THE SETTLING OF VERY FINELY DIVIDED MATERIAL IN WATER ETC. WITH ESPECIAL REF. TO DECANTATION METHODS IN ORE DRESSING

THESIS SUBMITTED FOR THE

DEGREE OF

MASTER OF SCIENCE

" The Settling of Very Finely Divided Material in Water and certain Dilute Alkali Solutions, with especial reference to Decantation Methods in Ore Dressing.

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Montreal, Canada.

May, 1925

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INTRODUCTION

In nearly all ore dressing operations the material has first to be crushed to a greater or less extent, and in many cases, it has to be ground very fine. Fine crushing of any brittle substance invariably produces a considerable amount of exceedingly minute particles. The fine material thus produced is usually mixed with water either during the crushing or in subsequent operations, and the portion of this water-ore mixture which is too fine to clarify immediately on settling is commonly called slime. The settlement of slime is therefore an essential problem in modern ore dressing.

The problem consists of the settling of solid particles from suspension, thereby obtaining a clear liquid and a thick bottom discharge. The settling area required per ton of solids and the density at which the thick pulp can be discharged are the most important factors in the solving of practical settling problems.

Prior to the introduction of the process of continuous decantation into cyanide practice, it was felt that slimes were a necessary evil on account of the losses in treatment and the difficulty of making a good leaching product. Since some slime is inevitably formed during crushing and grinding, crushing machinery was classified as to how much of this undesirable slime was produced, and elaborate and expensive stage crushing was developed to minimize the amount of slime.

In the earlier cyanide plants intermittent decantation was thought to be the only method of dealing with the slimes produced in grinding. This process was carried out in large flat-bottomed tanks, and was an expensive method, both in time and labour.

In 1902 the application of the counter current principle was attempted in a continuous way to the original decantation process, but the experiment was not a suceess. With the introduction of the Dorr Thickener in 1907 the process was made possible, and continuous settling on a large scale became practicable. In 1910 the first modern plant was put in operation and since then the process has extended its field until, at the present time, it is employed in practically every mill.

Since the capacity of any given slime settling tank can only be increased by increasing the settling rate of the slime, the realization that a flocculating agent could be added to the suspension, causing the agglomeration of the individual particles into flocs which fall with increased velocity, was of tremendous commercial importance.

The Dorr Thickener was the first effective appliance for continuous operation, all earlier settlers having been intermittent, the pulp being charged, allowed to stand for some time, the liquor decanted, and the thickened material removed. There are, of course, many other settlers, some of which are of importance, but none has proved so generally acceptable as the Dorr. It has therefore been chosen in the laboratory investigation under review as the type of modern settling machinery.

A discussion of the problem of settling might best be preceded by a brief description of the construction, operation and uses of the Dorr Thickener. A detailed description of the laboratory apparatus will be included in a later section of this thesis. This type of settling apparatus is essentially a cylindrical tank, generally of greater diameter than depth. It is fed at the centre of the top by means of a feedwell discharging below the surface. The material settles, the clear overflow at the top is collected in an annular launder, and at the bottom a very slow-moving mechanism, consisting of a central vertical shaft with radial arms at the lower end, scrapes the thickened pulp to the central discharge from which it is drawn at a fixed rate by a suitable pumping device. The shaft can be raised to prevent the imbedding of the arms in the thickened solids at the bottom if the continuous operation of the thickener is interrupted. Under constant operating conditions of feed and discharge there is an upper zone of clarification and a lower zone of thickening in the tank.

The field of application of the Dorr Continuous Thickener is an ever-widening one, but its most important application from its invention has been in the cyanide process. In that process it is used for thickening the grinding unit product to the proper consistency for agitation, and for Continuous Counter-Current Decantation with cyanide solvent, either with or without filters. It is also used in the flotation process for thickening the feed to the proper consistency, for thickening the flotation concentrate, and for water recovery. In concentration it is used for thickening previous to concentration, and for water recovery. Recently it has been introduced to replace ~~the~~ sludge collectors and other similar devices formerly used in the preparation of fine coal. It is also used in the chemical and other industries.

The desirability of a scientific knowledge of the phenomena of settling was realized even by the early investigators, including Rittenger, half a century or so ago, but it did not become of crying importance until the development of the cyanide process about 1895.

Later, Ashley and Caetani studied the problem from a purely theoretical standpoint, stressing the difference between crystalline matter and the colloid and the effect of flocculation and viscosity on settling rate.

In 1912 Forbes[1] published an article in which he out-

D.L.H. Forbes: Settling of Mill Slimes, Eng.& Min.Press. 93, 411 lined some general principles of settling, enunciated six conditions affecting settling, and presented a formula for the settling capacity of tanks. This paper was followed by one by Mischler[1], who set forth certain definite principles governing the settling of El Tigre Slime, and presented a formula by means of which laboratory results could be used as a basis of mill design.

In 1916 H.S. Coe and G.H. Clevenger[2] published a paper, which, though somewhat obscure in its presentation, gave a comprehensive analysis of practical settling problems in a continuous thickener. Their paper supported the conclusions reached by Mischler, and correlated the settling phenomena exhibited in laboratory tests with those shown in the continuous operation of a thickener. It also presented formulae for the determination of area and depth of tanks from the data obtained in small-scale settling tests.

A further consideration of the problem was commenced at McGill University during the session 1923-24 by R.C. Gegg, Research Fellow in Mining, the writer acting as his assistant during the period set aside for ore dressing work in the Fourth Year. Gegg's work opened up what appeared to be an intensely interesting field of research, and Dr. Porter suggested that the writer continue the experimental work to fulfill in part the

1 R. T. Mischler: Settling Slimes at Tigre, Eng.&Min.Press,94,643

2 Coe and Clevenger: Transactions Am. Inst. Min. Eng. (1916) 55

requirements of the Faculty of Graduate Studies and Research.

One of the chief difficulties experienced in the work of the previous year was due to the presence of exceedingly fine sand in the pulp which had been specially prepared for the investigation, but it was impossible to eliminate this trouble last year. In planning this year's investigation provision was made for using an almost sand-free slime, and the following scheme of investigation was adopted. Thickener tests were to be run at various dilutions of feed in order to prove or disprove the Coe and Clevenger theory, and to obtain further data on the operation of the thickener. Correlated small-scale laboratory settling tests were to be run coincident with the operation of Dorr. Clarification problems involving area as the controlling factor were to be first studied, and if sufficient time were available it was planned to at least begin an investigation into the mechanics of thickening.

THEORY OF SLIME SETTLEMENT

For a clear understanding of the many problems involved in slime settlement a study of the general phenomena of settling is necessary. Gegg, in his 1924 thesis has covered the theory of settling in so comprehensive a manner that it seems hardly necessary to treat the subject in as great detail in this thesis. The present thesis will therefore include in this section certain necessary definitions which have been adopted by previous writers on the subject; a short discussion of the theory of colloids in ore dressing, and a brief chronological summary of the principles and formulae presented by previous investigators.

To answer the pertinent question " What is slime ?", two definitions are required for two products, either of which might be loosely referred to as slime. These two products are:

(a) Natural Slime

(b) Metallurgical Slime.

Natural Slime may be defined as the minutely subdivided particles of kaolin, talc, or other similar constituents of an ore which occur minutely subdivided in nature, and which are liberated by crushing.[1].

Metallurgical Slime is a product which contains not only all the natural slime as above defined, but also a considerable portion of extremely fine sand, and even in some cases, some relatively coarse sand.[1]

1 J.W. Bell; IV Year Notes on Slime Settlement, McGill University

Mischler[1] defines slime empically as " the finer particles of pulp which will remain suspemded for five minutes in a 100:1 mixture of fresh water and ground ore; the temperature of separation being 60 deg. F.(16 deg.).

Mischler's definition omits any mention of essential fact, that is the depth of the vessel the pulp is suspended, but from the context, it is clear that he refers to a laboratory apparatus approximately a foot in depth.

Sand may be defined as the relatively coarse material of the pulp resulting from the comminution of quartz, calcite, feldspar, or other massive gangue matter, varying in size from that of a pea to impalpable powder.

Settling rate is expressed in terms of the depth in feet of clear liquid formed per hour.

Dilution is expressed in terms of the ratio by weight of liquid to solids, the " L:S Ratio." In tables, charts, and formulae, the first factor only of the L:S Ratio is used. Thus the figure 5 designates a dilution of 5:1. 1

Settling Problems in Thickeners.

From a consideration of the problem of thickener capacity, it is apparent that the rate of settlement in a thickener is one of the controlling factors in its capacity, the capacity varying directly with the settling rate, other

1 R.T. Mischler: Capacities of S.S. Tanks, Trans AIME, 58,102

conditions remaining constant. Also, the chief practical factor in the settlement of metallurgical pulp is the settlement of a the comparatively small portion of "natural slime", the sand settling so rapidly during the time required to settle the natural slime that its settlement does not enter into the problem. In other words, " the capacity of a Dorr Thickener with respect to the sand portion of a slime pulp is limited only by the tonnage that can be handled by the revolving rakes and the discharge outlet.[1]"

It is also evident that an increase in slime settling rate will increase the capacity of the settling apparatus. According to Deane[2],"the problem thus resolves itself into the control of the settling rate of the slowest settling particles in a suspension and is governed by the same general principles that apply to colloids. With coarse particles, gravity is the controlling factor, but as the particles become finer and finer, the effect of gravity is gradually reduced and is eventually overbalanced by the forces of surface energy and Brownian movement, and a colloidal state is reached where the dispersed particles remain in permanent suspension in the liquid," unless disposed of by other than gravitational means.

If we consider the settlement of a highly diluted metallurgical slime in a cylinder we observe that the coarsest particles settle rapidly to the bottom while the finer particles will settle at a much slower rate. Stokes in 1850 showed that

1 J.W. Bell: IV Yr. Ore Dressing Notes, McGill University. 1
2 W.A. Deane: Settling Problems, Am.Electro-Chem.Soc. Apr. 1920. 2

the particles, excepting those of colloidal size, will fall with a velocity given by the formula

$$v = \frac{2}{9k} r (d - d') g,$$

in which v is the velocity, r is the radius of the particle, d and d' are the densities of the particle and medium respectively g is the acceleration of gravity and k is a constant depending upon the viscosity of the solution.

Neglecting the self-evident effect of the differences in densities and of gravity, the Stokes formula, applicable to particles approximately 50 microns in size, can be simplified to

$$v = \frac{C\,d}{k}\ \frac{A}{k},$$

where A is the area of the particle.

It is apparent from a consideration of the formula that the velocity of fall is directly proportional to the area of the particle and inversely proportional to the viscosity of the medium through which it falls. The factors involved in area and viscosity are discussed in the following paragraphs.

Viscosity.

Since the viscosity of a liquid is inversely proportional to the temperature, it may be stated as a principle of settling that 'Settling rates increase as the temperature increases, other things being equal.' It is known that the effect of temperature change on viscosity, and hence upon rate of settling, is greater at low temperatures than at high. Although the use of waste steam to prevent the chilling of slimes in winter might be practicable, heating of mill solutions above ordinary summer temperature is unprofitable.

Forbes (opus cit) shows that the physical characteristics of the ore influence settlement to a considerable extent. He states that the " viscosity of the water also increases with an increase in the percentage of colloidal particles in the slime". He probably means the degree of subdivision of the ore instead of the physical characteristics of the ore.

Area.

Again considering the Stokes formula, it is apparent that the velocity of fall of a particle varies directly with the square of the radius. Settling rates can therefore be increased by increasing the size of the particles in suspension. The suspension may be changed by "flocculation" from a large number of fine particles with very slow settling rates to a relatively small number of agglomerations of these particles which settle at an increased rate.

Before attempting a discussion of flocculation in its various phases, a brief explanation of the theory of colliods is desirable.

The investigations of Dr. Ashley[1] have established the conception of the existence of suspensions of smaller and smaller particles. Suspensions of clay have been prepared in which the

[1] Ashley, Bulletin U.S. Geol. Surv. 388, (1909)

particles, although distinguishable under the microscope, remain permanently suspended. Further, the investigations of Zsigmondy with colloidal solutions under the ultramicroscope have established the conclusion that a colloidal solution is simply a suspension of extraordinarily fine particles. There is no break between a suspension of large gold particles in water and the typical colloidal solution of gold,-a perfect continuity of the suspension series is indicated. The following classification is due to Zsigmondy:

Dispersoids.

1. Coarse- Particles over 0.1 micron in mean diameter.
2. Colloid- Between 0.1 and 0.001 micron in mean diam.
3. Molecular- Below 0.001 micron in mean diameter.

The differences in physical behaviour between the suspensions of the series is one of degree only. In coarse suspensions, gravity is the controlling factor, but as the particles become finer, gravity becomes less and less important while, at the same time, surface energy and Brownian movement become more and more important until the colloidal state is reached in which the particles remain in permanent suspension. Since a colloid is composed of very fine particles of one substance suspended in another, the total surface of contact will be great, bringing into effect the forces of surface energy.

Many theories have been advanced to explain the stability of the colloid, including 1. The Strain Theory (Ostwald); 2. The Theory of Repulsion of the Water Molecules (Edser); 3. Air bubbles and flocculation (Edser); and 4. The Theory of Ionic Adsorption.

The latter theory is now generally accepted, and is based on the assumption that the particles are electrically charged, these charges being of the same sign. The particles thus repel one another and remain in permanent suspension.

Two explanations are advanced for the origin of the charge. Coehn states that " when two substances are in contact, the substance with the higher dielectric constant will be charged positively." Since water possesses the higher dielectric constant, the ore particles will be negatively charged. The second explanation is based on the preferential adsorption by the ore particle of the OH ions, formed by the ionization of water into H and OH ions.

The charges on the particles must therefore be neutralized or reduced by introducing a charge of opposite sign in order to destroy this condition of stability. This takes place if we add to the water, which is a non-conductor, a soluble substance which gives it conductive powers. Such a solution is commonly called an electrolyte, and on its addition or that of another colloid, the neutralized particles are agglomerated by gravity and assisted by Brownian movement into flocs, producing the condition of flocculation.

Since a suspension is more or less flocculated with reference to another suspension, the terms "flocculation" and "deflocculation" are relative terms, the latter being simply a condition of "less flocculation." For this reason the term "degree of flocculation" is preferable.

The degree of flocculation is affected by many factors of which the conductivity of the electrolyte is one. Free[1] classes the neutral salts of the alkali and alkaline earths in their order of flocculating power as follows: Sodium, Potassium, Ammonium, Magnesium, Calcium, and Barium; the three latter being considerably more active than three former. He has also suggested the possibility of preferential flocculation,- of flocculating certain minerals in an ore while other minerals remain unflocculated.

In ore dressing flocculation is generally produced by the addition of lime, which, though less potent than many other substances is more suitable for other reasons. Deane (opus cit) has stated the following requirements for a flocculating agent in ore dressing:

1. It should be inexpensive.

1. Free: Colloids and Colloidal Slimes, Eng Min Press 101, 249etc.

2. It should have little or no detrimental effect on either the solids or the liquid under treatment.

3. It should not introduce reagents which would be deleterious to subsequent treatment.

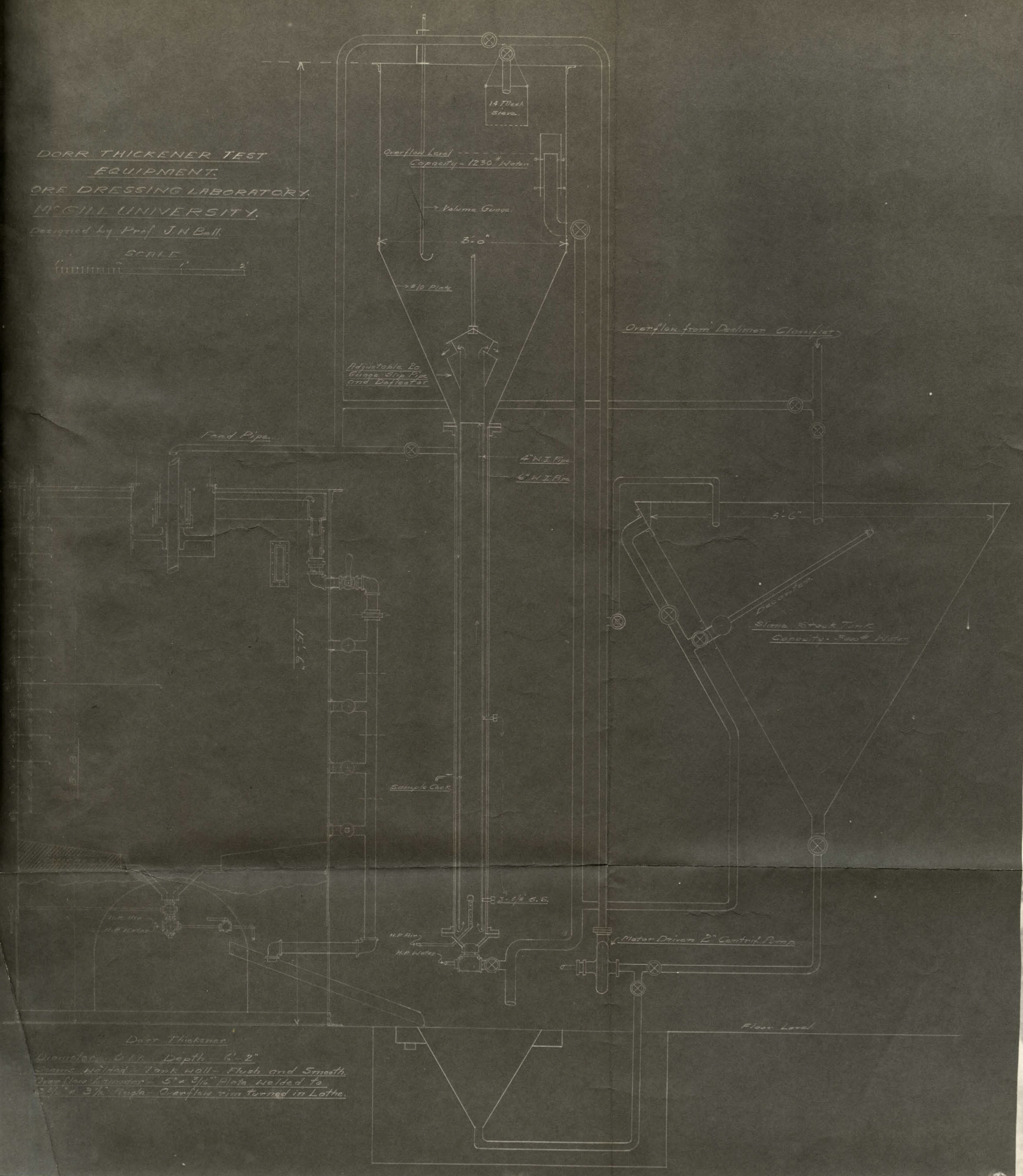
4. It should permit of a low moisture content in the thickened sludge.

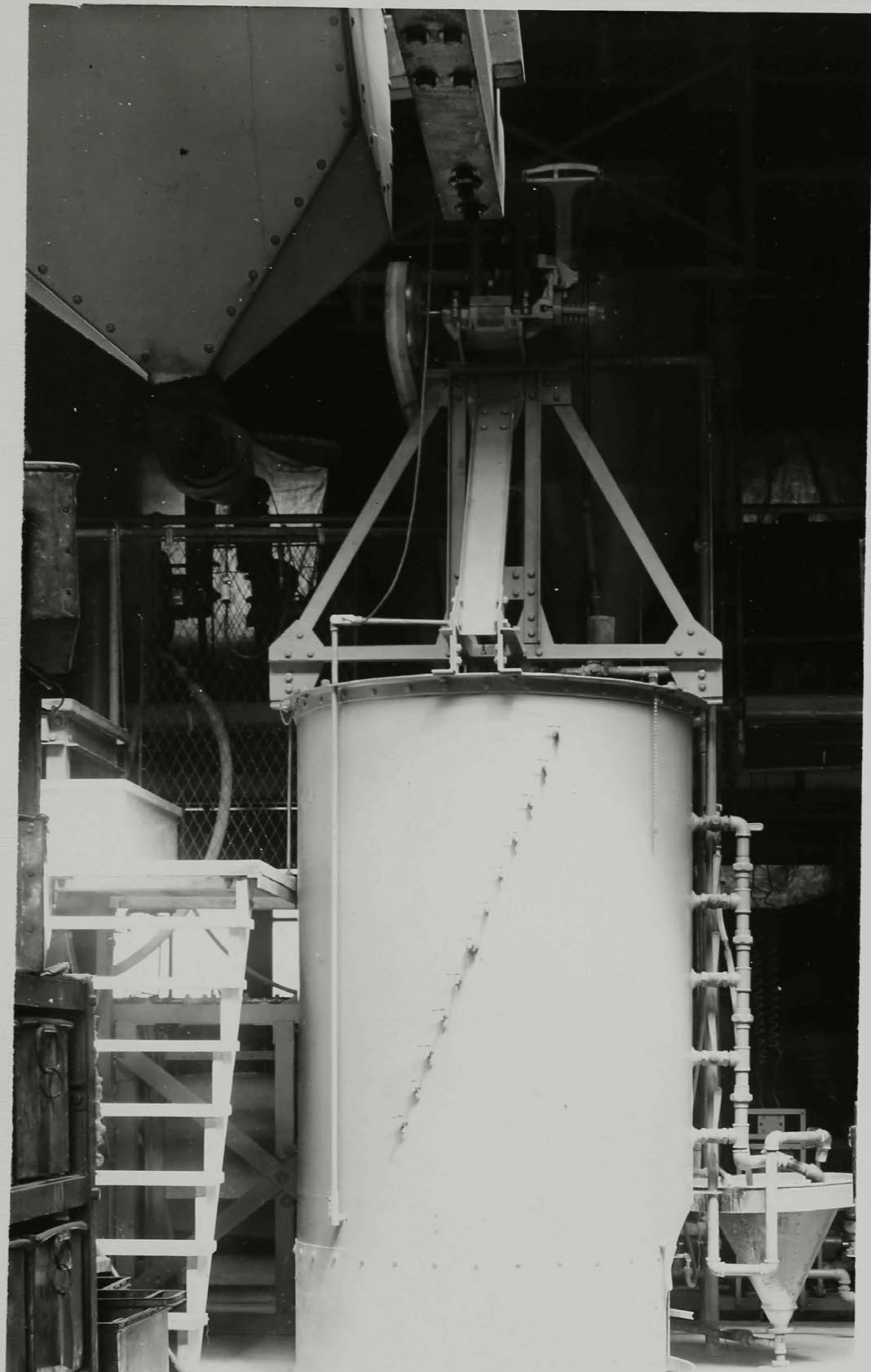
In reference to the last requirement, it is manifest that, as well as increasing the settling rate of the dilute pulp, flocculation causes slime to reach compression at higher dilution than when not flocculated.

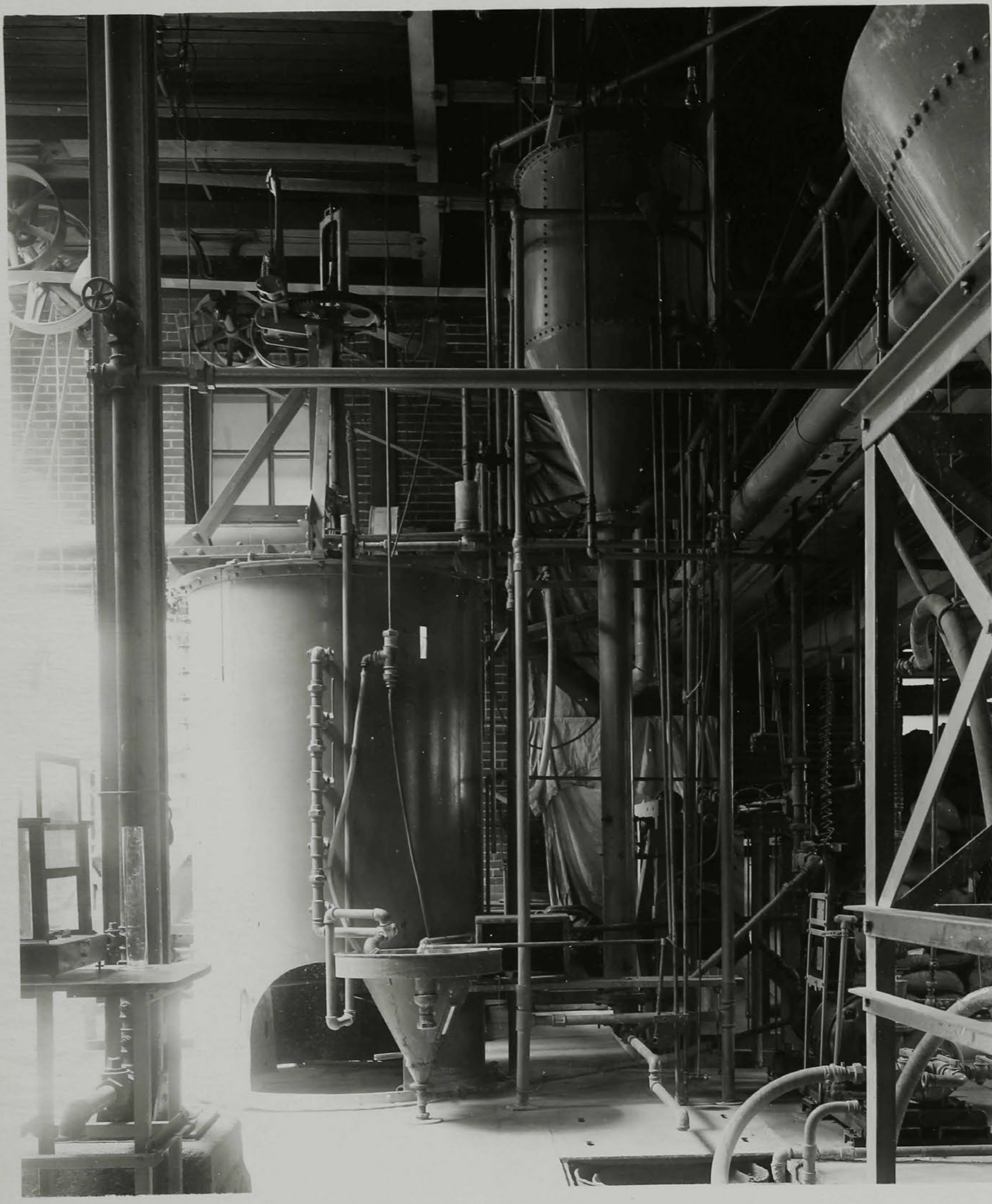
Lime is commonly employed in the cyanide process on account of its cheapness and also because of its usefulness as an alkaline protector for the cyanide.

In the clarification of certain trade wastes the addition of colloids as flocculating agents is practised.

The speed of flocculation has an important effect in settling. If rapid, the suspension will settle at a uniform rate, while a gradually increasing rate of settlement will occur where the growth of the flocs is slow. Also, the physical character of the flocs will affect the rate of settling, compact flocs possessing a faster settling rate than those of the long, stringy type.


DORR THICKENER TEST
EQUIPMENT.
ORE DRESSING LABORATORY.
McGILL UNIVERSITY.
Designed by Prof. J. N. Bell.
SCALE
14 Mesh Sieve.
Overflow Level
Capacity - 1230# Water
Volume Guage.
3'-0"
#10 Plate
Adjustable to Guage Slip Pipe and Deflector
Overflow from Deslimer Classifier
Feed Pipe.
4" W.I. Pipe
6" W.I. Pipe
5'-6"
Decanter
Slime Stock Tank
Sample Cock
3-5/8" S.S.
H.P. Air
H.P. Water
Motor Driven 2" Centrif. Pump
Floor Level
Dorr Thickener
Overflow rim turned in Lathe.





Development of settling phenomena in a thickener and related methods for determining the capacities of thickeners.

The theoretical considerations discussed thus far have led up to the application of general settling principles to slime settlement in thickeners. Before outlining the various methods presented by previous investigators for determining the capacities of slime-settling tanks, a summary of the phenomena exhibited by slime in process of clarification may be given.

As stated in a previous section of this thesis, an upper zone of clarification and a lower zone of thickening are maintained in a continuous thickener. This may be more clearly understood by first considering the behaviour of a thin metallurgical pulp allowed to settle in a glass cylinder after thorough shaking. The pulp at first forms a homogeneous unflocculated mass, the coarse sand particles settling immediately. After an interval of time, the length of which depends on the speed of flocculation, a flocculent structure is assumed by the material still suspended, and the slime flocs nearest the bottom settle, building up a compact mass in which the flocs are in intimate contact. This is called the "thickening zone". Above this thickening or compression zone and separated from it by a transition zone is an upper zone of free settling pulp of constant gravity. A zone of clear water is present above the free settling zone. Mischler describes the free-settling zone as the horizon of evenly flocculated dilute pulp in which the flocs do not press one upon the other.

In a continuous thickener all four of these zones are generally present. In the "free-settling" portion of the tank the flocs of colloidal matter that are produced by the electrolyte are sufficiently dispersed to settle by gravity through the liquid in which they are suspended. This settlement takes place at a constant or gradually diminishing rate until the critical point is reached, at which point compression of the flocs begins.

Critical dilution is defined by Mischler[1] as the dilution at which the flocs begin to touch. It is the highest dilution at which channels or tubes form in the pulp, these channels or tubes furnishing passageways to the surface for the clear liquid set free in the bottom of the vessels. Its position in relation to the free-settling and the thickening zones is given by Coe and Clevenger[2] at the top of the thickening zone where the flocs, although resting one upon the other, have not yet been compressed. A marked retardation in settling rate occurs as the critical point is reached.

In the thickening zone, the flocs have drawn so close together that no further settlement can take place without compression of the flocs themselves, the liquid set free in the compression having to force its way out of the compression zone through the channels mentioned above. In this zone settling rates are approximately proportional to pulp depth.

1 Mischler: Capacities of Slime Tanks, Trans. A.I.M.E. 58 ,104
2 Coe and Clevenger: Capacities of S.S. Tanks Trans. A.I.M.E. 55 356

Methods for determining the capacities of slime-settling tanks.

The preceding paragraphs have included a statement of the general principles of settling, the effect of flocculation and other agents on settling rates, and the application of settling phenomena as seen in glass graduates-"quiet settling"-, to settlement in a continuous settling apparatus, which, it may be repeated, is usually circular in shape, the feed entering at the centre, and the clear liquid overflowing at the periphery.

In the following paragraphs a summary of the results of practical importance obtained by previous investigators for the design or remodelling of settling equipment is given in the order of their publication.

Forbes[1], in 1912, included in his paper a discussion of the conditions affecting settling of slimes, and suggested a formula for the capacity of slime-settling tanks based on the standardization of these conditions. The latter included (1) Size and shape of the particles, (2) Percentage of colloids present, (3) Dilution of the pulp, (4) Height of the column of pulp in which settling takes place, irrespective of the horizontal cross section, (5) Average specific gravity of the slime particles, and (6) Presence and amount of electrolytes in the water. The methods suggested by Forbes were not immediately practicable. Later in the same year Mischler[2] published the

1 D.L.H. Forbes: Settling of Mill Slimes Eng Min Press 93,411
2 R.T. Mischler: Capacities of Slime Tanks Eng Min Press 58,102

results of his experiments on El Tigre slime. He enunciated two important principles of settlement

1. That the settling rates of free-settling pulp is independent of pulp depth.
2. That the settling rate of thickening pulp is dependent upon pulp depth,

and presented a formula by means of which the area required to settle one ton of dry solids per day of twenty four hours could be calculated from settling rates obtained in graduates. The development of this formula $A = \frac{1.33(F - D)}{R}$, where F is the L:S Ratio of the Feed, D is the L:S Ratio of the Discharge, and R is the Settling Rate, is given in detail in his paper. Mischler points out that the rates of quiet settling in the laboratory graduates and those in the continuous thickeners differ in the case of Tigre slime, the latter being generally less than the former. He believes however, that the rate of settling obtained in the laboratory can be used with a fair degree of accuracy to represent the rate of continuous settling in tall tanks.

In 1916 H.S. Coe and G.H. Clevenger[1] presented a paper which covers both free settling and thickening and is the most complete exposition of settling problems thus far published, although many of the important points are obscurely presented.

1 Coe and Clevenger: Capacities of Slime Tanks Trans AIME 55,356

Their conclusions may be summarized as follows:

1. Clarification is a function of area, that is, the depth of tank is of no consequence in thickening pulps which are to be discharged at a consistency which is still free settling, except that sufficient depth must be allowed to care for fluctuations in the feed and changes in the character of the pulp feed.

2. In thickening pulps to a consistency where the liquid must be expelled by compression, the tank must be given sufficient depth to retain the pulp for the length of time required to thicken it to this consistency. In other words, "thickening is a function of time".

3. The consistency of discharge possible is determined by allowing a cylinder of thick, but free settling, pulp to settle, taking readings every few hours up to the point of practical cessation of settling.

4. The required area may be determined by applying the formula $A = \frac{1.33(F - D)}{R}$, where A is the required area in square feet per ton of solids per twenty four hours, F is the L:S ratio of pulp which settle at a rate of R feet per hour, and D is the L:S ratio of the thickest pulp which can be economically obtained.

5. The required depth may be found by computing the capacity of the thickening zone necessary to contain a supply of solids equal to the total capacity of the tank for the number of hours to thicken

the pulp to the density required in the discharge, and to this depth adding an allowance for the pitch of the drag in the thickener andfor depth of feed,and a further allowance for storage capacity when the discharge may be closed.

It is apparent from a study of the above formula that as long as the character of the feed pulp remains the same the area of the tank required to settle one ton of dry solids per day will remain the same, irrespective of the dilution of the feed pulp. This is an important point, and although evident from a close study of the Coe and Clevenger paper is not definitely stated by them.

Two other important conceptions are presented by Coe and Clevenger, that of a zone of least capacity in the depths of continuous settling tank, and that of the building up of this zone to form a predominant zone in the free-settling portion of the tank. In order to discuss these points emphasized by Coe and Clevenger a clear understanding of the development of their formula for capacity, and hence area, is necessary. Gegg has expressed this more clearly than the original writers as follows:

Consider a Dorr thickener operating at capacity, the slime level remaining at a constant height, and the density of discharge being constant. Since there is a clear overflow at the top of the tank and a thick discharge at the bottom, it is reasonable to assume that there are zones within the free-sett-

settling portion of the thickener, ranging from the high dilutions at the slime level to the critical dilution, below which the flocs are in compression. In other words, there is a decreasing degree of dilution from the top of the slime to the critical point. The pulp in settling from its original feed dilution passes through these intermediate dilutions.

Consider any one of these hypothetical zones in the free-settling portion of the tank, and let its dilution be L:1. Since the flocs contain included water they possess a L:S ratio which depends on certain factors such as concentration of electrolyte and temperature. Assume this ratio to be D:1.

Then, in each pound of solids discharged from the zone considered, there will also be discharged D pounds of liquids, and (L-D) pounds of liquids clarified.

Let C represent the capacity of the zone, in terms of pounds of solids discharged by 1 sq. ft. of zone in 1 hour. Then C(L-D) represents pounds of liquid clarified per hour by 1 sq. ft. of zone.

Further, let R be the settling rate characteristic of the dilution of the zone. Then R represents the depth in feet of clear solution formed per hour, or, in other words, R equals the cubic feet of clear solution formed per sq. ft. per hour. Therefore 62.35 R equals the pounds of clear solution formed per hour.

From above, C (L - D) also equals the pounds of clear solution formed per hour.

$$C\ (L - D) = 62.35\ R$$

$$\text{i.e.}\quad C = \frac{62.35\ R}{(L - D)}$$

A = Area required to settle 1 ton of dry solids per 24 hours

$$= \frac{1.333\ (L - D)}{R}$$

Hamilton[1] outlines the method for testing for the size of thickener units, based on the formula presented by Coe and Clevenger. Pulps are made up of different dilutions between the dilution of the feed and the dilution of the discharge. The samples are thoroughly agitated by shaking and are then allowed to settle in 1000 cc glass graduates. The rate of settlement of each sample for 10 minutes is noted and these observations checked by shaking and settling again. The various values of L and the corresponding settling rates R are substituted in the Coe and Clevenger formula, taking D as the ratio of solution to solids in the discharge required . The largest calculated area will be the required area. It is apparent that values of A have been found for a series of hypothetical zones in the free-settling portion of the tank.

1 E.M. Hamilton: Manual of Cyanidation pp 81-2.

Discussion of the Coe and Clevenger theory.

From a consideration of the development of the Coe and Clevenger formula it will be seen that the formula is expressed in terms of slime. Coe and Clevenger do not explain why the percentage of standard slime could be neglected in their formula. In his discussion of the formula Gegg states that "since slime represents some percentage of the total solids present, this factor, when applied to both L and D in bringing them to terms of slime, will be found in C in the original formula. If C is reconverted to terms of total solids(sand plus slime), it will be found that the result will be the same as that found if the factor had been neglected. In other words, the factor cancels, and for a given feed of given sand content, in a given tank, we have a definite capacity for total solids, which bears a relation to the capacity for slime in the ratio of sand-plus-slime to slime. The amount of slime in the pulp can be disregarded, and provided the ratio is constant, the exact value, which is difficult to ascertain, need not be found."

It will be remembered that in the derivation of the formula, the dilution 'd' of the floc represents the dilution of discharge. Gegg believes that this is a correct assumption, since the returning water from the thickening zone enters the free-settling zone,and as a result the discharge from the zone is the algebraic sum of the floc dilution and the returning water. This sum equals the actual dilution of discharge.

The effect of this rising current on the dilution, and hence on the rate of settlement in the free-settling portion of the tank is discussed in a later section of this thesis.

In the earlier part of this discussion two other important features of the Coe and Clevenger theory, namely the conception of a zone of least capacity and of a predominant zone were introduced. These features will now be discussed.

From a study of the formula $C = \frac{62.35\ R}{(L - D)}$, it will be seen that the capacity of each of these hypothetical zones will differ, on account of the two variables L and R, and their places in the formula. One of these zones will have less capacity and so require a larger settling area than any of the others. Since each floc must pass through this zone in its settlement through the free-settling portion of the tank then the amount of solids fed to a given tank cannot exceed the capacity of the slowest zone. In other words, the ability of the free-settling portion of the tank to handle free settling material is limited by the ability of this zone of least capacity to discharge solids.

Further, since this zone of least capacity will be receiving more solids than it is able to discharge, it will gradually build up until it extends from the top of the compression zone to the top of the slime in the free-settling portion. Thus there is a predominant zone extending throughout the free-settling portion of the tank, its dilution being that of the calculated zone of least capacity.

The experimental verification of the existence of the predominant zone is perhaps the most interesting result of the investigations conducted this year.

Since every particle of slime must pass through this zone of least capacity, it will be the same for all dilutions of feed. In other words, irrespective of the dilution of the feed, the capacity of a thickener to handle solids is constant, provided the ratio of slime to total solids in the feed is constant, and the discharge density remains the same. The results of this year's investigation, although not absolutely conclusive on this point, go far towards proving that this somewhat startling theoretical conclusion is true.

CHRONOLOGICAL SUMMARY OF INVESTIGATIONS.

As stated in the Introductory section of this thesis it was decided to specially prepare a pulp as nearly sand-free as possible as the first step in carrying out the plan adopted for this year's work. Fortunately the requirements of Mr. A.E. Cave's work on the Oliver Filter laboratory investigation and those of my own were identical in this respect, and the preparation of the desired slime was begun at once as a joint enterprise.

Tinguaite - a holocrystalline coarse-grained eruptive, occuring as an intrusive sheet in the limestone east of Mount Royal - was selected as the most suitable local rock. This same rock, which is very uniform, was selected many years ago by Dr. Porter for his rock crushing experiments, and has since been employed for nearly all of the McGill work of this character. Its composition[1] follows,

Silica	46.30	percent.	Sp. Gr. 2.58.
Alumina and Iron Oxide	28.20	"	
CaO	3.20	"	
MgO	0.63	"	
Loss on Ignition	5.64	"	
Alkalies (by difference)	16.30	"	

The rock was crushed to 2 in. in the Gates crusher, this product then being fed through the stamp mill, using an 80 mesh sieve. When crushing was first started, the stamps were fed with 100 lbs. of water per min., giving 37.0 percent -200 mesh product.

1 W.G. Mitchell "Mechanics of Rock Crushing." M Sc. Thesis 1914.

Later the quantity of feed water was decreased to 175 lbs. per min., giving a 41.8percent -200 mesh product.

The stamp mill product was classified in a deslimer cone, the underflow going to waste, while the overflow was stored in the floor storage tank.

A wet screen test of the classifier overflow showed that the pulp still contained a small amount of fine sand of approximately -200 mesh, and it was decided to re-classify it in the Dorr Thickener. The thickener was filled to the overflow level with fresh water, and a definite quantity of pulp added from the storage tank. Settlement then took place, its progress being observed by samples taken from the small cocks placed five inches apart in the side of the thickener. When these samples showed that most of the granular material had reached the bottom of the tank, the pulp still in suspension was drawn off through one of a series of one inch cocks in the side of the thickeber. This dilute pulp was pumped to a large storage cone and allowed to settle. Clarified water was siphoned off at intervals from above the settled material, thus increasing the capacity of the storage tank.

The thickener was charged again and again until all of the pulp in the floor tank had been classified. A considerable amount of fine granular material had settled on the bottom of the thickener, as no solids had been drawn off from the discharge outlet during the operations just described. By forcing air at forty lbs. pressure through the discharge outlet into the thickener these settled solids were given a thorough agitation, and then allowed to settle again. By this means an additional amount of slime was recovered, and the final underflow of the thickener was dried and stored to be used in Cave's work.

Small scale settling tests were made on the pulp to determine the effect of temperature, dilution and etc. on its rate of settling. Various methods of carrying out these small tests were tried out, and a box to contain the graduate used in the settling tests was constructed to give the best possible means of reading the position of the pulp level.

Two thickener tests were run in January, the apparatus still being identically the same as that used, by Gegg in his tests. The difficulty encountered last year by Gegg ~~of~~ in accurately regulating the quantity of discharge again manifested itself, and the "gooseneck" arrangement, making use of the hydrostatic head of the pulp in the thickener, was designed. The results and discussion of these tests and a description of the discharge control are given in detail later.

Another test, using a higher dilution of feed than in the January tests, was run in February, and again the results were somewhat unsatisfactory in their bearing on ~~the ultimate~~ an important object of the investigations - that of proving or disproving the Coe and Clevenger theory and formula- although some intersting data regarding the operation of the thickener was obtained.

It was noted, first, that the method of feeding the thickener was unsatisfactory as slight variations occurred in the quantity of pulp fed in a given time, and second, that the specific gravities of discharge plus overflow of the Dorr could not be obtained, by weighing a sample in a 1000 cc. graduate, as accurately and rapidly as desired. Whenever the quantity of discharge was changed, since the overflow remained constant in amount, the density of the discharge plus overflow necessarily changed, and a slight variation in the specific gravity of the mixture could not be detected by the method employed. In order to eliminate this difficulty, Prof. Bell designed a spec. grav. indicator which recorded accurately and continuously the sp. gr. of the discharge plus overflow.

The next few weeks were spent in the installation of the several pieces of accessory apparatus mentioned above, and in their calibration. The calibration of the feed apparatus involved a large amount of work as the effects of viscosity and temperature on the velocity of flow through the feed pipes from the pachuca had to be considered. The apparatus was calibrated for eight different dilutions of pulp, as it was our expectation to run eight tests, using these dilutions of feed, as a final series.

Some difficulty was experienced in keeping the pump, handling the discharge plus overflow of the Dorr from the collecting cone to the top of the pachuca, running at a constant load, as it occasionally lost its suction from the collecting cone below. Another cone, feeding by gravity to a second pump, was installed to eliminate this difficulty.

The final series of tests was commenced on March 10th and complested on March 29th. The first three tests, desigznated Tests 1, 2, 3, were run continuously, the change from one feed dilution to another being effected by removing a calculated amount of pulp from the pachuca, and adding water to bring up the level to the overflow. The solution, which at the conclusion of Test 3 was slightly cloudy, was wasted, and a fresh supply added to the system. Tests 4, 5, and 6 were then run, the feed dilution being changed by cutting down the quantity of thickener discharge until the density of pachuca pulp reached the desired value.

Small-scale settling tests on the bottle samples of feed and discharge from each of the tests were made, and capacities and probable areas calculated by applying the Coe and Clevenger formula.

The complete results , including the results of the small-scale tests as well as data of the thickener tests, are given in later sections.

GENERAL SUMMARY OF INVESTIGATION

The more important developments in connection with the 1924-25 Dorr Thickener Investigation may be outlined as follows:-

(1) Improvements in the Equipment.

In the laboratory investigation of settling with a Dorr Thickener, the pulp (solids plus water) has to be kept in continuous circulation. A supply of pulp is maintained in agitation in a Pachuca agitator feed tank, and the feed to the thickener is drawn from it. The clarified overflow and thickened underflow must be re-combined in the exact proportions required to make a pulp of precisely the same specific gravity as the supply in the feed tank before it can be returned to it. If the specific gravity of the mixed overflow and discharge differs from that of the feed, the result is a change in the specific gravity of the feed and the whole system is thrown out of equilibrium. All of the difficulties in this connection have been solved by Prof. Bell during the present session, and with care it is now possible to operate the thickener for any length of time without any change in the specific gravity of the feed greater than 0.001.

(2) Predominant Zone.

As the result of the improvements noted above, it is now possible to hold the operating conditions in such exact equilibrium for the period of time necessary to enable the formation of, and consequently prove the existence of, a zone of least capacity or predominant zone. Tests 2-3-4-5 and 6 offer convincing experimental proof of the soundness of Coe and Clevenger's Zonal theory. In two of these tests, the existence of a zone of pulp of uniform specific gravity and occupying about half of the total volume of the tank has been demonstrated.

It is of interest to note that the specific gravity of this zone is 1.093 in Tests 2 and 5, 1.096 in Tests 3 and 4, and 1.102 in Test 6. Additional data will probably permit an explanation of these differences.

(3) Effect of Feed Dilution.

The conclusion that the capacity of a thickener is independent of the dilution of the feed into it, now seems to be well established by the experimental results obtained during the present session. In Tests 4, 5, and 6 the feed dilutions were 9.1 to 1. 11.5 to 1, and 16.7 to 1. while the pounds of dry solids settled per minute were 2.81, 2.81, and 2.87 respectively.

R.T. Mischler claims that the capacity of a thickener settling Tigre Mine ore slime is governed by the settling rate of the feed. It seems probable that his conclusion is erroneous. This matter will be discussed in more detail later.

(4) Change in Settling Rate produced by Air Agitation.

The work under review has disclosed in a very striking manner the changes which can be produced in the settling rates of pulps of exactly the same dilution without any alteration in the strength of the electrolyte or the temperature.

During Test 3, it was discovered that the settling rate of the feed to the thickener was about 10 percent slower than the settling rate of the combined discharge and overflow although the gravity, temperature, and electrolyte strength were practically identical. Tests indicated that the amount of fine sand in the two pulps was practically the same and consequently the difference in the percentage of colloidal material in the samples.

Some time later, the writer discovered that, although in Test 3 the settling rate of a sample taken from the predominant zone was 0.46 feet per hour, the settling rate of a sample of discharge material of exactly the same specific gravity tested several weeks after the first sample was rated was 1.01 feet per hour, or over twice as fast. Upon learning this, Prof. Bell suggested that a study of the effect of air agitation on the settling rate of a pulp sample be made.

The first test demonstrated that the settling rate of a sample of pulp after being maintained in violent agitation with compressed air for a period of one hour was only 50 percent of the rate it had before it was subjected to this agitation. This change in settling rate is caused by the change in the degree of flocculation. Further tests showed that, upon standing, the settling rate increased slowly until finally it again reached its initial faster settling rate. Tabulated data of this very important investigation is given in Table 6.

The work naturally opens up a large field for further investigation, and incidentally explains why the settling rate of the discharge from the Dorr Thickener is faster than the settling rate of the feed to it. In the feed tank, the settling rate of the pulp is reduced by its violent agitation. Upon passing into the thickener, it remains for a period of from 5 to 6 hours in a state of almost quiet suspension, and in that time its settling rate regenerates until when discharged, the settling rate of the pulp is approximately 10 percent faster than it was when the pulp entered the thickener.

(5) Area based on the Theory that $A = \frac{1.33\ (F - D)}{R}$

In the course of the investigation two methods were employed in applying the formula to calculate the probable area required to settle 1 ton of solids per 24 hours.

(1) In four of the thickener tests, a sample of the predominant zone was taken, its settling rate determined immediately, and the probable area calculated. This will be designated the 'Zone 6 Probable Area', as in Tables 2 and 6

(2) Upon the conclusion of a thickener test, samples of the feed and the discharge were taken, stored in 3000 cc bottles with ground glass stoppers, and set aside until time could be found for making a series of settling tests at various dilutions. When this data was available, calculations to determine the probable area were made. Area arrived at in this way will be called

'Settling Test Probable Area'- as in Tables 5 and 6. Taking into consideration the fact that the samples in (2) remained in a quiescent state for from one to three weeks in conjunction with the developments outlined in Section 4 of this summary, we now know that these samples had a much slower settling rate at the time they were taken than at the time they were tested to determine area. At the latter time the regeneration of the settling rate was no doubt largely or wholly completed.

It is therefore intersting to note that the average Zone 6 Probable Area is about 7.3 sq. ft. per ton, and the average Settling Test Probable Area is practically the same. However, although the two methods for determining probable area give practically the same result, it was found that they are in radical disagreement in the matter of the specific gravity of the predominant zone. In the Zone 6 Probable Area data, the average specific gravity of the true Predominant Zone is found to be 1.096. In the Settling Test Probable Area data, the Predominant Zone is indicated to be a zone of specific gravity 1.048.

Turning to a consideration of settling rates, in the Zone 6 Probable Area data it is found that the average settling rate of pulp of sp. gr. 1.096 is about 0.50 ft. per hr. In the Settling Test Probable Area data it is found that the average settling rate of samples of discharge pulp of Sp. Gr. 1.096 is about 1 ft. per hr.. The ratio of the two settling rates is t therefore about 2 : 1. Curiously enough the liquid-solid ratio of pulp of gravity 1.048 is about 12, and the liquid-solid ratio of pulp of gravity 1.096 is about 6. The ratio of the two ratios is therefore 2 : 1, see Table 5.

All of these peculiar differences are attributable to the regeneration of settling rate due to the quiescent condition of the samples. Possibly we may have in the above outline of facts merely numerical coincidence. On the other hand, it seems remarkable that two samples of pulp, whose settling rates are radically different, indicate approximately the same area required to settle one ton of pulp in twenty-four hours, and especially in view of the great change in the liquid-solid ratios of the true and indicated predominant zones.

(6) Comparison of Probable Area with Actual Area.

Comparison of the average actual area required per ton with the average computed area reveals the interesting fact that about thirty-three percent more area is required than is called for by the application of Coe and Clevenger's formula to results of settling tests on both Zone 6 and Discharge and Feed samples. Much more data will be requiredto establish a final conclusion in this regard.

It does however seem possible that Coe and Clevenger may be in error in applying their formula regardless of whether the discharge is

(a) Free settling, or

(b) Below critical dilution.

As long as the discharge pulp is free settling, one would suppose that no water or very little would be squeezed out of the slime flocs by compression. If, however, compression of the flocs takes place, and even a very minute ascending current of water is thus created, it seems possible that the settling rate of the predominant zone might be appreciably retarded, in which case R - the Settling Rate- would be diminished and as a result the Area increased.

The planned extension of the investigation will undoubtedly throw further light on this and other points of much interest.

Discussion of Mischler's determination of Area for Tigre Slime.

In his paper on settling problems at El Tigre, Mexico, Mischler states that area at El Tigre is invariably governed by the settling rate of the feed horizon. According to Mischler, tests at the dilution of the feed, termed by him "Settling Rate of Feed Tests", should represent the imperfectly flocculated condition occurring near the feedwell as well as the more complete flocculation at the tank periphery, thus obtaining the settling rate over the entire pulp surface. He believes that this result is attained when the first 0.05 ft. settled in the small-scale tests furnishes the basis for the calculation of the settling rates correponding to the feed dilutions.

Although Mischler claims that area at El Tigre is invariably governed by the settling rate of the feed dilution, he generalizes his formula, $A = \frac{1.34\,(F - D)}{R}$, where F is the L : S Ratio of the Feed, D is the L : S Ratio of the Discharge, and R the Settling Rate of Feed, by admitting the possibility of a governing dilution introduced by Coe and Clevenger , thus rendering it applicable should area be governed by a zone in the depths of the tank.

The formula,as presented in his latest paper, is

$A = \frac{1.34\,(F - D)}{R}$, where A = Area in sq. ft. required per ton of dry solids per 24 hours; F = L : S Ratio of Governing Dilution

1. R.T. Mischler Slime Settling Tanks, Trans. A.I.M.E. 58, 111.

and R = Settling Rate of Governing Dilution. The formula as presented in Mischler's last paper is thus identically the same as that of Coe and Clevenger.

Mischler states that, in case doubt exists that area might be governed by the permeability of some horizon below that of the feed, a series of settling tests at lower free - settling dilutions are run. In this series, observations are not started until after flocs are fully developed and maximum settling rates are attained. He believes this condition to be fulfillled when the second 0.05 ft. settled in the tests furnishes the basis for calculating the settling rates corresponding to the lower dilutions in the depths of the settling tank.

In order to prove his statement that area at Tigre is governed by the settling rate of the feed dilution, Mischler calculates the area required to settle Tigre pulp in two ways[1]. First by substituting in the formula $A = \frac{1.333\,(F - D)}{R}$, (where F is the L:S Ratio of the Feed, and R is the Settling Rate of the Feed (first 0.05 ft. settled in the tests)), the values obtained for the Settling Rate of the proposed feed(14.1:1), and the proposed Discharge (2.3:1)), the area obtained being 20sq. ft. --based on the Settling Rate of the Feed. The second area is obtained by applying the Coe and Clevenger formula (Mischler's amended formula) $A = \frac{1.333\,(F - D)}{R}$, where F is the L:S Ratio of the governing dilution, and R is the Settling Rate of the governing

1. R.T. Mischler Slime Settling Tanks Trans. A.I.M.E 58 p. 111

dilution, to the various free settling dilutions between that of the proposed feed (14.1:1) and the proposed discharge (2.3:1)., the largest calculated area, and thus the required area being 16 sq. ft.

In the following table, the writer has included the data given on page 121 of Mischler's paper, and also the calculated areas obtained from the application of both Mischler's original formula and Coe and Clevenger's formula to the settling test results presented in the table on that page.

Settling Rate of Feed Tests   Disch. L:S Ratio 2.3 : 1.

L:S Ratio	Set. Rate	Area
14.5	0.86	18.9
14.1	0.78	20.6
13.1	0.66	22.0
10.7	0.46	24.3
9.6	0.39	32.2
7.8	0.32	22.9
6.3	0.27	19.7
5.7	0.25	18.1
5.1 (Crit. Dil.)	0.24	8.9

Free Settling Rates.

14.5	1.20	13.55
14.1	1.12	14.05
13.1	0.92	15.64
10.7	0.75	14.95
9.6	0.67	14.50
7.8	0.57	12.86
6.3	0.50	10.64

Mischler Area Selected = 20 sq. ft.

Max. Coe and Clevenger = 15.64 "

Mischler concluded that, since the area obtained from the Settling Rate of Feed -20 sq. ft.- was greater than that based on the Settling Rates of the various free settling dilu- ions, the former was the correct area& However, a study of the table on the preceding page shows that, inadvertently or other- wise, Mischler chose a proposed feed dilution which gave a re- quired area very little greater than that given by the Coe and Clevenger method. If, for example, he had chosen the dilution of the proposed feed say 9.6:1, then the area required, based on the Settling Rate of Feed, would have been 32,2 sq. ft., which seems to be an absurd figure; while the area determined by the Coe and Clevenger method would, of course, be the same as that required for a feed dilution of 14.1:1, or any other feed dilution for that matter. In other words, the area required to settle 1 ton of solids from a feed dilution of 9.6:1 to a discharge dilution of2.3:1, calculated by the Mischler method, based on Settling rates of Feed, is twice the area required determined by the Coe and Clevenger method, based on the Settling Rates of the various free settling dilutions.

Again considering the Settling Rates of Feed Tests in the preceding table, it will be seen that, while a feed dilution of 13.1:1 and 10.7:1 require areas which differ very little from each other, a feed dilution of 9.6:1 would require 32.2 sq. ft.

It therefore seems probable that the area calculated by either method would check closely with actual plant require- ments at El Tigre. It seems to be more in the nature of a coincidence than anything else that this should be true, and that Mischler conclusion that area is invariably based on the Settling Rates of Feed at El Tigre is probably erroneous.

Another interesting point arising from a study of Mischler's results is that the area given by the Coe and Clevenger method is approximately 75 percent of the actual plant area required at El Tigre. This figure checks closely with that obtained in the McGill tests, the "Settling Tests Probable Areas" in the latter tests being generally 75 percent of the Actual Areas obtained in the laboratory Dorr Thickener Tests.

PART 2

Laboratory Apparatus.

Procedure.

Sample Test.

Discussion of Individual Tests.

Conclusion.

LABORATORY APPARATUS.

The first tests this year were carried out in the apparatus used by Gegg in his investigations, the thickener being installed in February 1924. That apparatus has since been declared by the chief engineer of the Dorr Company to be the finest installation of its kind in any ore dressing laboratory. Close observation of the early tests by Professor Bell led to a number of modifications which will be described in a later paragraph of this section, and there is no doubt that the apparatus used in the later tests this year is very much more satisfactory even than that used last year.

The apparatus used in Gegg's work and in this year's first tests may be described as follows:

The laboratory thickener is 5 ft. in diameter and 6ft 2 in. high. The sloping concrete bottom is 2ft 6in above the f floor of the laboratory, in order to permit of easy access to the discharge outlet. A scale drawing, supplemented by photographs areappended.

The thickened solids are gathered by a slow-moving mechanism into an 18in, 60deg. cast iron cone, placed in the centre of the tank bottom. The spigot, whose discharge is regulated by a cock at the apex of the cone is 1in. in diameter. A 3/8 in. pipe carries the discharge to the exterior of the thickener shell. This pipe is bushed to a 1in. nipple, and the discharge is turned downwards by means of an elbow. Caps,with orifices of various sizes, can be screwed on the end of the 1in. nipple so that the quantity of discharge can be regulated more accurately than by means of the spigot cock. A galvanized iron launder carries the discharge to a collecting cone placed in the floor tank adjacent to the thickener.

The annular overflow launder is 4ft. 11in. in diameter, and is suspended internally by three bolts fastened to brackets connected tothe tank itself with adjustable nuts which permit the launder to be accurately levelled. The overflow passes down inside the thickener by a 1in. pipe which can be connected to any one of a series of 1in. nipples with cocks, placed at intervals of 1 ft. throughout the depth of the tank. The launder can thus be placed at any desired levl .

Twelve 1/8 in. sampling cocks are placed on the outside of the tank with 5 in. extensions into the thickener to get clear of the shell. The first cock is 8 in. from the top of the tank, and the others are 5 in. apart and staggered 2 in. from the vertical. Representative samples of the pulp at various horizons in the tank are thus obtainable.

The feed is delivered centrally into an 18 in. diam. 15 in. deep feedwell, through the centre of which passes the vertical shaft leading to the spiral mechanism at the bottom. The bottom of the feedwell is formed of a 1 1/2 in. board, with a 2 1/2 in. hole in the centre through which the central shaft of the thickener passes, a loose fit. A large number of 1/2 in.

holes in this board allow the feed pulp to enter the thickener with a greatly reduced velocity from that in the feed pipe from the pacuca.

The pachuca agitator is 14 ft. high, and is made up of three sections, a 6 in. Wrought Iron pipe 8 ft. high, an inverted truncated cone 3 ft. high, which is 6 in. in diameter at the apex and 3 ft. in diameter at the top. The central pipe is 4 in. in diameter, and is fitted with an adjustable 20 gauge galvanized iron slip pipe and deflector which acts as a baffle to the rising pulp in the central pipe. Compressed air is admitted at the bottom of this central pipe to provide the agitation. An overflow pipe, discharging in the collecting cone below, is placed 1 1/2 ft. below the top of the pachuca, and when filled to this level the agitator holds 1230 lbs. of water.

The 1 in. feed pipe, with a 1 in. cock to control the quantity of feed to the thickener, taps the central pipe of the pachuca.

The slime pulp when not in use is stored in the floor tank near the thickener. By means of a cross at the pump above this cone additional slime can be added to the thickener-pachuca circuit if required.

Equipment Added This Year.

To eliminate the danger of extraneous material getting into the pulp, it was decided to use a storage tank above the f floor level instead of the floor tank previously used. This new tank is an inverted sheet metal cone, 5 ft. 6 in. in diameter, holding 3000 lbs. of water, and connected at the apex to the centrifugal pump at the collecting cone below the thickener. It is provided with a decanter so that clarified liquid could be drawn off above the settled material if a thick pulp were required.

An additional collecting cone from which the pulp is pumped to the top of the pachuca is placed above the pump level, thus ensuring a constant gravity feed to the pump. The discharge and the clear overflow of the thickener, the pachuca overflow, and the overflow from the Specific Gravity Indicator, are collected in this cone and pumped to the top of the pachuca by a 2 in. motor-driven centrifugal pump.

In all of last year's tests and in the earlier tests run this year, the accurate regulation of the quantity of solids discharged from the thickener presented a difficult problem. Caps, with various orifices, were screwed over the thickener discharge pipe in the earlier tests, but this method did not give stisfactory results. Professor Bell suggested that accurate control of the discharge could be obtained by utilizing the difference of hydrostatic head of pulp in the thickener, and the head in a vertical pipe which might be connected to the thickener discharge. The apparatus designed to make use of this difference of head consists of a 2 in. tee, connected at the bottom by means of a 3/8 in. flexible rubber hose to the thickener discharge pipe and, and discharging at the side through a 3/4 in. rubber hose into the collecting cone. By raising or lowering this "gooseneck" the flow from the thickener can thus be controlled with great accuracy. The gooseneck is attached to a wire rope passing over a small pulley directly above and wound around a hand controlled drum, placed where it is easily accessible during the test.

The cock, in the feed pipe from the pachuca to the feed-well of the thickener, which regulated the quantity of feed to the thickener in the early tests was a plug cock of good quality, but of ordinary design, and accurate control of the feed was impossible. Since very accurate control of feed is necessary, it was decided to use a feed control operating on the same principle as the apparatus described above for regulating the Dorr discharge. The new feed control consists of a 2 in. tee, connected at one side by a 3/4 in. flexible rubber hose to a 1 in. brass pipe tapping the pachuca approximately 1 ft. below the overflow level, and discharging through a 1 1/2 in. pipe into a small tank which empties into the feed well of the thickener. The relative position of this tee or "gooseneck" and the pulp level in the pachuca, which is kept at a constant height by means of the overflow pipe, can be changed by raising or lowering ths gooseneck thus permitting less or more solids to be fed to, the thickener. The position of this gooseneck is read on a scale, marked in hundredths of a foot, placed, for convenience, near the glass window of the Dorr. The calibration for the device is given in the appendix.

The feedwell used in the first series of tests is described above. The feedwell installed for the final series was designed to prevent surging of the slime in the thickener by decreasing the velocity of the feed pulp to a minimum. The pulp from the small feed tank below the gooseneck entered the inner one of two cylinders, which were 5 in. and 6 in. diameter and 7 in. and 5 in. high, the outer cylinder being closed at the bottom. The pulp flowed under the inner cylinder, which was raised 1 in. above the bottom of the outer, and rose in the outer, flowing over the top at a greatly reduced velocity from that in the feed pipe from the pachuca. These two cylinders rest on the spokes of a sheet metal pulley 20 in. in diameter whose cast iron core is bolted to the vertical shaft of the thickener.

The specific gravity indicator for the discharge plus overflow of the thickener consists essentially of a 1/8 in. brass pipe 12 ft. in height in which the slime is maintained at a constant height by means of an overflow leading to the collecting cone, and a second 1/8 in. brass pipe of greater height and connected to the other pipe by a U tube. A continuous sample of the thickener discharge plus overflow is fed to the 12 ft. pipe from the cone feeding the pachuca, this 12 ft. column of pulp balancing a column of water of varying height in the second brass pipe. The height of this water column depends of course on the density of the pulp in the 12 ft. pipe,t, and this density is read on a graduated scale placed near the pachuca. This scale is marked in thousandths so that readings of the specific gravity to 0.001 are obtained. A slight zero correction,due to the velocity with which the pulp sample enters the bottom of the 12 ft. pipe, must be applied to the readings.

PROCEDURE FOR THICKENER TESTS.

This section is divided as follows:-

(1) General explanation of procedure necessary to prove or disprove the Coe and Clevenger theory.

(2) A brief summary of the procedure followed in the first tests.

(3) A description of the procedure followed in the latter tests.

General Procedure of Investigations.

In order to verify experimentally the theoretical conclusions presented by Coe and Clevenger, it is first necessary to conduct a series of tests on the Dorr Thickener with different dilutions of feed and, if possible, a discharge of constant density, thus obtaining the actual capacity of the thickener; and, second, to carry out a correlated series of small scale settling tests, thereby obtaining the theoretical capacity by applying the Coe and Clevenger formula to the series of settling rates obtained.

When the thickener is running at capacity we should e expect to find, in verification of the Coe and Clevenger theory, that

1. The maximum theoretical area "(Settling Test Probable Area in the Tables)" required per ton of solids per day, obtained from settling tests in glass graduates "small-scale settling tests" is equal to the actual area per ton of solids per day obtained in a thickener.

2. The dilution of slime giving this maximum area in the

small-scale tests is equal to the dilution of the predominant zone in the thickener.

3. The area required per ton of solids per day calculated from the settling rate of the predominant zone in the thickener tests, using for F in the Coe and Clevenger formula the dilution of the predominant zone, is equal to the actual area required p per ton of solids per day by the thickener.

(2) A Brief Summary of the Procedure followed in the first Tests.

As stated in the previous discussion, the thickener must be operating at capacity in order to prove the hypotheses enunciated on the previous page. A thickener is operating at capacity when:

1. The density of the discharge plus overflow is equal to the density of the feed.
2. The height of the slime level is constant, and further adjustment of the feed is necessary.
3. The density of the discharge is constant.
4. The slime-to-total-solids ratios are equal in both feed and discharge plus overflow. Gegg believed that this could be verified by obtaining the settling rates of the feed and the discharge plus overflow simultaneously, since it seems evident that the sample with the faster settling rate contains more sand and less slime than the one with the slower rate of settling. In the tests made this year however, a slight difference in the settling rates of feed and discharge plus overflow was noticed in all of the thickener tests, even in those in which the first three conditions for operating capacity, stated above, remained constant for 18 hours. It seems probable that this difference is due to the effect of the pachuca agitation on the degree of flocculation of the pulp. This point is discussed in Sect 4.

The method of conducting the first three tests on the Dorr Thickener was indentically the same as that employed by Gegg last year, except that the slime was stored in the large storage cone at the completion of the tests instead of being allowed to settle in the thickener, and that the pulp contained very much less sandy material.

The thickener was filled to the overflow level with f fresh water containing 0.25 lbs. per ton of CaO. The pachuca was then charged with thick pulp from the storage cone, and after a short agitation, this pulp was charged into the Dorr, an equal amount of overflow water being wasted. This procedure was repeated until the full amount of slime was in the thickener, the amount of each charge being measured by the graduated rod in the pachuca. The pachuca was then filled to the overflow level with water containing 9.25 lbs per ton of CaO.

The pachuca was then connected to the thickener, both as to feed and discharge, and the thickener overflow was wasted. The quantity of solids discharged from the thickener was regulated by using an outlet cap with an orifice of proper size. When the density of the pachuca reached the required value for the test, the Dorr discharge was decreased, and the overflow returned to the pachuca through the collecting cone, thus establishing a closed circuit. The feed was opened sufficiently wide to keep the thickener pulp level at a constant height.

The Specific Gravity of the Feed, Discharge plus Overflow from the collecting launder, and the Discharge, were taken every 15 minutes by wighing a 1000cc. sample in a glass graduate.

When the three conditions of balance:-

1. Density of feed equals density of discharge plus overflow,
2. Height of slime level is constant,
3. Density of discharge is constant,

were fulfilled, the thickener was considered to be operating at capacity. This balance was then maintained for one or two hours, during which the density samples of the twelve thickener cocks and weight samples over a definite period of time of the feed and discharge plus overflow obtained. These time-weight samples of feed and discharge plus overflow should be of the same weight.

Bottle samples of the feed, discharge, and overflow w were then taken to be used in the small-scale settling tests.

(3) Procedure followed in the Final Series of Tests.

(a) Procedure followed preliminary to actual test.

The Dorr Thickener was filled to the overflow level with water containing 0.25 lb. per ton CaO, and the pulp from the storage tank charged into the thickener after agitation and measurement in the pachuca.

When all the slime was charged into the thickener, the pachuca was filled to its overflow level with water containing 0.25 lb. per ton CaO.

The slime in the Dorr was allowed to settle for two or three hours, so that a thick discharge could be obtained, the rakes being started a short time after the slime was charged to prevent their becoming embedded in the thickened material.

(b) Procedure during the Test.

The feed to the thickener was started by lowering the feed gooseneck between the pachuca and the thickener, and the Dorr discharge was started by lowering the discharge gooseneck. This discharge, emptying into the collecting cone at the base of the thickener, was pumped into the pachuca at the top through a 20-mesh sieve to remove foreign matter and small lumps of consolidated slime. The thickener overflow was wasted until the specific gravity of the pachica pulp approximated that decided on for the feed dilution of the particular test. The feed gooseneck regulating the amount of feed to the thickener was adjusted, and the thickener overflow returned to the pachuca through the collecting cone, thus establishing a closed circuit. Since the density of the discharge plus overflow was now too high, the quantity of discharge was reduced and regulated to give a discharge plus overflow density equal to that of the pachuca pulp.

<u>Actual Test.</u>

When the feed density equalled the density of the discharge plus overflow,

the slime level remained at a constant height without alteration of the quantity of feed,

and the discharge density remained constant, the thickener was considered to be balanced. This balance was maintained over a period of time ranging from ten to twenty hours as compared with one to two hours in the previous tests.

The following tests were made every half hour during the complete run, including the time spent in balancing the ciruit.

1. Specific Gravity of the Feed.

   This is obtained by taking a sample of the pachuca pulp from the sample cock adjacent to the thickenerefeed pipe, and weighing it accurately in a 250cc. flask. The spec. gravity is obtained by calculation from the spec. grav. of the dry slime previously determined, an accuracy to three decimal places being obtained.

2. Specific Gravity of the Discharge.

   A 250cc. sample of the discharge was taken, and the spec. grav. obtained as above.(1).

3. Specific Gravity of the Discharge plus Overflow.

   This is obtained by reading the continuous-recording sp. gr. indicator. Since this apparatus records the density continuously, it is possible to maintain the sp. gr. of the Disch. plus O'flow. at aconstant value. As a slight change in its density will cause a corresponding change of the pachuca pulp density, and hence of the thickener feed density, this indicator is of tremendous value an running the tests. Any change in the Disch. plus O'flow density can be detected at once, and the thickener discharge re-adjusted

4. Specific Gravity of Thickener Cock 6.

A 250cc. sample of pulp is taken from Cock 6 in the thickener, this cock being placed 33 inches below the overflow launder. The sp. gr. is calculated as in 1. and 2.

Settling tests of the disch. plus o'flow and the feed were made while the thickener was running in balance.

After the thickener had been running in balance for ten or twelve hours, spec. grav. samples were taken from each of the twelve cocks in the side of the thickener. Cock 7 was fitted with a 28 in. pipe extending almost to the centre of the tank. This pipe, 1/8 in. in diameter, passed through a stuffing box in the side of the tank so that samples could be obtained at various points in the thickener.

1000 cc. samples of the pulp from Cock 6 were tested for settling rate. This gave the Predominant Zone Settling Rates, and from these results the "Zone 6 Probable Areas" were calculated by applying the Coe and Clevenger formula.

In some of the tests, weight-time samples of the feed and of the discharge plus overflow were taken to check the calibration of the feed apparatus.

2500 cc. bottle samples of the feed, discharge, and overflow were taken at the completion of each test, to be used in the small-scale settling tests.

Changing Dilution of Feed.

In the first three of the final series of tests, the procedure employed in changing the feed dilution was as follows:-

Since the feed dilution of the next test was always higher than that of the preceding test, the required density of feed pulp was obtained by removing a calculated quantity of pulp from the pachuca, and adding water to bring the pulp level back to its original height at the overflow level. Both the feed and discharge cocks were closed while this operation was being carried out.

The pulp in the pachuca was circulated in closed circuit from the bottom of the tank through the pump at the collecting cone and returned to the top, while, at the same time, air agitation was going on.in the pachuca. The spec. grav. of the pachuca pulp was obtained every few minutes during this circulation and agitation by 250cc. weight samples.

When the density of the pulp in the pachuca was uniform, the thickener feed and discharge cocks were opened, and the discharge plus overflow returned to the pachuca. The actual test was then carried on as described in the previous section.

2. In the last three tests it was felt that a somewhat thicker discharge might be obtained by running the excess solids from the pachuca into the thickener, when changing to a higher dilution of feed, instead of removing these solids from the system as described above.

The quantity of feed to the thickener was not changed, but the amount of solids discharged from the thickener was reduced to give a discharge plus overflow density equal to that of the required feed.for the next test.

It required about one hour for the density of the pachuca pulp to reach that of the discharge plus overflow. When this was realized, the test was carried on as described in this sectiom under (3) Actual Test.

Procedure in Small Scale Tests.

(1)

Determination of Specific Gravity of Dry Solids

After thoroughly mixing the sample of pulp, fill up a 1000cc. calibrated flask-the weight of which is known- to the 1000 cc. mark.

Weigh the flask full.

Filter, dry, and weigh the solids.

The specific gravity of the dry solids is obtained from the following calculation:-

Let weight in grams of 1000cc flask plus pulp be $\underline{a}$

And " " " " 1000cc flask be $\underline{b}$

Then weight in grams of pulp a - b $\underline{c}$

Let weight of solids in 1000cc pulp be $\underline{d}$

Spec. Grav. of water 1

Then c - d = grams of water in pulp cc. of water.

1000 - (c - d) = cc. of Solids.

Then $\dfrac{d}{1000 - (c - d)}$ = Specific Gravity of Solids.

(2) Determination of Required Settlement Area.

A. To determine the area of the thickener unit, pulps are made up of different dilutions between the dilution of the feed and the dilution of discharge. These pulps are put in 1000cc. graduates and shaken, after which the rates of settlement of each pulp for 10 minutes is noted, and these observations checked by shaking and settling again.

The details of the method used by the Dorr Company differ somewhat from that employed by the writer, and bothare described.

A. The Dorr Company's method is to fill the 1000cc. glass graduate with the thoroughly mixed sample, and shake. The solids are then allowed to settle approximately 1/4 inch. Record the cc. reading of the pulp line and the time at which the reading was taken. Allow the solids to settle undisturbed for 3 minutes, at which time again record the reading of the pulp line. Take similar readings at 6 and 9 minutes.

Allow the pulp to settle until 100cc. of clear solution can be decanted off. Decant off 100cc., shake, and repeat as above When this has been done, decant off 100cc. more of clear solution. The pulp volume is now 800cc. Again determine the rate of settlement as before. Make one more decantation of 100cc., and repeat Filter, dry, and weigh the solids.

B Fill a suitable vessel with 1500cc. of feed pulp of the same dilution as above. Allow the solids to settle and decant off 500cc. of solution. Place the remaining 1000cc. of pulp in the graduate and obtain rates of settlement at dilutions corresponding to 1000cc., 900cc., and etc. as outlined above.

C Measure out 2000cc. of pulp of feed dilution, decant off 1000cc. of solution, and repeat.

D Measure out 3000cc. of feed pulp, decant off 2000cc., and repeat as above.

The required area is obtained as follows:-

Obtain the value of 1cc. in feet by measuring the number of cc. graduations on the cylinder corresponding to 1 ft. Convert all the readings in cc. per 9 minutes into feet per hour.

In the Lab. Graduate, 1cc. = 0.01183 feet.

Then Settling Rate, in Feet per Hour

$$= \frac{0.01183 \times 60}{90} = 0.0079 \times (\text{cc. sett. in 9 mins.})$$

Calculate from the weight of solids in the cylinder and the Sp. Gr. of the dry solids (determined by Procedure 1), the dilutions corresponding to the respective rates of settlement.

Apply the formula $A = \frac{1.333\,(F - D)}{R}$, where F is the ratio of solution:solids which settle at the rate of R ft. per hr., and D is the ratio of Liquid to Solid obtained in Proc. 3 . The largest calculated area will be the area required in sq. ft. per ton of solids settled per 24 hours.

Notes on the Method employed by the writer.

Since the graduations on the cylinder are 10cc. apart, it is apparent that it would be more accurate to record the time when the pulp line reaches the graduation rather than endeavour to estimate the cc. reading between the 10cc. graduations. For this reason the writer departed from the method used by the Dorr Company in the following manner: The time when the pulp line reached each 10cc. graduation on the cylinder was recorded during a period of 9 minutes. A complete numerical example is given in the tabulation of Test 5 under the next Section of this thesis.

The formula $A = \frac{1.333\ (F - D)}{R}$ was applied to the results of the settling tests of each of the thickener tests, and D was taken as the L : S Ratio of the discharge obtained in each test.

The results given in Tables 6&7 (Predominant Zone Probable Area) were obtained by applying the formula to the results of settling tests made on samples taken from Cock 6 of the Dorr, the settling rates being determined immediately after taking the cock sample. In the application of the formula, F was taken as the L : S Ratio of the Predominant Zone in the thickener test, R as the Settling Rate of the pulp in the Pred& Zone sample, and D as the L : S Ratio of the thickener discharge for the particular test.

The writer would like to point out a mistake which occur in Hamilton's description of the method used in making the small-scale settling tests. On Page 84 of his Manual of Cyanidation, Hamilton states :" The ratio of liquids to solids at each density is found by calculation from the sp. gr. of the dry slime, which must of course be determined. For instance, in the case of A 1, assume that when the reading is taken the line of pulp has settled to 800cc., and that the weight of dry solids present found by subsequently drying the whole is 190 grams." Sice the pulp is free settling, at least in the upper portion of the graduate where the settling rate readings are taken, then the dilution when the pulp line is at 800 cc. will be the same as when the pulp line is at 780 or 750cc., or if the pulp has only settled to 850cc. Thus the dilution for each graduate of pulp will be the same for each position of the pulp line, and is calculated from the weight of dry solids in the full graduate, -1000cc. of pulp.

Procedure 2. Determination of the max. dens. of discharge.

Mix the sample and fill a 1000cc. cylinder to the 1000 cc. mark. Thoroughly mix by shaking. Allow the pulp to settle undisturbed, taking readings in cc. every 20 min. at the pulp line When there is an abrupt decrease in the settling rate, after which seetling constantly decreases, compression or hindered settling has begun. After this, record readings at one, two, or three hour periods, depending on the rate of settlement, stirring the pulp gently with aglass rod after each reading. When no further subsidence of the pulp line is noticed after five hours, consider that the final density has been reached.

Filter, dry, and weigh the solids. Calculate the final density as follows; recording all figures for subsequent use; Only consider the pulp in the compression zone, and let a, b, and c represent the readings after the repective time intervals.

Let w = grams of dry solids in the graduate,

G = sp. gr. of dry solids

D = sp. gr. of solution

Then, $\frac{w}{G}$ = cc. of dry solids in graduate = C

Then $\frac{D(a - C)}{W}$, $\frac{D(b - C)}{W}$, etc., is the ratio by weight of solution to solids after the respaective intervals of time.

Calculate each dilution and record the results. The final density will represent the final density of thickener discharge.

PROCEDURE FOLLOWED DURING A THICKENER TEST.

Showing Log Sheets, Methods of Taking Samples, and Data obtained, of an actual Thickener Test.

SAMPLE TEST No. 5

The procedure followed before and during the actual test is explained in the preceding section.

LOG SHEET. -- Showing method of recording data obtained during the thickener tests.

Time 12 M	Feed Sp Gr	Indicator	Disch. Sp Gr	Zone 6 Sp Gr	Feed G Guage
1 AM	1.053	1.057	1.176	1.096	
1-30	1.053	"	1.170	"	2.9
2-00	1.052	1.056	1.168	1.095	3.0

Notes were taken in the above manner, the complete data sheets for each test being given in the Appendix.

COCK SAMPLES

These were taken after the thickener had been operating at capacity for 10 or 12 hours.

2.	1.0260	Sp. Gr.	7.	1.0930
3.	1.0930		8.	1.0930
4.	1.0920		9.	1.0930
5.	1.0930		10.	1.0930
6.	1.0920		11.	1.1270
			12.	1.1520

Showing Sp. Gr. of Predominant Zone = 1.0930

SETTLING TEST ON COCK 6 SAMPLE.

Time	CC Reading	Interval (in secs.)
0-00	940	
1-18	930	78
2-39	920	81
3-56	910	77
5-14	900	78
6-31	890	77
7-47	880	76
9-04	870	77
		Aver. 77.7 secs.

$$S.R. = \frac{0.01183 \times 60 \times 60}{77.7} = 0.548 \text{ ft./hr.}$$

Settling Test Results applied to determine Area.

Zone 6 Probable Area

$$\text{Area} = \frac{1.333\ (6.14 - 3.35)}{0.548} = 6.78 \text{ sq. ft.}$$

L:S Ratio of Zone = 6.14 Sp Gr. 1.094
L:S Ratio of Disch. 3.35 " 1.465

Actual Area

Feed = 35 lbs. per min. (pulp)
$= 35 \times \frac{12}{100} \times 0.72 = 3.02$ tons dry solids per day.

$\frac{\text{Area}}{} \quad \frac{19.24}{3.02} = 6.35$ tons dry solids per day.

Act. Area of Dorr = 19.24 sq. ft.

Table 6

Illustrating the Calculation of Maximum Area with the Data obtained in a Series of Laboratory Settling Tests.

Area = 1.33 (F-D) ÷ R

Test 3 Discharge Sample.

Specific Gravity of Discharge in Test 3 -------- 1.170

Liquid-Solid Ratio --------------------- 3.32 = D

Specific Gravity of Sample Tested	L.S.Ratio. F.	Settling Rate Ft. per Hour R.	Calc. Area. Sq. Ft. P.T. per 24 Hrs.
1.037	16.25	2.80	6.2
Indicated Zone → 1.044	13.92	1.87	7.5 ← Maximum Area
1.052	11.46	1.53	7.1
1.061	9.71	1.30	6.5
1.069	8.50	1.15	6.0
1.076	7.72	1.13	5.2
1.083	7.04	1.09	4.5
1.093	6.23	1.04	5.0
1.098	5.90	0.98	3.5
1.104	5.53	0.87	3.4

DETAILED DISCUSSION OF INDIVIDUAL TESTS.

Test 1

As shown in the data sheets for this test, given in the Appendix, the Specific Gravity of the Discharge was constantly decreasing for 12 hours, after which the thickener was considered to be running in balance. Table 1, showing the Spec. Gravities of the 12 cocks, shows that there was a gradation of density in the free-settling zone of the tank, and therefore, that the Predominant Zone was not built up. Table 2 shows that the pounds of solids settled per minute was 3.49. This is explained by the fact that the Predominant Zone was not built up, and that the tank was therefore handling a greater quantity of slime than it would handle if it were operating at capacity.

Test 2

Table 1 shows that a Predominant Zone, extending from Cock 3 to Cock 10, was built up. The data sheets for this test show that it required some 10 or 12 hours before Zone 6 had reached its constant density.

Test 3

The Predominant Zone in this test extended from Cock 4 to Cock 8. The Zone 6 Probable Area is approximately 75 percent of the Actual Area required in the test.

Settling Tests made on the Feed and Discharge plus Overflow show that the Settling Rate of the Feed was 0.811 ft. per hr.

Specific Gravity of Sample from	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Sample Cock NO. -- 1	1.000	1.000	1.000	1.000	1.000	1.000
2	1.072	1.057	1.005	1.029	1.026	1.025
3	1.084	1.093	1.076	1.074	1.093	1.080
4	1.092	1.093	1.095	1.096	1.093	1.101
5	1.092	1.093	1.095	1.096	1.093	1.101
6	1.100	1.093	1.096	1.096	1.093	1.101
7	1.104	1.093	1.096	1.096	1.093	1.102
8	1.106	1.093	1.096	1.096	1.093	1.102
9	1.106	1.093	1.104	1.096	1.093	1.102
10	1.106	1.095	1.106	1.099	1.093	1.103
11	1.112	1.124	1.136	1.106	1.127	1.129
12	1.116	1.133	1.136	1.124	1.152	1.137
Sp. Grav. Discharge	1.142	1.169	1.170	1.156	1.165	1.169
Pounds Solids in						
Zone 1---2-- (170)	6.0	7.7	0.6	3.8	3.8	3.3
2---3 (500)	63.0	60.8	32,5	42.2	48.7	42.4
3---4 (500)	71.5	75.6	68.4	68.2	75.6	73.6
4---5 (500)	74.6	75.6	77.4	78.0	75.6	82.0
5---6 (500)	78.5	75.6	77.4	78.0	75.6	82.0
6---7 (500)	82.8	75.6	78.0	78.0	75.6	82.3
7---8 (500)	85.3	75.6	78.0	78.0	75.6	82.8
8---9 (500)	86.4	75.6	81.2	78.0	75.6	82.8
9--10 (500)	86.4	76.9	85.2	79.6	75.6	83.4
10--11 (500)	88.6	88.6	98.4	83.7	89.4	94.1
11--12 (507)	94.0	105.8	111.8	95.0	114.6	109.1
12-Empty Tank (688)	144.4	169.0	171.0	156.5	177.5	171.0
Total Lbs. Solids in Dorr Thickener.	961.5	962.4	959.9	919.0	963.2	988.8

Notes.- The numbers in parentheses represent the volumes of the respective zones in terms of 'lbs. of water'. In all of the above tests, the depth of clear solution above the slime level was 11-5/16 inches. This maintains the slime level 5/16 inch below the bottom of the feed-well. The 'predominant zones' are enclosed in heavy black lines.

while the Settling Rate of Discharge plus Overflow was 0.858 ft. per hour.

The slime level in this test appeared cloudy, and as we had been assured by the Dorr Company that it was impossible to operate a test thickener continuously for more than one or two days, it was decided to allow the solids to settle in the thickener at the completion of the test. The solution was then drawn off, and fresh water, containing 0.25 lbs. per ton of lime, was substituted for the cloudy solution. It seems probable that the cloudiness of the slime level was caused by the constant addition of lime, since the slime had been settled previously for a length of time, adding time of all previous tests, equal to or greater than, the time of these final tests, 1, 2, and 3.

Test 4

In the three previous tests, the change to a higher dilution of feed was effected by withdrawing a calculated quantity of pulp from the pachuca and adding water to bring the level back to its original position. As the L:S Ratio of discharge obtained in these tests was much higher than that desired, it was decided to keep the same amount of solids in the system . This result was obtained by raising the discharge gooseneck, thus reducing the quantity of solids discharged from the thickener. In this way the density of the discharge plus overflow was reduced, resulting in a decrease of the pachica pulp density.

Table No. 2

Area Based on Zone 6.	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Sp. Grav. Zone 6	1.100	1.093	1.095	1.096	1.093	1.101
Sp. Grav. Discharge	1.142	1.169	1.170	1.156	1.165	1.169
L.S. Ratio Discharge	3.951	3.257	3.235	3.561	3.345	3.260
L.S. Ratio Zone 6.	5.770	6.235	6.095	6.025	6.235	5.710
(F - D)	1.819	2.978	2.860	2.464	2.890	2.450
1.33 (F - D)	2.419	3.958	3.803	3.278	3.843	3.260
Settling Rate in Feet per Hour.			o.461	0.532	0.548	0.479
Area- Square Feet per Ton per 24 Hrs.			8.25	6.16	7.01	6.80
Area Based on Feed.						
Feed. Pounds per Minute	23.00	21.00	25.00	28.30	35.00	50.75
Specific Gravity.	1.103	1.084	1.065	1.065	1.052	1.036
Liquid-Solid Ratio.	5.590	6.945	9.080	9.080	11.46	16.71
% Solids.	15.18	12.58	9.910	9.910	8.02	5.65
Lbs. Solids Settled per Minute	3.49	2.64	2.48	2.81	2.81	2.87
Tons Solids Settled per 24 Hours.	2.52	1.90	1.78	2.02	2.02	2.06
Dorr Tank Area----	19.24	Sq.	Feet.			
Area- Square Feet per Ton per 24 Hrs.	7.65	10.10	10.78	9.53	9.51	9.32
Liquid Distribution.						
Lbs. Liquid in Feed.	19.5	18.4	22.5	25.5	32.2	47.9
Lbs. Liquid-Discharge	13.8	8.5	8.1	10.0	9.4	9.3
Lbs. Liquid-Overflow.	5.7	9.9	14.4	15.5	22.8	38.6
% Total Liquid Clarified.	29	54	64	61	71	81

The Discharge Density of this test, as given in Table 1 is 1.156. This appears to be incorrect as compared with the Discharge densities of the other tests of the series. Also, the Areas calculated from the Settling Tests results of the Zone 6 sample and the Feed and Discharge samples are less than the Areas of the other tests. This indicates that the discharge density is lower than the correct value.

Test 5

This test shows a Predominant Zone from Cock 3 to Cock 10. The Actual Area required in this test is about one-third greater then the Settling Test Probable Areas.

Test 6

This test was run for 30 hours, and shows a Predominant Zone of slightly higher spec. grav. (1.1015) than the previous tests. The Actual Area in this test is slightly less then that in Test 5.

CONCLUSION

A general summary of the conclusions reached this year was given in the earlier part of this thesis. The writer has included in this section a discussion of the effect of the rising current on the settling rate of the pulp in the free-settling zone. The ideas presented in the following paragraphs were discussed after the previous section was written.

When pulp is thickened in a glass graduate, water is displaced by crowding and compression of the flocs. The water passes upward to the overlying clear solution. The change in position of the water is accomplished without any alteration in the total volume of the pulp. No doubt thickening is retarded by the ascending current.

The condition noted above must also be true in the case of the thickening which takes place in a continuous thickener. The water displaced or squeezed out must go somewhere, and since it is not drawn off in the discharge, it must migrate upward. This would create an ascending current and consequently reduce the settling rate of the pulp in the predominant zone.

Now if the rising current has an appreciable effect on the settling rate of the zone, the laboratory determination of settling rate in a glass cylinder would be appreciably in error, or perhaps it would be better to say that it would be appreciably wrong unless the thickening condition in the cylinder duplicated that in the tank.

The effect of a rising current can only be determined experimentally. An apparatus, consisting of a glass graduate fitted with a porous bottom, through which a current of water of very small magnitude could be sent, was suggested by Professor Bell. The study of this rising current effect should form the most important part of the future investigations.

Prof. Bell has suggested that the quantity of ascending water for a thickener test might be calculated by assuming that the amount of water in pounds which moves up through the predominant zone

= (L:S Ratio Zone - L:S Ratio Dich.) x Dry Solids per min.

The argument for this basis is that somewhere between the bottom of the zone and the point of discharge, the pulp changes from the L:S Ratio of the Zone to the L:S Ratio of the Discharge, and it appears that this can only be accomplished by the crowding together of the flocs with a corresponding displacement of water.

If the above is true, R in the formula may be an indeterminate quantity.

From a consideration of the above points, it would appear that the Coe and Clevenger theory is in error not only when applying the formula to discharges below critical dilution, but also when the discharge is of lower dilution than that of the predominant zone, since the rising current would be caused by the displacement of the water in "thickening" from the predominant zone to critical dilution, as well as by "thickening" from critical dilution to the density of discharge.

In this year's tests, it was necessary to add lime at regular intervals throughout the total time of the tests, resulting in the fouling of the solution. In order to overcome this difficulty, some other flocculating agent, which would not be a affected to as great anextent by the air, must be used. If sufficient storage capacity were available, a sypply of fresh s solution,containing 0.25 lbs. per ton CaP, could be maintained, and some means devised for continually replacing some of the solution.

In conclusion, the writer desires to acknowledge the interest shown,and the advice given, by Dr. Porter.

The entire investigation was carried out under the direct supervision of Professor Bell, to whom the writer is deeply indebted for his assistance in the actual running of the tests and in discussing the results.

Mr. A.E. Cave rendered very valuable assistance throughout the year.

The writer desires to thank Messrs. Cochrane, Duchemin, and Holland, of the Fourth Year Mining Class for their assistance during the tests.

A. K. [signature]

APPENDIX

Tables 3, 4, 5, 6,

Data Sheets.

Showing Settling Rates determined in glass graduates to compute Area required to settle I ton of Solids per 24 hours.

L : S Ratio	Spec. Grav.	SETTLING RATES Test C	Feet per Hour Testn3 Disch	Zone 6	Test 4 Disch	Zone 6	Test 5 Feed	Disch	Zone 6	Test 6 Feed	Zone 6
I6.7	I.036										
I6.7	I.036		2.80					3.58		2.46	
I5.4	I.039		2.54		2.59		2.70	3.25		2.I3	
I3.9	I.043	I.83	I.87		2.II		2.0I	2.46		I.69	
II.9	I.050	I.70	I.6I		I.57		I.55	2.I4		I.53	
9.9	I.060	I.I4	I.30		I.29		I.25	I.77		I.I8	
7.9	I.074	0.77	I.I3		I.II		0.98	I.44		0.95	
6.2	I.093	0.45	I.04				0.80	I.I3	0.55	0.77	
6.I	I.095	0.43	I.0I	0.46							
6.0	I.096	0.4I	I.00		0.93	0.53					
5.7	I.I0I	0.35	0.92				0.76	I.I02		0.70	0.48

N.B. Areas calculated from these settling rates are given in Table ___

Calculated Area - Maximum Theoretical Area calculated from Settling Tests of Samples of:

Discharge. Test 3	Disch. Test4	Feed Test 5	Disch. Test 5	Feed Test 6	Aver.
sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
7.5	7.7	7.5	5.9	8.2	7.4

N.B. These are maximum areas, complete areas are tabulated in Table___

Table ____

Calculated Area - based on Settling Tests of Samples from Zone 6, made during Dorr Thickener Test.

Test	3	4	5	6	Aver.
	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
Calculated Area	8.2	?	7.0	6.8	7.3
Actual Area	10.8	9.5	9.5	9.3	9.8
Percentage - based on Calc. Area - Actual Area					74.5%

Table 5

Showing the Differences in Specific Gravities of 'Predominant Zones' indicated by Settling Tests on Feed and Discharge Samples from Thickener Tests, and 'Predominant Zones disclosed by Dorr Thickener Tests.

Specific Gravities of Predominant Zone indicated by Settling Tests made on Samples of:

Test 3 Disch.	Test 4 Disch.	Test 5 Feed	Test 6 Disch.	Test 6 Feed	Average	L : S Ratio
1.044	1.058	1.050	1.041	1.049	1.048	12.4

Spec. Grav. of Predominant Zones - Dorr Thiskener Test No.

3	4	5 ; 5	6	Average	L : S Ratio.
1.095	1.096	1.093	1.101	1.096	6.0

N.B. The 'Predominant Zone' in upper table is the dilution of slime requiring maximum theoretical area, i.e., the dilution corresponding to the maximum area determined from the settling tests.

DORR THICKENER TEST No. 1

March 20th 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
9 -00	1.103	1.111	1.125	1.164		1.102		0.30	18
9 -30	1.103	1.111	"						
10-00	1.102	"	"		0.26			0.28	
10-30	1.102	1.112	"	1.160					
11-00	1.103	"	"			1.106		0.26	18
11-30	1.101	1.110	"	1.146		1.104			
12 N	1.102	"	"	1.160		1.104		0.24	
12-30	1.103	"	"	1.150	0.24	1.106		0.24	
1 -00	1.104	"	"	1.142		1.103			
1 -30	1.103	"	"	1.142		1.101		0.23	
2 -00	1.103	"	"	1.142		1.102			
2 -30	1.104	1.113	"	1.142		1.102		0.23	
3 -00	1.104	1.115	"	1.142		1.102		0.26	
3 -30	1.103	1.113	"	1.142		1.100		0.26	
4 -00	1.103	1.112	"	1.142		1.101			
4 -30	1.104	"	"	1.142		1.096		0.25	
5 -00	1.104	"	"	1.142		1.096		0.25	
5 -30	1.103	"	"	1.142	0.24	1.096		0.25	
6 -00	1.104	"	"	1.142		1.098		0.24	
6 -30	1.103	"	"	1.142		1.098		0.25	
7 -00	1.103	"	"	1.142		1.098			

Zones taken at 3pm. Feed = 1.125 Guage = 22.8 lbs./min.

Revs per hour of rakes 21.1

DORR THICKENER TEST No. 2

March 21st 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
	Removed 40 lbs. Solids from Pachuca (242 #pulp @ 1.102) Agitated in closed Pachuca circuit for 1 hour.								
10-pm	1.084	1.091	Pachuca in closed circuit						
10-30	1.086	1.090	"	"	"	"			
FEED	OPENED	10-30 pm 1.40							
10-45	1.086	1.094	"					0.25	
11-00	1.088	1.096	"			1.100	0.23		
11-30	1.084	1.090	1.45	1.186		1.100	0.23	0.25	19.0
12 M	1.084	"	1.50	1.172		1.100	0.25		
12-30	1.086	"	1.60	1.172		1.100	0.25	0.23	
1-am	1.088	"	1.7			1.100	0.24	0.26	
1 -30	1.086	1.085	1.60			1.102	0.24	0.24	
2 -00	1.085	1.086	1.50			1.101	0.23	0.26	19.0
2 -45	1.085	"	1.00	1.168	0.23	1.078	0.25	0.23	
3 -30	1.084	"	0.75	1.176		1.080	0.25	0.23	
4 -00	1.084	1.091	0.80	1.180		1.080	0.27	0.25	
4 -45	1.084	"	1.00						
5 -00	1.084	1.087	"			1.080	0.26	0.24	
5 -30	1.083	"	1.05	1.172	0.23	1.080	0.26	0.26	
6 -00	1.083	"	0.95	1.164		1.076	0.25	0.24	19.0
6 -30	1.084	"	0.975	1.164		1.078			
7 -00	1.084	1.088	"	1.164		1.080	0.24	0.26	
7 30	1.083	1.087	0.965	1.164		1.080	0.25		

DORR THICKENER TEST No. 2

March 21st 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
8 -00	1.082	1.087	0.965	1.164	0.24	1.080	0.23		
8 -30	1.083	"	"	1.164		1.080	0.23	0.23	19.0
9 -00	1.083	1.088	"	1.164		1.082	0.23	0.24	
9 -30	1.084	1.090	"	1.164		1.082			
10-00	1.083	"	0.975	1.164		1.082	0.23	0.26	
10-30	1.083	"	"	1.166		1.084		0.26	
11-00	1.084	"	1.000	1.166		1.084		0.25	
11-30	Stopped pump and re-packed it.								
12 N	1.086	1.092	1.00	1.166		1.086		0.23	
12-30	1.084	1.090	"	1.168		1.086		0.25	
1 pm	1.083	"	"	1.168		1.088		0.25	
1 -30	1.083	"	"						
2 -00	1.084	"	"	1.167		1.091		0.25	
2 -30	1.084	"	"	1.166		1.090		0.23	
3 -00	1.083	"	"	1.167		1.090	0.24	0.26	
3 -30	1.084	"	"	1.167		1.090		0.26	
4 -00	1.084	"	"	1.167		1.090		0.25	
5 -00	1.084	"	"			1.090			
6 -00	1.084	"	"					0.25	
7 -00	1.084	"	"	1.169		1.092		0.24	
8 -00	1.084	"	"	1.169	0.24	1.092	0.25	0.25	
8 -30	1.084	"	"	1.169		1.092		0.26	
9 -00	1.084	"	"	1.169		1.092		0.25	

DORR THICKENER TEST No. 3

March 22nd 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
280 lbs. pulp removed from Pachuca. Agitated in closed circ.									
11-20	1.066								
11-30	1.067								
11-40	1.066								
11-45	FEED OPENED								
12 M	1.0665	1.070	1.0						
1 -00	1.066	"	1.2			1.095	0.24	0.26	19.0
1 -30	1.067	1.071	1.30	1.210		1.095			
2 -00	1.067	1.070	1.40	1.181		1.095		0.24	
2 -30	1.065	1.070	1.45						
3 -00	1.065	"	1.50	1.180		1.096		0.26	
3 -30	1.066	"	1.60	1.180		1.098		0.25	
4 -00	1.067	"	1.70	1.180		1.097		0.25	19.0
5 -00	1.0655	"	2.00	1.174		1.098		0.24	
6 -00	1.0655	"	1.80	1.174		1.0955		0.26	
6 -30	1.0655	"	1.20	1.174	0.24	1.0975		0.25	
7 -00	1.0655	"	1.00	1.185		1.0955		0.26	
7 -30	1.066	"	"	1.185		1.0955		0.24	
8 -00	1.067	"	"	1.185		1.0955		0.23	
9 -00	Discharge Blocked								
10-00	1.066	1.07	1.30	1.174	Slime level is irregular, overflow slightly cloudy.				
11-00	1.064	1.07	1.40	1.175	0.25	1.076			19.4
11-30	1.065	"	"	1.174		1.0[illegible]		[illegible]6	

DORR THICKENER TEST No. 3

March 23rd 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
12 N	1.063	1.070	1.40	1.172	0.24	1.073	0.25	0.26	19.5
1 pm	1.066	"	"			1.078		0.24	
1 -30	1.066	"	"	1.170		1.086		0.24	
2 -00	1.065	"	"	1.172		1.087		0.26	
2 -30	1.065	"	"	1.171		1.088		0.26	19.5
3 -00	1.064	"	"	1.171		1.087		0.26	
3 -30	1.065	"	"	1.169		1.089		0.25	
4 -00	1.064	"	"	1.171		1.088	0.23	0.24	
4 -30	1.063	"	"	1.168		1.089		0.26	
5 -00	1.064	"	"	1.171		1.089	0.24	0.25	
5 -30	1.064	"	"	1.170	0.24	1.090		0.25	
6 -00	1.064	"	"	1.168		1.090			
7 -00	1.064	"	"	1.176?		1.090		0.25	
8 -00	1.065	"	"	1.176		1.090		0.25	
8 -30	1.066	"	"	1.166		1.090		0.25	
9 -00	1.065	"	"	1.171		1.090			
10-00	1.065	"	"	1.171		1.090		0.25	
11-00	1.065	"	"	1.170	0.24	1.095		0.26	
11-30	1.065	"	"	1.171		1.096			
12 M	1.065	"	"	1.170		1.096	0.24	0.25	20.0

DORR THICKENER TEST No. 4

March 25th 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
12 M	FEED OPENED		1.40	1.243				0.26	
12-30	1.068	1.072	"						
1 -00	1.069	"	1.6	1.196		1.098			
1 -30	1.065	"	1.8	1.186				0.25	
2 -00	1.064	"	2.1	1.184		1.098	0.24	0.25	
2 -30	1.066	"	"	1.181				0.24	
3 -00	1.0665	1.070	2.25	1.179		1.098		0.25	15.0
3 -30	1.0655	"	"	1.176					
4 -00	1.066	"	1.50	1.171				0.25	
4.30	1.066	"	1.60	1.172		1.098	0.24	0.26	
5 -00	1.066	"	1.50	1.167				0.26	16.2
5 -30	1.066	"	1.55	1.164		1.098	0.23	0.24	
6 -00	1.065	"	"	1.164	0.24	1.098		0.24	
6 -30	1.066	"	1.60	1.162				0.24	
7 -00	1.065	"	1.70	1.160				0.26	
7 -30	1.965	"	1.73	1.158				0.25	
8 -00	1.0655	"	1.75	1.156		1.084	0.24		
8 -30	1.0655	"	1.80	1.155		1.083		0.25	
9 -00	1.0655	"	1.78	1.1485	0.24			0.25	17.2
10-00	1.066	"	1.70						
10-30	1.966	"	1.75	1.151		1.088	0.25	0.26	
1100	1.066	"	"	1.151		1.087		0.25	
11-30	1.065	"	"	1.153		1.087		0.25	

DORR THICKENER TEST No. 4

March 25th 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
12 N	1.0652	1.070	1.78	1.154	9.24	1.088	0.24	0.25	18.0
1 pm	1.0657	"	"	1.155		1.088		0.25	
1 -30	1.0650	"	"	1.154		1.089		0.25	
2 -30	1.0663	"	"	1.156		1.089		0.23	
3 -00	1.9652	"	"	1.156		1.090		0.26	
3 -30	1.0656	"	"	1.158		1.091	0.23	0.25	
4 -30	1.0656	"	"	1.157		1.091		0.25	
5 -00	1.0656	"	"	1.156		1.0895		0.24	
5 -30	1.0654	1.069	"	1.157	0.24	1.090	0.24		
6 -00	1.0654	"	"	1.156		1.092		0.26	
6 -30	1.0651	"	"	1.156		1.093		0.25	
7 -30	1.066	"	"	1.156	0.25	1.093		0.25	
9 -30	1.066	"	"	1.156				0.24	
10-30	1.065	"						0.25	
11-10	1.065								

Zone Samples taken at 10 pm.

DORR THICKENER TEST No. 5

March 26th 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
12 M	FEED OPENED, Pachuca at 1.065, Feed Guage at 2.8								
12-30	FEED CLOSED, Pachuca in closed circuit, REOPENED at 12-40								
1 -00	1.053	1.057	2.8						
1 -30	1.0515	1.055	2.9						
2 -00	1.052	1.052	"	1.176				0.23	19.5
2 -30	1.052	1.056	"	1.176					
3 -00	1.052	"	"	1.169		1.096		0.27	
3 -30	1.0535	1.0565	"	1.167					
4 -30	1.053	1.056	3.2	1.170		1.100		0.26	
5 -00	1.053	"	3.0	1.170	Slime level at correct height				
5 -30	1.0535	"	2.80	1.170	Slime level too high.				
6 -00	1.054	"	2.40	1.171		1.100		0.24	
7 -00	1.0535	"	2.25	1.171		1.094		0.23	19.2
7 -30	1.052	1.055	2.50	1.171					
8 -00	1.952	"	2.60	1.1675*	0.24	1.088*		0.25	
8 -30	1.052	"	2.65	1.166	0.24	1.087	0.24	0.25	19.2
9 -00	1.051	"	"	1.164		1.087			
10-00	1.052	1.056	2.69	1.163		1.085		0.24	
10-30	1.0516	1.055	"						
11-00	1.0516	"	"	1.162		1.085		0.25	
11-30	1.0515	"	"	1.159		1.085		0.25	
12 N	1.0522	"	"	1.160		1.086			
12-30	1.0518	"	"	1.159		1.085		0.26	

DORR THICKENER TEST No. 5

March 26th 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
1 P M	1.9514	1.055	2.690	1.161	0.24	1.087	0.25	0.26	19.2
1 -30	1.0520	1.055	"	1.163		1.087		0.25	
2 -00	1.0514	"	"	1.161		1.088		0.25	
2 -30	1.0520	"	"	1.161		1.088			
3 -00	1.0514	"	"	1.162		1.088		0.24	
3 -30	1.9520	"	"			1.088			
4 -00	1.0516	"	"	1.162		1.088		0.25	
4 -30	1.0518	"	"	1.163		1.089			
5 -00	1.0518	"	"	1.161		1.089		0.25	
5 -30	1.0520	"	"	1.160		1.089			
7 -30				1.165					
8 -00				1.165					
9 -00	1.052								

Weight Samples: Discharge 15.19 Overflow 19.94

9.31 8.31

For 1/2 minute---- 5.88 11.63

2 2

For 1 minute ----- 11.76 23.26

Total = 35.02 lbs/min.

DORR THICKENER TEST No. 6

March 26-27 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
10-30	1.052								
11-00	1.035	1.041	2.70	1.216				0.24	
11-30	1.037	1.040	2.80	1.186					
12 M	1.036	"	3.00	1.177		1.091	0.23	0.24	
12-30	1.037	1.041	"	1.178				0.23	
1 -00	1.036	1.040	"	1.174				0.23	
1 -30	1.035	"	2.5	1.167				0.23	
2 -00	1.0355	"		1.166		1.098	0.23	0.26	
2 -30	1.037	"	"	1.163	0.23	1.100		0.26	
3 -00	1.0375	"				1.100		0.26	
3 -30	1.038	"	"	1.164		1.100		0.26	
4 -00	1.038	"	2.0	1.164		1.100		0.25	
4 -30	1.0365	1.039	"	1.172		1.100		0.25	
5 -00	1.036	1.038	2.3	1.177		1.098		0.26	
5 -30	1.0352	1.035	2.25	1.174	0.24	1.100		0.25	
6 -00	1.0341	1.041	2.25	1.167		1.101		0.25	
6 -30	1.036	1.039	2.35	1.166		1.104		0.24	
7 -00	1.037	1.0385	"	1.166		1.102		0.24	
7 -30	1.036	1.036	2.50	1.169		1.101		0.24	
8 -00	1.0357	1.039	2.60	1.167		1.101		0.23	
8 -30	1.0359	1.037	2.70	1.166		1.102		0.23	
9 -00	1.035								
10-00	1.035								

Slime level low due to cylinder in feed pipe not being able to carry any more feed without overflowing.

DORR THICKENER TEST No. 6

March 26-27 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
10-30	1.0346	1.0375	3.10			1.1034		0.26	20
11-00	1.035			1.164					
11.30	1.034	"	"	1.164		1.1030		0.27	
12 N	1.0341	"	"	1.164		1.102		0.27	
12-30		"	"	1.166		1.103		0.26	
1 -00	1.0335	"	"	1.166				0.25	20.25
1 -30		"	3.05	1.164				0.25	
2 -00	1.0344	"	3.00	1.164	0.25	1.103			
2 -30		"	"	1.164				0.24	
3 -00	1.9332								
3 -30	1.0354					1.0983			
5 -00	1.0355	1.038	3.00	1.165					
5 -30	1.0356	"		1.165					
6 -00	1.0357	"						0.27	
6 -30	1.0360			1.1645		1.0928	0.25	0.27	
7 -00	1.0360	"		1.1645					20.25
7 -30	1.0358								
8 -00	1.0357	"	2.80			1.0947			
9 -30	1.0362	"	2.75			1.0959	0.24	0.24	
10-30		"	"	1.1674					
11-00	1.0363	"	"	1.1674		1.0967		0.24	
11-30	1.0365	"	"	1.1690	0.24	1.0967		0.25	
12 M	1.0362	"	"	1.1703		1.0[illegible]		[illegible]	

DORR THICKENER TEST No. 6

March 26-27 1925

TIME	FEED			DISCHARGE		ZONE		OVER-FLOW	TEMP.
	Sp.Gr. True.	Sp. Gr. Indic.	Guage	Sp.Gr.	CaO Lbs. P.T.	Sp.Gr.	CaO Lbs. P.T.	CaO Lbs. P.T.	°C.
12-30	1.0361	1.038	2.75	1.1706	0.24	1.0977	0.25	0.27	20.25
1 -30	1.0354	"	2.50	1.1724?		1.0981		0.26	
2 -00	1.0357							0.24	
3 -00	1.0362	"	2.63	1.1706		1.0989		0.23	
3 -30	1.0363	"	"	1.1710		1.0990			
4 -00	1.0361	"	"	1.1710		1.0999	0.24	0.23	19.5
4 -30	1.0363	"	2".65	1.170					
5 -00	1.0361	"	2.75	1.1609		1.1001		0.25	
6 -00	1.0360	".70	2.70	1.1686	0.25	1.1013	0.25		
7 -00	"	"	"	"		"			

Zone samples taken at 5 a m.

CALIBRATION OF PACHUCA TANK.

Weights represent lbs. of water.
Weight of Pulp is obtained by multiplying the weight of water by the Spec. Grav. of the Pulp.

			Weight from Bottom	Wt. from Feed to
Zero to 1st.	73.44	to Zero	1229.61	1134.11
Zero to 1st.	73.44	1st.	1156.17	1060.67
1st to 2nd.	70.13	2nd.	1086.04	990.54
" " 3rd.	71.57	3rd.	1014.47	918.97
" " 4th.	71.82	4th.	942.65	847.15
" " 5th.	71.00	5th.	871.65	776.15
" " 6th.	71.57	6th.	800.08	704.58
" " 7th.	71.38	7th.	728.70	633.20
" " 8th.	71.32	8th.	657.38	561.88
" " 9th.	73.44	9th.	583.94	488.44
" " 10th.	72.81	10th.	511.43	415.63
10th to Thick. Feed Pipe.	415.63	Th. F.P.	95.50	0.00
Th. Feed Pipe to Bottom	95.50		0.00	

Total Cubic Capacity to Zero (Overflow Level)
19.7 cubic feet.