL

Cu	Ni	Fe
83.5	61.3	23.0
16.5	38.7	77.0
100.0	100.0	100.0

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 34

DATE	Feb 8, 1922 19
ORE NO.	606
PULP RATIO	8.5 : 1
R.P.M. IMPELLER	

PULP TEMP.	START	°
	FINISH	°
	MEAN	°

NOTES:

195 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
3.00						Transferred		
3.05	Na_2CO_3			480 g		Pulp Ratio 1.34:1		
3.35	Water			713 #		# " 6.23:1		
3.48						Feed started		
	Oil 90 drops/min.- Feed water @ 0.4							
3.52						Start		
4.38						End		
						Feed	609	3.34
						Tails	610	
						Concs	611	9.00
						Feed 2.22#/min.		
						Total feed 96.5#		

REAGENT	%	LBS. P.T.
Oil:-		
X cake		7.0
Na_2CO_3		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe
	611	9.3	16.9	157.0	6.74	62.5	25.2	234.			86.0	56.6	19.7
	610	90.7	0.29	26.3	0.53	48.0	10.4	931.			14.0	43.5	80.3
				183.3		110.5		1184.			100.0	100.0	100.0
				1.83		1.10		11.84					
	609		1.85		1.10		12.0						

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	35
DATE	Feb 9 , 1923. 19
ORE NO.	606
PULP RATIO	8.8 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

190 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.30						Transferred		
	Water					Pulp Ratio 5.33:1		
10.51						Feed started		
	Oil9	92 drops/min.- Feed water @ 0.5						
10.55						Start		
11.40						End		
						Feed	612	2.80
						Tails	613	
						Concs	614	6.31
						Feed 1.87#/min		
						Total feed 81.2#		

REAGENT	%	LBS. P.T.
Oil:-		
X cake		8.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	614	7.8	18.15	141.5	5.60	43.6	27.0	21.0		
	613	92.2	0.54	49.7	0.72	66.3	10.4	1050.		
				191.1		109.9		1210.		
				1.91		1.10		12.1		
	612		1.95		1.14		12.3			

PERCENT OF TOTAL

Cu	Ni	Fe	
74.0	39.8	16.7	
26.0	60.2	83.3	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	36
DATE	Feb. 7, 1923 19
ORE NO.	606
PULP RATIO	8.4 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

272 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.30						Transferred		
10.37	Na_2CO_3			360 g		Pulp Ratio 1.13:1		
11.07	Water			774 #		" " 3.7:1		
11.21						Feed started		
	Oil 95 drops/min.- Feed water @0.6							
11.31						Start		
11.46						End		
						Tails	6.23	1.59
						Feed	624	1.90
						2 Conc	625	11.13
						1 Conc	626	16.94
						Feed 2.28#/min.		
						Total feed 169.0#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 7.0
FPL #24	95%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	626	10.0	12.6	126.0	3.96	39.6	24.7	247.0			59.8	39.8	19.2	
	625	6.6	5.85	38.6	3.70	24.4	25.8	170.0			18.4	24.5	13.2	
	623	93.4	0.50	146.7	0.38	35.5	9.4	877.0			21.8	35.7	67.6	
				211.3		99.5		1294.0			100.0	100.0	100.0	
				2.11		0.99		12.94						
	624		2.24		0.89		12.0							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.	FLOTATION TEST NO.	36A

NOTES:

Retreatment of #36 tails in M.S. Standard Machine

DATE	Feb 15, 1923 19
ORE NO.	
PULP RATIO	6 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.30						Charged		
2.40						Oil added		
2.48						End of test		
						Concs.	615	62 g
						Tails	616	800 g

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 0.2
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	615	7.0	6.8	47.6	3.84	26.8	30.4	81.3						
	616	93.0	.29	27.0	0.43	39.9	11.9	1105.						
				74.6		66.7		1318						
				0.75		0.67		13.18						
			0.68		0.58		10.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 36 B

DATE Feb. 15 1923 19

ORE NO.

PULP RATIO : 1

R.P.M. IMPELLER

PULP TEMP. START °

PULP TEMP. FINISH °

PULP TEMP. MEAN °

NOTES:

Retreatment of Test 36 tails in M.S. machine

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
						Conc	617	23.0g
						Tails	618	68.5g

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 0.2
FPL #24	95%	
Na$_2$CO$_3$		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	617	3.24	5.05	16.4	2.80	9.4	24.2	78.5						
	618	96.76	0.49	47.5	0.43	41.2	7.9	768.						
				63.9		50.6		841.5						
				0.64		0.51		8.41						
			0.68		0.58		10.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 36 C

DATE Feb 15, 1923 19

ORE NO.

PULP RATIO 6 : 1

R.P.M. IMPELLER

PULP TEMP.		
	START	°
	FINISH	°
	MEAN	°

NOTES:

Retreatment of # 36 tails

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
						Conc	619	22 g
						Tails	620	704 g

REAGENT	%	LBS. P.T.
Oil;		
GNS #5	5%	) 0.2
FPL #24	95%	
Na_2S		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL			
	619	3.03	4.8	14.5	3.40	10.3	31.2	9.5						
	620	96.97	0.14	13.5	0.42	40.7	8.1	785.						
				28.0		51.0		794.5						
				0.28		0.51		7.94						
			0.68		0.58		10.3							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 36 D

NOTES:

Retreatment of # 36 tailings

DATE	19
ORE NO.	
PULP RATIO	6 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
						Concs.	621	46 g
						Tails	622	792 g

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 1.0
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	621	5.5	3.65	20.5	2.60	14.3	30.3	166.5		
	622	94.5	0.24	22.6	0.58	54.8	8.8	830.		
				43.1		69.1		996.5		
				0.43		0.69		9.96		
			0.68		0.58		10.3			

PERCENT OF TOTAL

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 37

DATE 19

ORE NO.

PULP RATIO : 1

R.P.M. IMPELLER

PULP TEMP. START °

PULP TEMP. FINISH °

PULP TEMP. MEAN °

NOTES:

Test # 37 a failure -no concentrate.

Retreatment of # 36 tailings in large machine

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
						Oil 42 drops/min.		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	
FPL #24	95%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	%	WEIGHT	%	WEIGHT	%	WEIGHT	%	WEIGHT

PERCENT OF TOTAL

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	38
DATE	Feb 16,1923 19
ORE NO.	
PULP RATIO	8.6 : 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

210 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
11.00						Transferred		
11.18	H_2SO_4			467 g		Pulp Ratio 1.17:1		
11.38	Water			775 #		" " 4.25:1		
11.51						Feed started		
	Oil 72 drops/min.-Feed water @ 0.6							
12.00						Start		
12.45						End		
						Feed	627	3.48 #
						Tails	628	
						Conc.	629	11.31 #
						Feed 2.29 #/min		
						Total feed 99.5#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	5%	) 5.0
FPL #24	95 %	
H_2SO_4		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	629	11.4	9.65	110.0	2.22	25.3	35.9	398.0			76.0	35.0	26.3	
	628	88.6	0.39	34.6	0.53	47.0	12.6	1120.0			24.0	65.0	73.3	
				144.6		72.3		1518.0						
				1.44		0.72		15.18						
	627		1.46		0.89		15.7							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.	FLOTATION TEST NO.	39

NOTES:

157 # ore -60 mesh in Huntingdon Mill

DATE	March 15 1923 19	
ORE NO.	606	
PULP RATIO		7.56: 1
R.P.M. IMPELLER		
PULP TEMP.	START	°
	FINISH	°
	MEAN	°

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2/30						Transferred		
2.40	H_2SO_4			340 g		Pulp Ratio 1.14:1		
3.00	Water			580 #		" " 4.6:1		
3.15						Feed started		
	Oil 80	drops/min.		Feed	water	@ 0.55		
3.23						Start		
3.03						End		
						Feed	640	2.4#
						Tails	641	
						Concs	642	11.31
						Feed 2.4#/min		
						Total feed 69.6#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 5.4
FPL #24	99%	
H_2SO_4		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	642	16.3	11.6	189.0	2.46	40.1	37.1	605.			79.0	40.1	31.8	
	641	83.7	0.63	52.7	0.72	60.2	15.5	1298.			21.0	59.9	68.2	
				241.7		100.3		1903.			100.0	100.0	100.0	
				2.42		1.00		19.0						
	640		1.84		0.97		18.1							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	40
DATE	March 21 1923 19
ORE NO.	
PULP RATIO	: 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

170 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.00						Transferred		
10.25	H_2SO_4			386 g		Pulp Ratio 1.79:1		
10.43	Water			550 #		" " 5.95:1		
11.02						Feed started		
	Oil 70 drops/min.			Feed water		0.5		
11.12						Start		
11.57						End		
						Feed	643	2.42
						Tails	644	
						Conc	645	16.58
						Feed 1.61#/min		
						Total feed 70.1#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 8.0
FPL #24	99%	
H_2SO_4		10.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT
	645	23.7	6.86	163.0	3.42	81.0	38.2	905.		
	644	76.3	0.34	25.9	0.38	29.0	7.5	572.		
				188.9		110.0		1477.		
				1.89		1.10		14.8		
	643		1.95		1.19		15.0			

PERCENT OF TOTAL

Cu	Ni	Fe	
86.2	73.9	61.2	
13.8	26.1	38.8	
100.0	100.0	100.0	

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	41
DATE	March 21,1923 19
ORE NO.	606
PULP RATIO	10.3 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

200 # ore -60 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.25						Transferred		
2.28	Na_2CO_3			227 g		Pulp Ratio 1.45:1		
2.58	Water			700 #		" " 5.65:1		
3.05						Feed started		
	Oil 75 drops/min-			Feed water 40.5				
3.10						Start		
3.55						End		
						Feed	646	2.84
						Tails	647	
						Conc	648	16.89
						Feed 1.89#/min		
						Total feed 83.16#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	10%	) 6.2
FPL #24	90%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	648	20.3	7.8	158.0	2.58	52.4	28.1	571.0			85.5	70.0	47.2	
	647	79.7	0.34	27.1	0.28	22.3	8.1	646.0			14.5	30.0	52.8	
				185.1		74.7		1217.0			100.0	100.0	100.0	
				1.85		0.75		12.17						
	646		1.90		1.09		12.8							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	42
DATE	March 28,1923 19
ORE NO.	606
PULP RATIO	7.95: 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

200 # ore -100 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.30						Transferred		
	Water					Pulp Ratio 4.8:1		
11.30						Feed started		
	Oil 58 drops/min.-Feed water					0.5		
11.40						Start		
1200						End		
						Feed ~~Conc~~-	649	2.52
						Tails-~~Feed~~=	-650	
						Conc	651	15.85
						Feed 2.52#/min.		
						Total feed 73.08#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	1%	) 4.0
FPL #24	99%	

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	651	21.7	6.62	143.5	3.26	70.8	29.5	64.1			85.0	88.4	54.2	
	650	78.3	0.33	25.8	0.12	9.4	6.91	54.1			15.0	11.6	45.8	
				169.3		80.2		118.2			100.0	100.0	100.0	
				1.69		0.80		11.8						
	649		2.11		0.85		12.6							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO.	43
DATE	March 29,1923 19
ORE NO.	606
PULP RATIO	10.7 1
R.P.M. IMPELLER	
PULP TEMP. START	°
PULP TEMP. FINISH	°
PULP TEMP. MEAN	°

NOTES:

100 # ore -100 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
2.30						Transferred		
2.40	Na_2CO_3			193 g		Pulp Ratio 2.6:1		
3.10	Water			410 #		" " 8.9:1		
3.18						Feed started		
	Oil 62	drops/min.-		Feed	water @	0.1		
3.25						Start		
3.55						End		
						Feed	652	1.78#
						Tails	653	
						Concs	654	11.81#
						Feed 1.78#/min		
						Total feed 51.62#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	10%	) 5.0
FPL #24	90%	
Na_2CO_3		5.0

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	PERCENT OF TOTAL Ni	PERCENT OF TOTAL Fe	
	654	22.9	7.40	169.5	3.25	74.5	25.8	592.0			81.2	72.3	48.7	
	653	77.1	0.51	39.3	0.37	28.5	8.06	620.0			18.8	27.7	51.3	
				208.8		103.0		1212.0			100.0	100.0	100.0	
				2.09		1.03		12.12						
	652		2.16		0.98		12.4							

ORE DRESSING LABORATORY, MINING DEPARTMENT, McGILL UNIVERSITY.

FLOTATION TEST NO. 44

DATE March 29, 1923 19

ORE NO. 606

PULP RATIO 7.9 : 1

R.P.M. IMPELLER

PULP TEMP.		
	START	°
	FINISH	°
	MEAN	°

NOTES:

150 # ore -100 mesh in Huntingdon Mill

TIME H. M.	REAGENT	DROPS	C. C.	WEIGHT	R.P.M.	NOTES	SAMP. No's	WEIGHT
10.40						Transferred		
10.45	H_2SO_4			340 g		Pulp Ratio 2.5:1		
11.05	Water			375 #		" " 6.24:1		
11.20						Feed started		
	Oil 72	drops/min.		Feed water @		0.40		
11.25						Start		
11.55						End		
						Feed	655	2.54
						Tails	656	
						Conc	657	13.31
						Feed 2.54#/min		
						Total feed 73.66#		

REAGENT	%	LBS. P.T.
Oil:-		
GNS #5	10%	) 4.5
FPL #24	90%	
H_2SO_4		10#

SCREEN ANALYSIS OF FEED

GRADE	%	GRADE	%
+ 20		+ 100	
28		150	
35		200	
48		− 200	
65		TOTAL	

TIME MIN.	PRODUCT	% WEIGHT	% Cu	WEIGHT	% Ni	WEIGHT	% Fe	WEIGHT	%	WEIGHT	PERCENT OF TOTAL Cu	Ni	Fe	
	657	18.1	9.70	175.5	4.18	75.8	34.9	63.2			84.4	75.0	52.3	
	656	81.9	0.40	32.7	0.31	25.4	7.0	573.			25.6	25.0	47.7	
				2.08.0		101.2		1205			100.0	100.0	100.0	
				2.08		1.01		12.05						
	655		2.44		1.11		12.5							