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THE FLOTATION OF NON-SULPHIDE MINERALS

by

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A THESIS SUBMITTED FOR THE DEGREE

OF MASTER OF APPLIED SCIENCE

IN THE DEPARTMENT

OF

METALLURGY

THE UNIVERSITY OF BRITISH COLUMBIA

April 1939

CONTENTS.

Acknowledgements 3

Preamble 4

Conclusions:

(a) Quartz Flotation 5

(b) Barite Flotation 6

(c) Limestone Flotation . 8

Recommendations 9

Reagents:

(a) Frothers 12

(b) Collectors 12

(c) Activators 14

(d) Depressors 15

Theory of Flotation

(a) Phases of the Flotation System 18

(b) Mechanical Aspects .. 20

(c) Adsorption 28

(d) Theoretical Action of Reagents

(1) Collection 33

(2) Frothing 41

(3) Activation 46

(4) Depression 49

Preparation of the Ore 52

Tests 60

Assay Methods 142

Bibliography 147

Summary of Tests 149

- LIST OF ILLUSTRATIONS -

APPARATUS -		Page
(1)	Pebble Mills.	56
(2)	Flotation Machine.	57
(3)	Thermostatic Controlling Device.	58
(4)	Furnace.	59

GRAPHS -		
(1)	Time of Grind and Grade, - Recovery and Bulk.	92a
(2)	Pulp Density and Grade, Recovery and Bulk.	94a
(3)	Sodium Metaphosphate and Grade, Recovery - and Bulk.	131a
(4)	Temperature and Grade, Recovery and Bulk.	141a
(5)	Grade of Barite, Limestone and Quartz - in all Tests.	149
(6)	Recoveries, Bulk and Three Mineral Index - of all Tests.	150

- ACKNOWLEDGMENTS -

The writer wishes to acknowledge his indebtedness to all those who have in any way assisted in the preparation of this thesis. To Professor G. A. Gillies of the Department of Metallurgy of the University of British Columbia, under whose supervision this work was carried out, the author wishes to express his sincerest thanks. All analytical work was carried out under the guidance of Assistant Professor F. A. Forward of the Department of Mining and Metallurgy, whose help was invaluable in the assaying. Finally, but none the less sincerely the writer wishes to thank his colleague William A. Dayton for the stimulating encouragement and cooperation rendered by him throughout the course of the work.

- PREAMBLE -

A quarter of a century ago the concentration of ore by flotation was regarded as a remote possibility. Today, it is being universally practiced with an ever widening field of application. Its origin and growth have been concerned primarily with the separation of sulphide or metallic minerals from their associated non-metallic gangue minerals. In the last ten or fifteen years, however, it has been found possible to float almost any of the wide group of non-metallic substances, but selection of one mineral from another has been accomplished in only a few instances. It is with the prospect of expanding the present supply of information concerning the selection between these substances, that the work carried out in the preparation of this thesis is considered justified.

- CONCLUSIONS -

In stating these conclusions it must be noted that this thesis should be considered as a preliminary report on the flotation of barite, limestone, and quartz. The results obtained from the various reagents used, are not conclusive regarding their action, as time would not permit more than a cursory examination of each one, except in a few special cases, notably sodium metaphosphate and aluminum nitrate.

Depression of Sulphides:

The inhibition of sulphides was not complete. For further remarks see conclusions at the end of test 6.

Quartz Flotation:

(1) Quartz may be either floated or depressed according to the reagents used. Recoveries obtained varied between 1.8% and 98.0%. In the latter, the reduction ratio was 1.7:1 from a feed of 2.5:1. With further cleaning it is highly probable that this reduction ratio could be increased but there was insufficient time to varify this point.

(2) As an activator of quartz, copper sulphate was the most satisfactory of the heavy metal salts used within the experimental pH range (7.5 - 9.75)

(3) Lead nitrate acted as an activator for barite and limestone rather than as an activator for quartz. In comparison

with copper sulphate, lead nitrate increases the grade of limestone and decreases the grade of silica. Used in higher concentrations lead nitrate activates barite slightly but has no apparent difference in the effect on limestone or quartz.

(4) Sodium Aluminate has a relatively good depressing action on quartz and could therefore be used in place of Sodium Silicate, the standard reagent for this purpose.

Barite Flotation:

(1) It became apparent in these tests that it was difficult to selectively float barite and limestone with reagents other than Sodium Metaphosphate and Emulsol X-1.

(2) Barite can be separated from limestone most efficiently by the action of Sodium Metaphosphate as a limestone depressant. A series of tests conducted with varying concentrations of sodium metaphosphate indicates that 1.5#/ton of ore gives the best results when judged by the "Three Mineral Index".

(3) With the use of Sulphonated Castor Oil, it would be possible to make a bulk concentrate containing 95% of the barite, 90% of the limestone and only 11% of the quartz, which with adjustments could be improved. By the addition of sodium metaphosphate to the cleaner cells, a practically pure barite concentrate could be obtained. This is supported by tests 60 - 66 inclusive. The grade of this concentrate could be improved by a judicious control of temperature.

(4) The use of heavy metal salts as suggested by several investigators did not promote the barite.

(5) The tests support the opinion of I. W. Wark that the theory formulated by Professor Taggart and his associates regarding the solubility of mineral films is not adequate in all cases. It is recognized that the presence of the lead and copper sulphides were possibly detrimental to the selective flotation, but this is not substantiated by any of the results.

(6) A better differential action can be obtained when using a synthetic ore by employing a coarser cell feed. This is an experimental consideration, as in the majority of ores it is impossible to completely unlock the component minerals when ground to only 42% - 200 mesh.

(7) A higher pulp dilution gives an improved barite limestone separation, but this would be counteracted materially by a subsequent lowering of cell capacity.

(8) The desliming of a pulp previous to flotation substantially increases the selectivity between barite and limestone. It must be noted, however, that approximately 20% of the solids is lost as slimes. A satisfactory flotation treatment of the slimes could possibly be evolved, rendering the process economically practical.

(9) An increase in temperature causes the chemical reactions to go more nearly to completion. This applies especially to Emulsol X-1, resulting in a larger bulk concentrate. The depressing action of sodium metaphosphate on limestone is greatly improved in a higher temperature range.

(10) Variation in the pH range has apparently slight effect upon the flotation of barite, limestone, and quartz. It may be noted here that a pH lower than 7.5 could not be obtained due to the solubility of limestone in an acid solution.

Limestone Flotation:

The flotation of Limestone was not covered in these tests due to insufficient time.

- RECOMMENDATIONS -

(1) The sodium silicate used in these tests was in the insoluble anhrydrous form. Other forms such as the Ortho, Meta, and Hydrous, might be advantageously employed.

(2) A series of tests investigating Sodium Aluminate as a quartz depressant might be profitably carried out.

(3) If, in future testing, only the experimental or theoretical viewpoint is considered, it would be advantageous to use a coarser cell feed combined with a pulp of less than 20% solids.

(4) When endeavouring to obtain a purer barite concentrate, a shorter skimming period is advisable.

(5) It has been stated previously, that a deslimed cell feed would be desireable if such a great loss in slimes did not occur. Development of a satisfactory treatment for these slimes should be seriously considered by future investigators.

(6) The use of heat in many of these tests might be of definite advantage, as illustrated by the increased selective index when using a higher temperature with sodium metaphosphate as a limestone depressant.

(7) The following list of reagents based on their comparative solubilities is suggested from a study of solubility tables taken from Seidell's "Solubilities of Inorganic and Organic Compounds".

Desired Film	Solubility in Water Solution in gms/liter	Mineral to be floated	Reagent Suggested.
Calcium Butyrate Barium Butyrate	18 36	Limestone	Butyric Acid
Calcium Caproate Barium Caproate	22 3.9	Limestone	Caproic Acid
Calcium Chlorate Barium Chlorate	640 in sat. soln. 250 in sat. soln.	Barite	Potassium Chlorate
Calcium Citrate Barium Citrate	0.8 0.4	Barite	Citric acid was found to be slightly selective
Calcium Fluoride Barium Fluoride	0.016 in sat. soln. 1.60 in sat. soln.	Limestone	Sodium Fluoride
Calcium Formate	142 in sat. Soln.	Limestone	Sodium Formate
Barium Formate	236 in sat. soln.		
Calcium Hydroxide Barium Hydroxide	1.65 3.9	Limestone	NaOH had little effect Potassium Hydroxide Nickel Hyd. Alum. Hyd.
Calcium Nitrate Barium Nitrate	560 in sat. soln. 84 in sat. soln.	Barite	Copper Nitrate Lead Nit. was successful. Aluminum Nitrate
Barium Salicylate Calcium Salicylate	290 in sat. soln 22.9 in sat.soln	Limestone	Salicylic Acid Mono-acetic Salicylic Acid.

(8) If in limestone flotation, a suitable barite depressant is used, it is recommended that the sulphonated oils, particularly castor oil, be used as a collector.

(9) Sodium Sulphate in conjunction with Palmetic Acid for the flotation of limestone, warrants further investigation. See test 42.

- REAGENTS -

FROTHERS:

Pine Oil - used as a frother only, but found to have a slight collecting action for sulphides; therefore its use was discontinued in later tests.

Terpineol - constituting up to 60% pine oil one of the most pure frothers. Having slight collecting action it was used in all tests requiring a frother.

COLLECTORS:

Lissolamine A - Tri-methyl-cetyl-ammonium-bromide (Manufactured by C.I.L.) Used as a collector for silica. Has good frothing properties. For further information regarding this reagent see section on theory of collectors.

Retarder L.A. - composition unknown; a produce of C.I.L., used at Trail, B.C., for the flotation of silica away from magnesite. Found to be slightly less effective than Lissolamine A as a collector of silica - also requires a frother.

Emulsol X-1 - a sulphated higher alcohol manufactured by the Emulsol Corporation of Chicago Ill. Found

to be the best collector of barite used in these tests. It has a definite collecting action for limestone and requires no frother.

Oleic Acid - has a general collecting action for non-sulphides as well as sulphides. Appears to be the most suitable collector for use in a "rougher" cell. Has slight frothing action.

Fish Oil - as obtained from Cave & Co., Vancouver, B.C. Has a better collecting action for barite and limestone than for silica. Requires a frother.

Sulphonated Castor Oil - as obtained from Cave & Co., Vancouver, B.C. It is a good collector for barite and limestone having, however, no selective action. This reagent would probably be more suitable in a "rougher" cell than Oleic Acid due to its lesser collecting action on quartz.

Sulphonated Cod Oil - as obtained from Cave & Co., Vancouver, B.C. It has good collecting action for barite and limestone with no apparent selective action. In common with sulphonated castor oil and fish oil, it increases the grade of the limestone.

Sodium Oleate - a collector often recommended in the flotation of non sulphides, found in the case of this ore to be an inferior preferential collector to that of Emulsol X-1. The barite

grade was 20% lower, limestone grade 8% higher and the quartz grade 10% higher. Due to a 25% increase of bulk the barite recovery was higher. The tests indicate that it is also inferior to Sulphonated Castor Oil. This reagent required a frother.

Palmitic Acid - This reagent was recommended by Gaudin and Hansen in the separation of barite and limestone in the presence of Sodium Sulphate as a limestone depressant. It was not satisfactory in this ore as no selective action was evidenced. The addition of Terpineol as a frother was found to be necessary.

ACTIVATORS:

Copper Sulphate - generally used as an activator for quartz. Found in these tests to be more suitable than Lead Nitrate. Best results obtained in a pH range of 6-11. Also has a slight activating action on barite and to a lesser extent on limestone. This agrees with the results published by Hälbich in Uber die Anwendungsmoglichkeiten einiger Netzmittel in der Flotation.

Aluminum Chloride - used as an activator for barite, but poor results were obtained. This agrees with the results of Hälbich.

Lead Nitrate - used as an activator for quartz. It is less efficient than copper sulphates.

Citric Acid - found to have slight activating action for Barite. It was mentioned by R. Ralston in The Flotation and Agglomeration of Non Metallics (U. S. Bureau of Mines).

DEPRESSORS:

Potassium Cyanide and Zinc Sulphate - used jointly as a depressor of chalcopyrite and pyrite.

Potassium Dichromate - used as a depressor of galena and pyrite.

Sodium Silicate - used as a depressor of quartz in which it compares favorably with Silicic Acid. As it was quite insoluble it was added in all cases to the mill. For chemical action see notes on theory of depressors.

Silicic Acid - used as a depressor for quartz.

Lead Chromate - used as a depressant for limestone. The use of chromates was suggested by the use of solubility tables, the theory as supported by Wark, Rose & Macdonald being that insoluble coatings are less amenable to flotation.

Potassium Chromate - used as a limestone depressant. Results comparable with Lead Chromate.

Chromic Acid - used as a limestone depressant. Results obtained were unsatisfactory.

Chromous Oxide - used as a limestone depressant. Results obtained were unsatisfactory. This reagent

caused an unaccountably high pH value for the pulp.

Acetic Acid - The use of acetic acid is explained in conclusion of test 48.

Sodium Oxalate - and Oxalic Acid - used as depressants for limestone. For action see conclusion of test 44.

Aluminum Nitrate - used as a limestone depressant. Best results obtained using o.5 #/ton. For chemical action see conclusion test 55.

Sodium Aluminate - used as a quartz depressant for which property it may be compared favourably with Sodium Silicate.

Sodium Sulphate - The use of Sodium Sulphate was suggested as a theoretical limestone depressant but tests indicate the opposite, i.e. it has more of an activating action on limestone with no effect on barite flotation. See conclusion test 42.

Ferric Sulphate - This reagent was used as a limestone depressant, as a comparison of a heavy metal sulphate with Sodium Sulphate was desired. Results showed no difference between the two.

Sulphuric Acid - used to test the effect of a low pH on the flotation of barite, limestone, and quartz, and also to form a monomolecular sulphate coating. No satisfactory results obtained.

Sodium Hydroxide - used to test the effect of a high pH on the flotation of barite limestone and quartz. Gaudin suggested a pH greater than 10 for the inhibition of calcite. No satisfactory results were obtained due to the inability of attaining a high pH.

Argols - (Potassium bitartrate) - used as a quartz depressant. Found to have little effect.

Sodium Metaphosphate - used as a limestone depressant. This reagent was found to give the best results for limestone depression. For discussion of action see theory of depressors and for comparison of results of varying amounts see test 64.

Sodium Hexametaphosphate - this reagent suggested by Rose and Macdonald in U.S. Patent No. 2,040,187 as an inhibitor of limestone. The reagent showed a general depressing action.

- THEORY OF FLOTATION -

The theoretical foundation of flotation is based on the behaviour of surfaces - both liquid and solid. Surface phenomena will, therefore, be reviewed under the following headings; as related to the properties of the various reagents used, particularly those pertaining to non-sulphide mineral flotation.

1. Phases of the Flotation System.
2. Mechanical Aspects of Froth Formation.
3. Adsorption.
4. Reagents.

PHASES OF THE FLOTATION SYSTEM:

There exists in any flotation operation, three phases; gas, liquid, and solid; of which the liquid phase appears to be of greatest importance and the gas phase of least importance.

The gaseous phase presents its importance as the mechanism for lifting the segregated particles. Although the composition of the gas, considered as a phase, makes little difference, it can considerably affect the floatability of minerals if reaction proceeds between the gas molecules and the mineral surfaces, or dissolved reagents or the water itself. Thus, oxygen is often an oxidizing

agent, carbon dioxide forms carbonates, and hydrogen sulphide is a strong sulfidizing agent, all of which may play an important part as such in flotation systems.

The liquid phase has always been a dilute aqueous solution. Why this should be the case is quite evident when the properties of water are considered. Water is universally available and inexpensive, it has great solvent power, low electrical conductivity, yet great ionizing power, and high polarity which makes it suitable for flotation. Other liquids could be used for special flotation involving the recovery of valuable products.

A factor of great importance in performance of flotation systems is the hydrogenion concentration of the pulp. This is measured in the liquid phase and recorded as the pH or the logarithm to the base 10 of the hydrogenion concentration. By control of this factor (i.e. acidity or alkilinity) of the pulp, it is possible to float or depress various sulphide and non-sulphide minerals.

In contract to the fact that there is but one gas and one liquid phase, the number of solid phases may be large and of complex association depending upon the number of mineral species present.

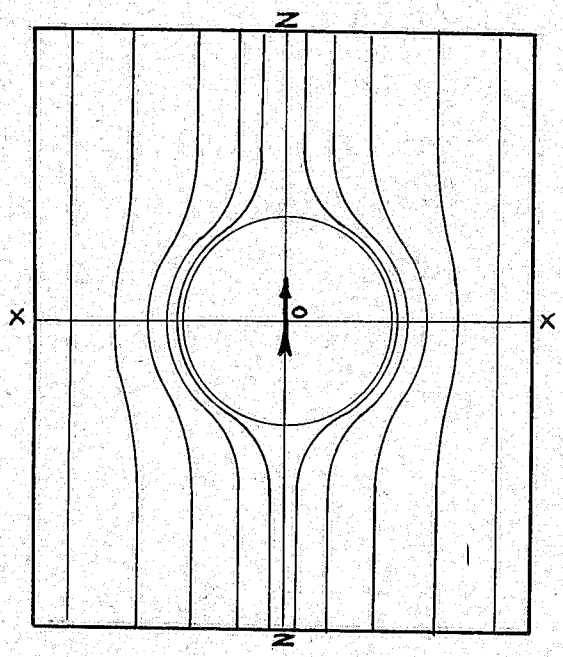
Most minerals are unionized and insoluble in water. Ionized substances have much greater solubility in water and are, therefore, rarer as minerals. Calcite is an exception, being an ionized mineral.

The polarity or non-polarity of minerals, together with the capacity of hydration which transforms the surface of certain otherwise non-polar minerals into polar areas controls their wettability by water and ultimately their flotation or non-flotation. The surface of a mineral adsorbs water molecules which forms a transitional layer between the crystal and the solution which cements water to the mineral. The case of a non-polar solid which cannot be hydrated is totally different - the phases must then be bound discontinuously.

MECHANICAL ASPECTS OF FROTH FORMATION:

A study of the mechanism of frothing resolves itself into the rate at which mineral particles come into contact with bubbles, whether or not they adhere to the bubble on contact, and bubble formation.

The extent to which bubbles and particles encounter each other is impossible to predict in a complex system such as an aerated pulp. Much information can be gathered however from the study of a simplified system. To represent such a system it is assumed that the bubble is spherical, rises vertically with uniform velocity in a perfect liquid which has no viscosity and is infinitely divisible. From the diagram which represents a bubble rising vertically in a perfect liquid, it can be seen that only particles which lie along the line ZZ will come in contact with the rising bubble. Ideal conditions such as this can not exist in an aerated

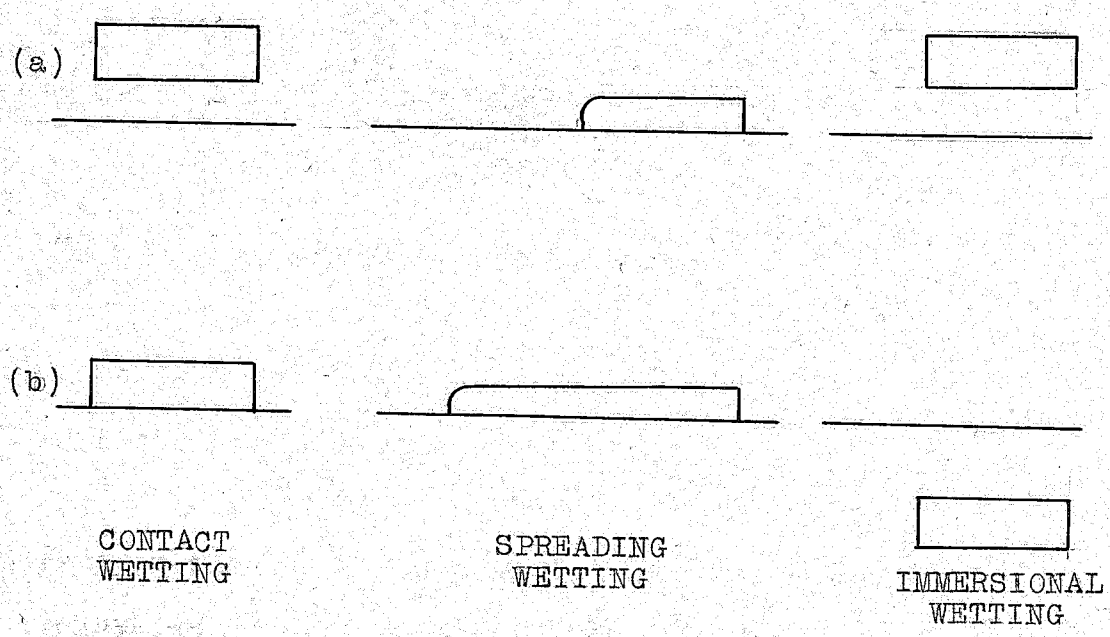


Flow Lines of Water
around a rising
bubble.

pulp. Here, there is rotation of bubble and particle, lateral movement, and non-spherical shape of particles, which will not allow settling in a straight line. All of these factors cause the collisions to be greater in number than that existing in a perfect system. Therefore it would seem that a rather fine bubble froth would be desirable, and fine particles would be undesirable as factors in probability of encounter - hence flotation.

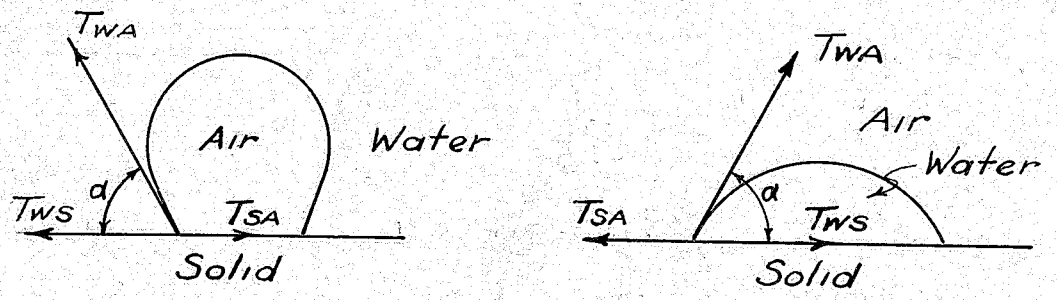
Gas-solid attachment may best be discussed under several headings - types of wetting, contact angle, selection in attachment, and bubble structure and form.

The essential condition for froth flotation is that a particle completely wetted by water become attached to an air bubble. A particle may become wetted in either of three ways - as shown -



CONTACT ANGLE -

The study of no other single property of minerals has been of such great significance in the theory of flotation as the study of contact angles. It is the measure of the tenacity of adhesion between mineral and air; that is, the tendency of a bubble to remain attached to a mineral, thereby rendering it floatable.



where TSA = Surface tension of Air-Water interface.

TWS = Surface tension of Water-Solid interface.

TSA = Surface tension of Solid-Air interface.

$$TSA = TWS + TWA \cos \alpha \quad \ldots\ldots (1)$$

In order that an air solid interface be established

$$TSA < TWA + TWS$$

hence work done to perform this will be

$$W = TWS + TWA - TSA$$

(where W = work done per unit area)

substituting in equation (1)

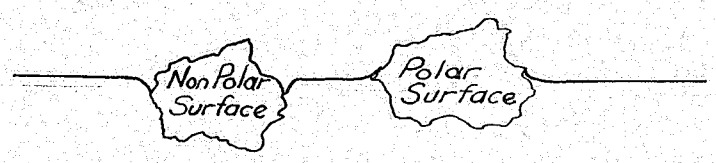
$$W = TWA\ (1 - \cos \alpha)$$

If $\alpha = 0^{\circ}$ then W = 0 and there is no tendency for the bubble to stick. If $\alpha = 180^{\circ}$, then W = 2 TWA, which is a maximum of adhesion tenacity.

Both α and TWA can be measured experimentally - which is obviously of great importance in flotation. It may be noted that not every factor influencing flotation also influences contact angle; although any factor influencing contact angle influences flotation. This is evidenced by the fact that frothers have no significant effect on contact angle as they lower the surface tension only slightly.

SELECTIVE ATTACHMENT - (1)

Attachment of particles to bubbles must be selective between minerals having different surfaces, in order that flotation be successful. If a particle having a non-polar surface encounters an air bubble so that direct adherence of air and solid exists at a certain instant, the contact angles that become established at the solid surface indicate a tendency for the gas to displace the water at the solid's surface. Similarly if a particle having a polar surface encounters an air bubble (which may be difficult because of the hydrated ions residing at the surface of such a particle) the contact angles indicate a tendency for the water to displace the gas at the solid's surface. Thus, one of the particles will tend to pass in to the gas phase and the other to return in the aqueous phase.



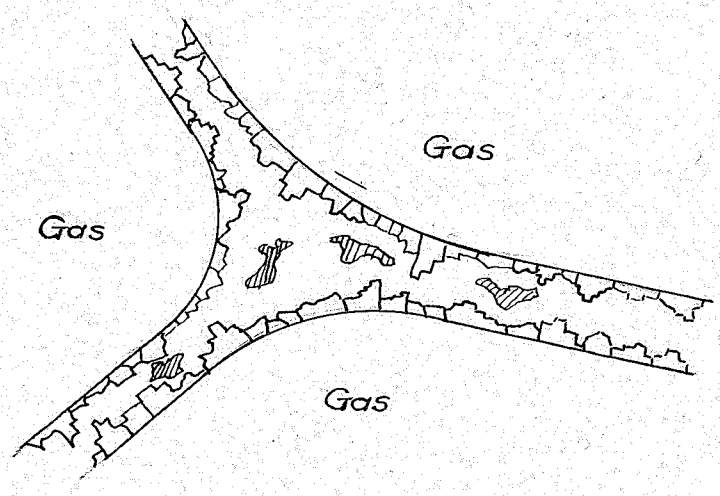
Return of particles having a polar surface to the aqueous phase is favored by the agitation and subsequent encounters involving the gas bubble and by the crowing effect exerted at the bubble surface by other particles which are better prepared to adhere to the gas

(1) Goudin Flotation P98.

BUBBLE STRUCTURE -

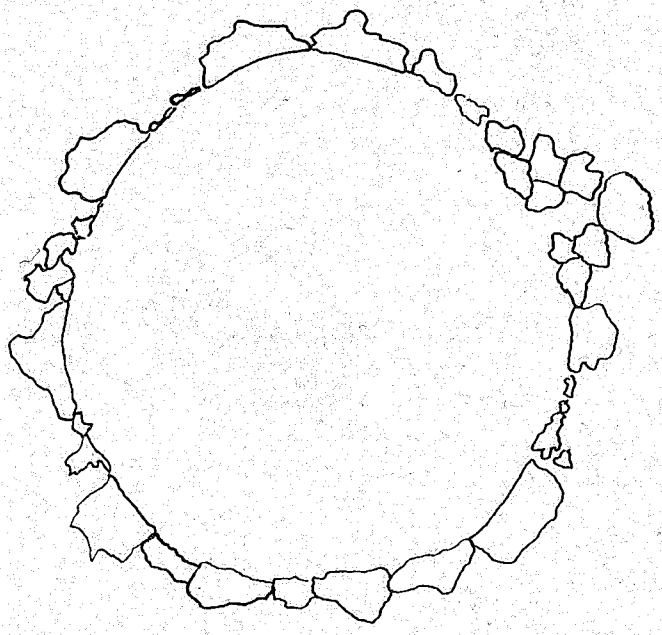
An aggregate of bubbles is a froth. The most desireable froth is one in which the bubbles rise with sufficient velocity to carry over an abundant concentrate, yet travel slow enough to allow drainage of unwetted material back to the pulp.

The bubbles vary in form during their life, due to several causes, (1) extent of mineralization of pulp. (2) size of particles. (3) size of bubble. They first appear spherical in shape, but due to loading they become forced together, where some unite to form larger bubbles, and eventually attain a polygonal outline.



Existence of a polygonal froth produces a filter through which the gangue material passes on its downward drainage. Coarse material would tend to become retained but this is counteracted by its fast settling rate in consequence of which it would not as likely be at the top of the froth. Fine particles, due their small descending velocity overflow with interbubble water.

In agreement with the second law of thermodynamics, (surface energy tends to be a minimum), particles adhere to a bubble wall with the largest area compatible under the circumstances. Due to this fact, the bubbles are lined one layer thick and present a smooth inner surface.



Camera-lucida drawing of a dry bubble (section) X80.

Several arguments have been put forth as to the correct size of bubble. Small ones, while they have a greater surface per unit volume, and more tendency to attach to fines, cost more to produce. They may also become heavily enough loaded to attain the same specific gravity of the pulp, thereby having no lifting power.

The correct theoretical size can be obtained from Allen's Law -

$$v = K\left[\frac{\sigma - \rho}{\rho}\, g\right]^{\frac{3}{2}} \frac{(a-b)}{\left(\frac{\mu}{\rho}\right)^{\frac{1}{3}}}$$

where K = A Constant (0.5)

σ = Specific gravity of bubble

g = Acceleration due to gravity.

a = Radius of bubble

b = A Constant (0.0034 cm)

μ = Viscosity of medium.

From this equation and other data,(1) the best ratio of bubble size to particle size in a pulp of 1.25 for calcite is the ratio of 8.5 :1

(1) - Gaudin - Flotation P104.

- ADSORPTION -

Adsorption is the term used to denote the formation of layers of molecules attached to, or attracted by, a solid surface.(2) Selective flotation is dependant upon a selective absorptive power of mineral surface for certain organic compounds.

The surface of a solid or liquid phase has an unbalanced inter-molecular force, not possessed by the interior. In the interior, the chemical attraction of an atom is equally distributed among the surrounding atoms. At the surface the atomic attractive force on one side exists unsatisfied, causing a definite chemical attraction to extend out into space. This force is capable of holding other molecules which come within the zone of influence, to a varying extent, depending upon the type of molecule so adsorbed. Discussion is here divided into two parts - adsorption at liquid surfaces and adsorption at solid surfaces.

(2) Millard - Physical Chemistry - P.138.

Adsorption at Liquid Surfaces:

Many organic substances when dissolved in water, lower its surface tension, while inorganic salts tend to slightly raise the surface tension. J. Willard Gibbs (1) states that this phenomenon is due to a higher concentration of the organic substances at the surface layer than in the bulk, whereas the surface concentration of inorganic salts must be lower than the bulk concentration. The organic substances are said to be positively adsorbed and the inorganic salts negatively adsorbed. The amount is given by Gibbs' equation -

$$A = -\frac{C}{R\theta}\frac{\partial T}{\partial C}$$

where A = Adsorption in gm. molecules /cm ^{2}

C = Concentration in % or gram molecules

R = Gas constant in ergs per degree cent.

θ = Absolute temperature in degrees Kelvin.

Langmuir has shown that Gibbs equation leads to the conclusion that the adsorbed layer is one ion or molecule thick(2). In this unimolecular film the organic molecules fix their orientation with respect to the surface, the direction dependant upon the type of molecule. For example, organic compounds

(1) Wark - The Principles of Flotation P.64.

(2) Gaudin.

such as those employed as frothers, are made up of an active and an inactive group, which orient themselves with their active group directed towards the water. In this way the adsorbed molecules become concentrated at the air-water interface on the inner and outer walls of the bubble, causing a lowering of surface tension.

Adsorption at Solid Surfaces:

Five different types of adsorption are considered by Kolthoff. (1)

1. Adsorption by a salt having an ion in common with the lattice.
2. Exchange adsorption between lattice ions in the surface and foreign ions from the solution.
3. Exchange between adsorbed "counter-ions" and foreign ions in the solution.
4. Molecular adsorption of non-electrolyte and true adsorption of salts.
5. Activated adsorption.

Type (1) is described as adsorption of potential-determining ions; such as the adsorption of heavy metal ions from solution by an electrode of the same heavy metal.

Type (2) is very common. Naponen (2) found that if barium sulphate was shaken with lead chloride, some of the lead ions in solution were replaced quantitatively by barium

(1) Journal Physical Chemistry, 40, 1027, (1936)

(2) Wark - The Principles of Flotation - P67.

ions from the crystal lattice, but the chloride ions were unaffected.

$$Ba\ SO_4 + Pb^{++} \rightleftharpoons pB\ SO_4 + Ba^{++}$$

Type (3) is made clear by an example. We have seen that silver iodide when thoroughly washed, still retains an excess of iodine ions, and that it is surrounded by an ionic atmosphere of hydrogen ions as counter ions. Lead ions from a dilute solution of lead nitrate can replace these hydrogen ions, themselves becoming the counter ions according to the equation.

$$2(AgI.....I) \vdots H^{+} + Pb^{++} \rightleftharpoons 2(AgI....I-) \vdots Pb^{++} + 2H^{+}$$

Type (4): Such substances as water and alcohol can be adsorbed by ionic lattices. They may be firmly held. For example even in a high vacuum, calcium fluoride holds fast to water adsorbed from the atmosphere. The water can not be removed even by heating to 400° C, but hydrogen fluoride is evolved instead.

$$CaF_2 + H_2O \longrightarrow Ca\ F\ (OH) + HF$$

Kolthoff considers that equivalent numbers of anions and cations can be adsorbed by an ionic lattice if the lattice and adsorbed salt have no ion in common, this process is equivalent to the adsorption of a salt. Thus it has been claimed that various salts are adsorbed on barium sulphate in unimolecular films.

Type (5): Activated adsorption: By activated adsorp-

is meant that the adsorbed molecule is chemically changed or strongly distorted by the adsorption. This property makes it possible to react with other substances not ordinarily touched.

Adsorption may be distinguished from chemical reaction. In practice there is a continuous range of adsorption phenomena from the loose van der Waal's adsorption to indisputable chemical reation. Inasmuch as all chemical reactions must begin as adsorption of ions or molecules, adsorption can be considered as chemical reaction.

- THEORETICAL ACTION OF REAGENTS -

COLLECTION:

Collection is that element of a flotation operation which comprises selective attachment of certain mineral particles to bubbles. Several theories of the operation of collectors have been advanced. Nearly all have been discredited or disproved, wholly or in part, by various writers in favor of the so called "chemical" theory. In a paper by Taggart, Taylor and Knoll(1), it was postulated that "All dissolved reagents which, in flotation pulps, either by action on the to-be-floated or on the not-to-be-floated particles affect their floatability funtion by reason of chemical reactions of well recognized types between the reagent and the particle affected". This hypothesis is intended to embrace within its generalization, collecting agents, depressing agents, and activating agents, both organic and inorganic. It is subject to the one limitation that the reagent must dissolve in the water of the flotation pulp, and react on the solid particles therein, to affect their floatability. This limitation however, does not mean that chemical reaction has no part in the functioning of the other types of substance. Nor the contrary. The exclusion

(1) Taggart Taylor & Knoll; Chemical Reactions in Flotation. Trans. A.I.M.E. 87,1930. P. 211.

simply narrows the field of discussion to the extent indicated.

Chemical reaction between soluble flotation reagent and the solid particles of the pulp was suggested as early as 1904 (1) and periodically supported since that time. The early all aqueous differential- flotation patents (2) aimed to effect, by digestion in strong aqueous solutions, chemical surface changes similar to those effected by the fractional-roasting processes. But when some of the same investigators found that very dilute solution of inorganic substances had somewhat the same effects on the floatability of certain sulphides as the strong solutions had, they apparently dropped the chemical-action idea, because with dilute solutions, there were no readily visible surface changes on the mineral affected. There have followed, in consequence, many theories.

W. Ostwald has advanced a theory of the action of soluble collectors, an essential part of which is that only a ring of the collector is necessary for flotation; the location of the ring being the air-water-mineral line of contact. The process by which this ring is assumed to be held is styled by him "adlineation". Its theory is based on the postulation that a soluble collector such as potassium, ethyl xanthate is conceived of as a three legged molecule which first adsorbs at the surface of bubbles and sulphide particles penetrates the bubble wall, drying immediately on the part extending into the gas cavity of the bubble, and the three-legged molecules simultaneously jump into position along the line of three-phase contact, with one leg extending into the gas, one into the liquid and one against the solid phase. In the

(1) De Bavay, U.S. Patent 864597 (1904)
(2) Ramage 967671; Wentworth 970002; & 980035; McGregor 972459; Horwood 1020353; etc.

compound potassium ethyl xanthate -

Ostwald conceives the ethoxy group as air-avid, the double bonded sulphur as metal-avid, and the SK group as water-avid.

This theory is in opposition to that adopted by Wark and Cox, (1) namely that a monomolecular film is adsorbed by the surface of the mineral, and that for oleaginous collectors, a thin film spreads on the surface. The only evidence advanced by Ostwald in opposition to Wark and Cox is that the amount of reagents added seems to be insufficient to form a unimolecular film. Gaudin, Glover and Hansen(1) demonstrated that the amount of reagent was sufficient. Further, the adlineation theory is not in accord with several experimental facts and accredited principles of surface physics. (2)

Ravitz and Porter (3) attack the chemical theory from a different angle. Using the investigations in the flotation behaviour of "oxygen-free" galena, in which they were able to float galena without a reagent, they concluded that their experiments supported the old idea of inherent floatability of certain minerals. This conclusion led to the statement that collectors such as xanthate may act as a cleansing agent

(1) Flotation Fundamentals Part 1. U. of Utah 1929

(2) Gaudin Glover & Hansen, J.Phys, Chem. Mar.1933. P.815.

(3) Ravitz and Porter, A.I.M.E. Tech.Pub. 513 (1934)

to remove oxidation surface products leaving the non-polar sulphide free for the displacement of water by gas.

A group of investigators, among whom may be numbered Takakuwa (1) and Ralston (2) follow Sullman (3) in ascribing flotation to differential flocculation of the particles to be floated - without examining the mechanism that controls flocculation. Since the chemical theory deals with the antecedent step, the argument is not effective as a theory.

Another theory is advanced by Otis D. Welsch (4) suggesting that the flotation of mineral particles, sulphide or non-sulphide, is the result of buoyancy created by developement, by chemical means, at the surface of the particle, of a volatile substance. He supports his theory by citing the works of such writers as R. S. Dean, A.W. Allen, Taggert and others.

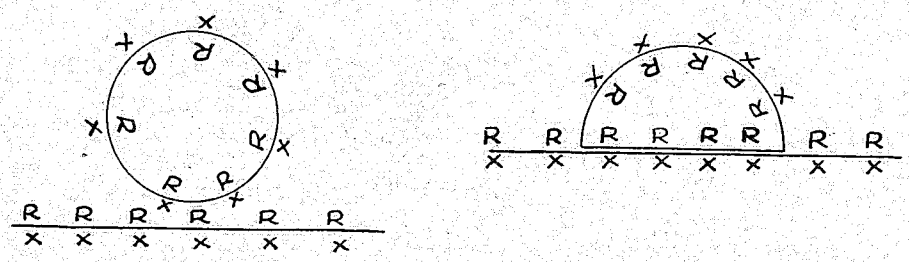
However, the theory as presented does not seem convincing.

The generally accepted "chemical" theory of collection as sponsored by Taggart and Gaudin, infers that a collector attaches itself to a mineral surface by chemical reaction. It does not deny the fact that collectors are adsorbed as unimolecular films - it employs the properly

(1) Takakuwa; Proc. World Eng. Congress, Tokio. 1929.
(2) Ralston; Trans. A.I.M.E. (1930) 87, P. 247.
(3) Sulman, Trans. Inst. Min. & Met. (1919) 29, 44.
(4) Welsch, E & M.J. Oct. 1932 P. 529.

defined and clearly understood definition of adsorption - that adsorption is nothing more than a concentration of solute at an interface (the mechanism of concentration may or may not be chemical reaction).

Collector agents employed are capable of forming a very slightly soluble compound with some intrinsic compound or surface ion of the mineral to be floated. They have the characteristic of being of a dual nature; part of their molecule is polar (and water-wettable) while another part is non-polar (and non-water-wettable). Thus, in the case of sodium xanthate, the sodium end is polar and the xanthate (Alkyl) end is non-polar. Similarly, after precipitation, as the metallic xanthate, the metallic end of the molecule is polar while the xanthate end remains non-polar. Their orientation of such reagents (termed heteropolar) can be illustrated as follows -



R - Alkyl inactive group.

X - Active Group.

Increased length of the hydrocarbon chain results in increased effectiveness of the collector. No definite optimum has, however, been established for the number of carbon atoms in the non-polar part of the molecule. The

property of non wettability in the exposed part of the molecule is essential to a solid substance or its coating, to be amenable to collection in a flotation froth.

Modern usage has included promoters in the term collectors. All collectors (therefore promoters) contain both polar and non-polar groups - all must be adsorbed to be effective. Those used in present day flotation practice are mainly xanthates and aerofloats or their derivatives. Both of these reagents release active water-repellent anions on dissociation -

from a xanthate $R.O - O\begin{matrix}=S\\ -S\end{matrix}$ and a cation M^+

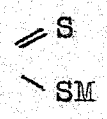
from an aerofloat $\begin{matrix}R.O\\ R.O\end{matrix}\!\!>P\begin{matrix}=S\\ -S\end{matrix}$ and a cation H^+

These anions are strongly adsorbed at all water surfaces owing to their water repellant hydrocarbon (R.O.) chains, and some come in contact with the particles of ore at every water-solid interface. The double bonded sulphyr atom (= S), or possibly the whole group $\begin{matrix}=S\\ -S\end{matrix}$, appears to have the property of attaching itself to the surface of sulphide minerals and some native metals, rendering them water repellent and therefore floatable.

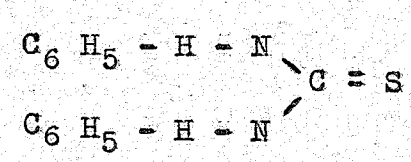
Of the possible xanthates, only potassium and sodium ethyl, butyl and amyl xanthates are used, with the potassium being in preference to the sodium compounds. As a rule the low xanthate is less powerful but more selective than the higher alkyl forms.

Aerofloats are made in various grades depending upon the percentage of $P_2 S_5$ contained. They are not as strong as higher xanthates in action, but they are preferred in flotation of pyritic ores, due to their lesser action on the pyrite. Because of the presence of free cresylic acid, which is a frother, aerofloat has both frothing and collecting (or promoting) properties.

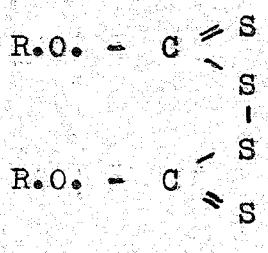
In addition to the above mentioned promoters, which contain a group of the type



there are others with single or double sulphur groups. Thiocarbanilide with the single sulphur group -



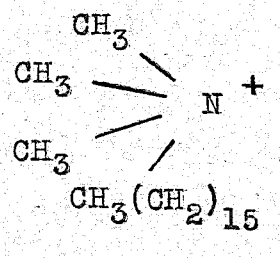
or di-xanthogens with double sulphur group of the type



are typical. Both are less employed than aerofloats or Xanthates, although they are quite effective in their own particular fields.

A new class of reagent has recently been introduced - of which the active water repellent part is contained in the cation. The substituted quaternary ammonium

compound as used by Wark [1] in the flotation of silica, is of the cation active class. He employed tri-methyl-cetyl-ammonium bromide, (commercially known as Lissolamine A), which dissociates into a cation



and an anion Br^-.

Here, the active ion carries a positive charge in contrast with the negative charge on the active ion of the xanthates, aerofloats and similar promoters. It appears that this property makes the compound a promoter for silica and other rock forming minerals.

Many cation-active compounds are known, the properties of which have been investigated. Most of them bring up sulphides as well as non-sulphides without selective action - some will float the whole of an ore.

(1) I. W. Wark, "The Physical Chemistry of Flotation" J. of Phys. Chem. Vol. 40 May 1936.

- FROTHING -

Frothing is the most conspicuous of the phenomena comprising the flotation process. It is of vital importance, being the factor controlling overflow; hence concentration. The mechanism of the formation of bubbles by frothers is purely physical and is based on one of the properties of liquids - namely surface tension.

J. Willard Gibbs (1) has shown that a substance lowers the surface tension of a liquid only by adsorption. If two liquids are then mutually soluble there can be no adsorption. In all probability, therefore, the so called soluble frothing oils are in colloidal suspensions rather than true solutions.

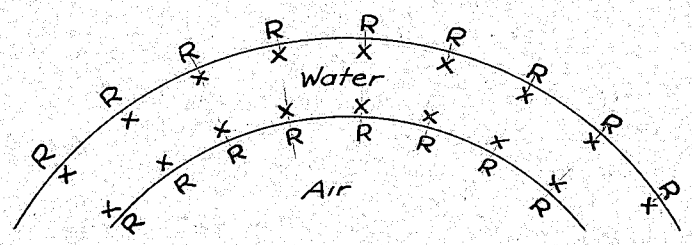
The frothing agents are found by experiment to concentrate in the bubble films, thereby lowering the surface tension of water. This is in complete accord with the principle of minimum energy, inasmuch as any other behaviour of such substances would not produce a state of minimum surface energy. (2)

A study of substances which lower the surface tension of water shows that they are, practically without exception, organic compounds, whereas substances which raise the surface tension are inorganic compounds.

(1) Thermodynamische Studien

(2) Frothing, G.R.M. del Guidice; E & M J; Vol 135 (1934) P. 153.

Statistical analyses [1] of the structure of molecules of good organic frothing agents has shown that they are invariably made up of two distinct groups - namely a hydrocarbon group and some one of the following groups: OH (hydroxyl), CO(Carbonyl), COO(ester), COOH(Carboxyl), CONH(Amide), NH_2(amino). Further, the analysis has shown that the solubility in water decreases with increase in length of the hydrocarbon chain. The net effect then, is that all frother molecules must have an insoluble water repellent (hydrocarbon) group coupled with a soluble water-avid (hyroxyl , carboxyl, carbonyl, etc.) group. As a hypothesis, it is conceived that the hydroxyl end of the molecule of these substances is attracted by, and tends to dissolve in water, the hydrocarbon end does not.[2] (Without water repellence of the hydrocarbon end, these molecules would be drawn into the interior of the water.) These two tendencies, therefore result in the adsorption of the reagent at the water surface with the hydrocarbon end of the molecule away from the water.



(1) A. F. Taggart, T.C. Taylor, & C.R. Ince; Trans. A.I.M.E. (Milling Methods 285) 1930.

(2) Langmuir and Harkness.

The frothing agent, due to the water avidity of the hydroxy group, and the air avidity of the hydrocarbon group, collects in the bubble film.

There is less surface energy or state of tension, in the air-water-reagent interface than in the water-reagent interface - hence bubble formation. In other words, the formation of bubbles with the frothing agent in their films, represents a restoration of equilibrium in a system by a decrease in tension. (1)

The attachment of mineral particles to bubbles is due to the lesser energy of the air-solid interface, than that of the solution-solid interface. At the solution-solid interface there is a certain tension. When an air bubble presents itself at the surface, the tension becomes lowered, thereby restoring the equilibrium of the system.

Good frothers are organic compounds with a solubility of around one gram per litre of water, of the general form -

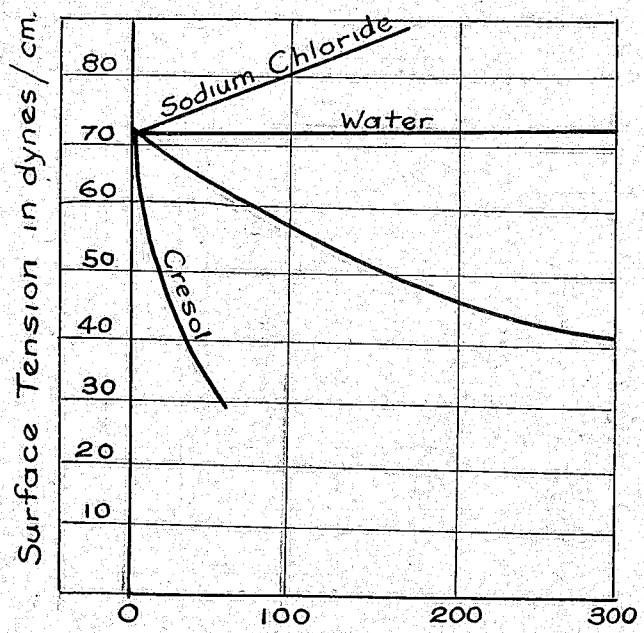
$$R \begin{cases} OH \\ COOH \\ CO \\ COO \end{cases}$$

where R is a hydrocarbon with a carbon content equal to about six. These compounds concentrate at the air-water interface and function by causing rapid changes in surface tension for relatively small changes in concentration. (2)

(1) A. J. Weinig & C.B. Carpenter; The Trend of Flotation; Vol. 32 (1937) P.21.

(2) G.R.M. del Guidice; Frothers; E & M.J; Apr. (1934) P.155.

Frothing tests have found that if a large amount of frothing agent is already in use, little increase in frothing effect may be expected by further additions of reagent.



Conc. in g.p.l. of water
Surface tension curve obtained by adding prepared solution of oleic acid in benzene to a given clean surface of water.

In most cases frothers are oils or oily substances, generally distillation products of wood or coal. Animal products have not been found so effective for this purpose. Various reagents on the market are made to form different froths, grading from "brittle" or quickly broken bubbles to the other extreme of voluminous persistent bubbles. Fineness of grinding has a stabilizing effect upon the froth, often increasing recoveries.

Pine oils, pine tars, wood tars, coal tars, creosotes, and their derivatives have been used as frothing agents, some

of which also have a collecting action. Modern practice is turning towards steam distilled pine oil, cresylic acid, coal tar derivatives and higher aocohols. The quantities are very small and must be individually determined by trial.

- ACTIVATION -

Activation agents are generally inorganic anions or cations which react with the surface of minerals to be floated, thereby modifying them, so that these surfaces may subsequently react with collectors to form thereon, adherent water repellent films. It is generally conceded that the mechanism of activation by heavy-metal salts involves metathesis between the activator and a surface ingredient of the mineral, resulting in the deposition of a compound of the metal of the activator at the mineral surface. By use of a table of water solubilities, an activator can be chosen, whose cation forms with the anion of the mineral to be floated, a less soluble compound than that formed between this same ion and the cation of the mineral. A limitation is that the reaction product between activator and mineral must not be both highly insoluble and highly resistant to chemical reaction.

The type example of sulphide mineral activator is copper sulphate in connection with sphalerite. Copper sulphate changes the surface of sphalerite to covellite which is readily floatable with a xanthate collector.

Research in the field of non-sulphide mineral activation as carried out by Gaudin, Hälbich, Kraeber and Boppel; has developed a new class of reagents, of which the active part is contained in the cation. Investigations

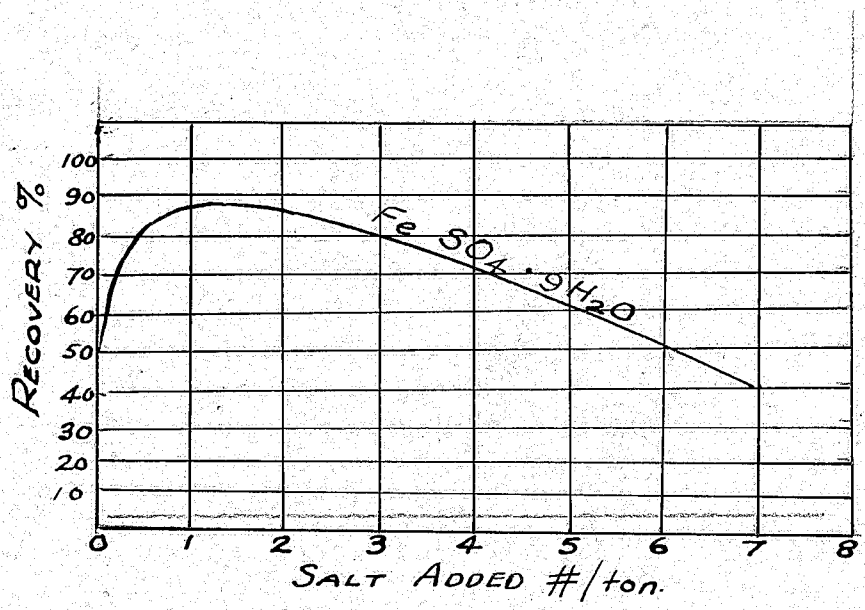
have shown carbonate and silicate minerals may have their surfaces so altered by heavy metal salts, that they can be floated by collectors which formerly had no effect in the absence of an activator.

Copper sulphate used in the flotation of calcite is typical of the cation-active class. Here, presumably the calcite becomes coated with a film of some less soluble salt that is able to adsorb the collector. Gaudin and others[1] assign this activation by copper (and also by lead) salts, of calcite floated with soap, to exchange of Ca with Cu and Pb. ions at the calcite particle surfaces. They assert that copper and lead soaps are less soluble than calcium soaps. (In general, the corresponding anion has no effect: thus manganese and chromium chlorides activate quartz, but potassium permanganate and potassium dichromate do not). Gaudin and Hansen [2] found that nitrates and sulphates of several heavy metals activate calcite for flotation by heptylic and undecylic acids. No metallic salts were found to activate calcite using oleic acid as a collector, due probably to the low solubility of oleates of the heavy metals, causing insufficient oleic acid to remain in solution for the production of a good froth. It should be noted that an excess of activator almost invariably leads to depression of the mineral -

(1) Gaudin; Univ. of Utah, Pub. 1 (1928)

(2) A. M. Gaudin, H. Glover, M. S. Hansen, & C. W. Orr; Flotation Fundamentals, Part 1. Univ. of Utah & U.S. Bureau of Mines. Tech. Paper #1. (1928)

With the tervalent Metals more effective than the bivalent



Flotation of calcite with heptylic acid 12#/Ton.

- DEPRESSION -

Depressors are usually inorganic anions which prevent the "adsorption" of a collector by some minerals but not by others. It has not yet been established whether the depressor is adsorbed itself by the mineral, or whether they alter the chemical nature of the solution so that the collector cannot be adsorbed from it. Gaudin and his collaborators have shown that excess of any heavy metal salt depresses almost any mineral and that many inorganic anions, if in sufficiently high concentration, will depress most minerals. Metallic ions are seldom used as depressants in practice but occasionally a combination of both anion and cation is employed.

Wark and Cox (1) have done extensive research work on the action of cyanide as a depressor for copper and iron sulphide minerals. Plant practice and research have agreed that the most important sulphide depressors are alkalies, particularly lime and sodium carbonate. With xanthate as a collector, sufficient alkalie will depress any mineral; consequently selective separation depends to a large extent on pH control.

Although little is known about the depression of non-sulphides, there are a few valuable practical reagents in use. Sodium silicate can be regulated to activate or depress silica. With an acid salt it forms a gel on the

(1) Wark and Cox, A.I.M.E. (1934) P.189, 245.

the surface of quartz. Most investigators [1] have found that the sodium silicate produces a gelatinous combination of metal oxide and silica, not simply silica gel and no obvious reason for supposing that the gel is attached to the quartz "because of related chemical properties". Bartel and others have shown this adsorption to be hydrolytic - that is, silica adsorbs the basic constituent preferentially and leaves the acid in solution. Silica is then said to be "activated" because the adsorbed ions are capable of forming with oleic acid a floatable surface of insoluble base-metal soap. The adsorbed base-metal ions are also capable of forming with sodium silicate a hydrous gel which acts as a depressor. Sodium silicate should be used in excess so that all metal ions will be taken up - this is counteracted by interaction of sodium silicate with oleic acid.

Just as some salts capable of forming insoluble soaps activate calcite, certain other salts which form colloidal hydroxides, result in depression of calcite. Chromium and alluminum nitrates are typical.

In their investigations, Rose and Macdonald [2] have found that certain partially or incompletely molecularly hydrated phosphates such as sodium netaphosphate, inhibit the flotation of non-sulphide minerals. Under suitable conditions, sodium metaphosphate brought into contact with limestone

(1) J. M. Patek; Soap Flotation; E. & M.J. Mar. 1934 P. 125.
(2) Rose & Macdonald; U.S. Patent No. 2,040,187.

(calcite) coated with calcium oleate, will so modity the coating of calcium oleate as to inhibit the flotation of limestone. If the sodium metaphosphate is added first, the formation of the floatative calcium oleate film is prevented. The surface of barite is also similarly effected, but to a minor extent, allowing the selective flotation of barite.

- PREPARATION OF THE ORE -

The research, as originally planned, called for an ore composed of selected gangue minerals from a local mine. An ore of this type was obtained, but after several tests it became apparent that its complex composition would introduce factors beyond the scope of the proposed work. Consequently it was decided that further work would be more advantageously carried out on a synthetic ore.

The synthetic ore minerals consisted of crystalline barite, clear white marble, clean silica sand, and sulphides composed of galena, chalcopyrite and pyrite; all of a very pure grade. These minerals were mixed in the following approximate proportions -

Barite	-	20.0
Limestone	-	25.0
Quartz	-	40.0
Sulphides	-	15.0
		100%

A second mixture was made up without the sulphides, when it was discovered that the reagents used almost invariably floated the sulphides before the gangue minerals. The approximate proportions of this mix was -

Barite	-	30.0
Limestone	-	30.0
Quartz	-	40.0
		100 %

Each of the minerals was crushed in stages on a laboratory type jaw crusher and rolls, being mechanically screened after each reduction stage until the final product was all - 14 mesh. The separate minerals were then weighed out and thoroughly mixed in the above proportions. Two similar mixes were prepared as the supply in each case became exhausted.

Grinding tests were made to determine the time best suited for a satisfactory grind. From the results of which are tabulated below, the 30 minute grind was considered most satisfactory.

All screen tests were carried out on a mechanical screening machine each sample being screened for 25 minutes.

MESH	P.M. FEED	GRINDING TIME 5 Min.	15 Min.	30 Min.	60 Min.
10	0	0	0	0	0
10/14	0	0	0	0	0
14/20	2.9	0	0	0	0
20/28	10.9	0.8	0	0	0
28/35	12.6	2.1	0.3	0	0
35/48	18.9	10.0	1.5	0	0
48/65	24.7	25.9	9.3	0	0
65/100	8.2	16.6	19.2	1.4	0
100/150	3.5	8.8	16.5	7.7	0.9
150/200	2.4	5.5	11.0	15.9	4.8
-200	15.7	30.3	42.2	75.0	94.3

Head Sample:

To obtain a representative sample for a head assay, the mixture was coned, quartered, and split on a Jones riffle until 600 grams of the ore was obtained. This sample was then pulverized to enable it to pass through a 100 mesh screen, thoroughly rolled and sacked preparatory to assaying by the method described in the section "Assay Methods".

Standard Test Conditions:

All tests unless specifically stated otherwide, were treated under the following standard conditions.

(a) Grinding - carried out in (7½x6" inside) porcelain pebble mill.
Charge - Ore = 500 grams.
Water = 500 grams.
Iron free pebbles = 2950 grams.
Speed of pebble mill = 60 rpm.
Time of grind = 30 minutes.

(b) Cell Procedure

The ore from the mill was washed into a Fagergren unit flotation cell (as in photograph) and water added until the pulp density was 4:1. Required reagents were added and the pulp "conditioned" for 3 minutes. At the end of this period, the air was turned on and regulated so that a satisfactory froth was produced for the ensuing 10 minute "skimming" period.

On completion of each test, a 50 cc sample of the concentrate (and the tailing where it was thought necessary), was taken for a pH determination, obtained on a Leeds and Northrup Galvanometer.

Note - Insoluble reagents were usually added to the pebble mill charge. All concentrates and tailings were dried in stainless steel pans, weighed, screened through a 65 mesh screen, thoroughly rolled, sacked and assayed for Barite, Limestone, Quartz, and in the case of the first mix, for Sulphides.

Calculation of Recovery:

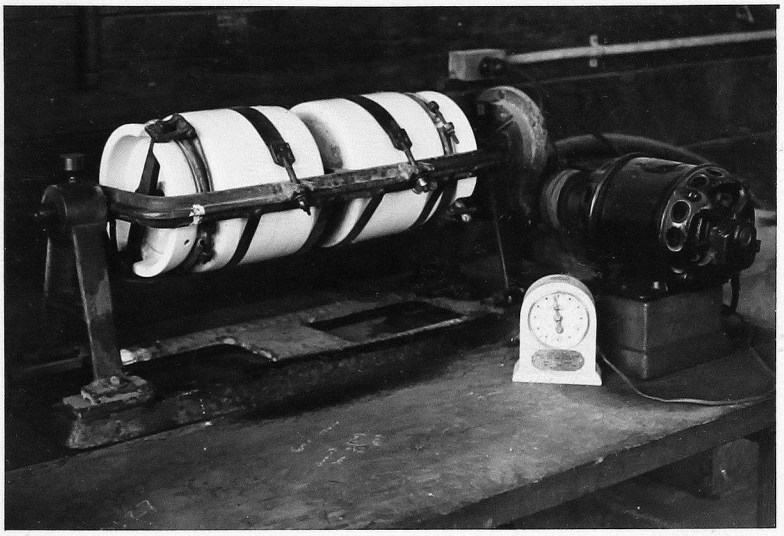
$$\frac{\text{Wt. of Concentrate}}{\text{Wt. of Concentrate Wt. of Tailing}} \times 100 = \%\ \text{Recovery.}$$

Calculation of Three Mineral Recovery Index:

Sum of the pereent recoveries of the desired concentrate and the remaining tailings. This number gives a convenient indication of the general result of a test.

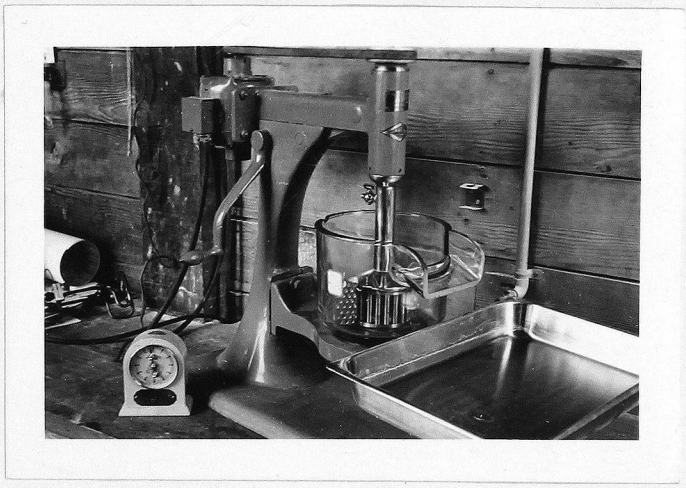
Temperature Test Procedure:

Several tests were carried out with the object of determining the effect of an increased temperature on the flotation of Barite Limestone and Quartz. The procedure followed was as follows. A standard mill charge was added to the cell and the pulp density brought down to 4:1 with water. The pulp was aditated while a thermostatically controlled heater regulated the temperature of that desired. On obtaining a constant temperature the reagents were added and standard procedure followed from that point.



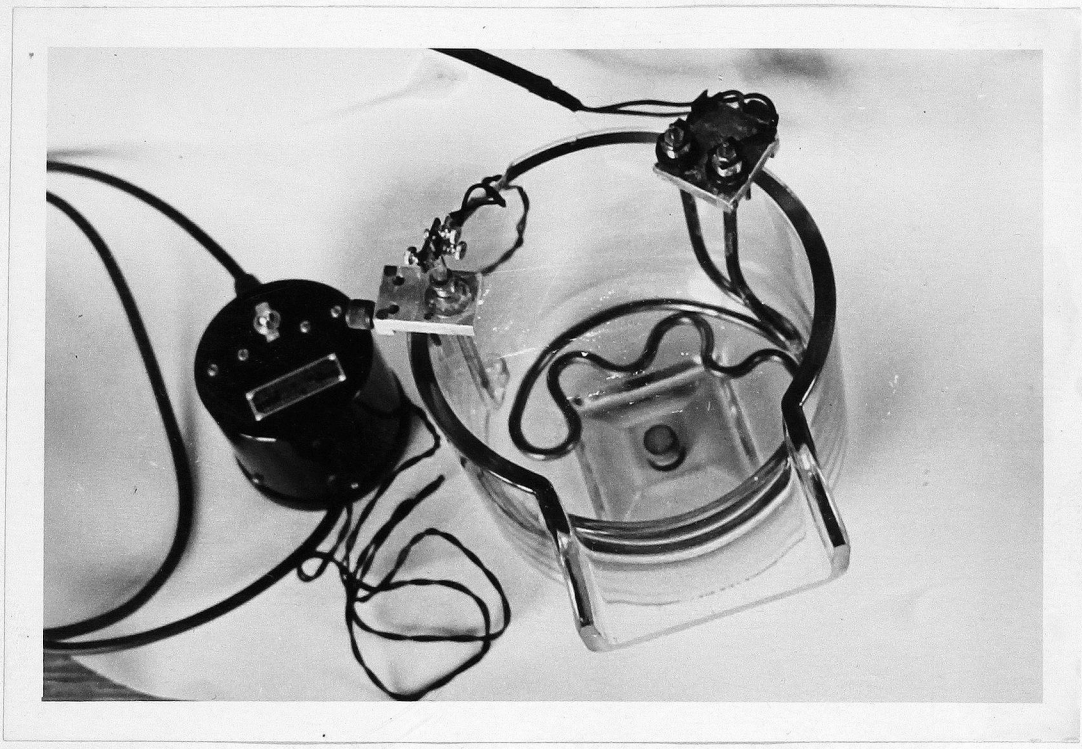
- PEBBLE MILLS AND TIMER -

- CELL IN OPERATION -



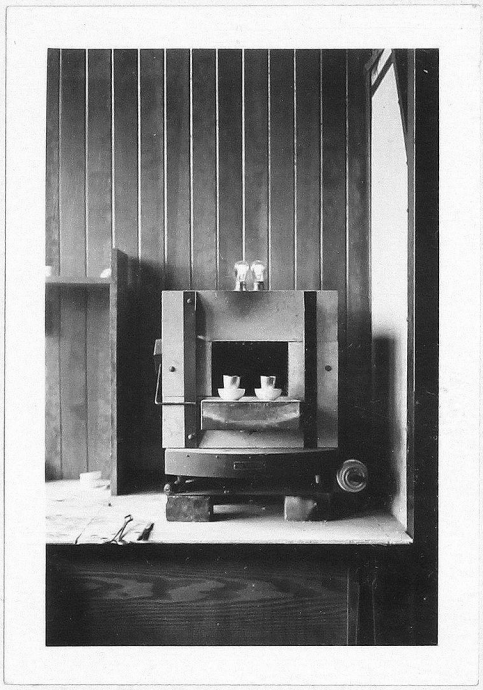
- FAGERGREN FLOTATION UNIT -

- AND TIME CLOCK -



THERMOSTATIC TEMPERATURE

CONTROL



- FUSION FURNACE -

TEST 1.

To test the effect of Trimethyl cetyl ammonium bromide (Lissolamine A) on the flotation of non-sulphides.

Charge to Pebble Mill

Ore	-	1000 Grs.
Water	-	500 Grs.
Grind	-	60 Mins.

CELL

Concentrate 1

Added	-	Lissolamine A - 0.16#/Ton
Cond.	-	3 Mins.
Skim.	-	10 Mins.
pH	-	8.30

Very high sulphide content - fair froth.

Concentrate 2

Added	-	Lissolamine A - 0.08#/Ton
Cond.	-	1 Min.
Skim.	-	5 Min.
pH	-	8.50

Copious but slightly mineralized froth.

Concentrate 3

Added	-	Lissolamine A - 0.08#/Ton
Cond.	-	1 Min.
Skim	-	6 Min.
pH	-	8.15

Concentrate & froth similar to No. 2.

TEST No.	% WT.	ASSAY %					RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100.0	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
TICI	8.6	2.5	9.4	20.8	25.4	14.5	1.0	3.3	4.5	28.5	57.5
C2	4.3	5.9	15.6	36.5	13.3	5.3	1.2	2.7	3.8	5.0	10.3
C3	4.5	13.2	23.7	25.5	6.3	2.7	2.9	4.3	2.9	5.6	5.7
T	82.6	24.0	27.5	42.8	2.7	0.7	94.9	89.7	88.8	60.9	26.5

Conclusion:

See Test 6.

TEST 2.

To test the effect of Retarder LA. on the flotation of non-sulphides.

CHARGE - to Pebble Mill

Ore - 1000 Grs.

Water - 500 Grs.

Grind - 60 Mins.

CELL

Concentrate 1

Added - Retarder LA. - 0.41#/Ton
#5 Pine Oil - 0.07#/Ton

Cond. - 3 Mins.

Skim - 10 Mins.

pH - 8.35

Gangue did not start to float until most of sulphides had been taken off.

Concentrate 2

Added - Retarder LA. - 0.16#/Ton

Cond. - 3 mins.

Skim - 10 Mins

pH - 8.20

Weak, poorly mineralized froth.

TEST No.	% Wt.	ASSAY %					RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
1	11.6	12.2	23.8	6.9	12.3	7.4	6.9	11.3	1.8	33.3	38.5
2	1.0	21.5	36.4	17.3	4.0	1.3	1.1	1.5	0.4	0.9	0.6
T	87.4	21.3	24.7	44.9	3.2	1.4	92.0	87.2	97.8	65.8	60.9

Conclusion: - See Test 6.

TEST 3.

To test the effect of Retarder LA. on the flotation of non-sulphides, using an iron rod mill for grinding.

CHARGE - to Rod Mill

Ore - 1000
Water - 1000
Grind - 10 Mins.

CELL

Concentrate 1

Added - Retarder LA - 0.41#/Ton
3% Pine Oil - 0.07#/Ton
Cond. - 3 mins.
Skim - 10 mins.
pH - 8.27

Poor froth - sulphides up at first.

Concentrate 2

Added - Retarder LA.- 0.16#/Ton
Cond. - 1 Min.
Skim. - 5 min.

Fair froth, little mineralization.

RESULTS:

TEST No.	% Wt.	ASSAY %					RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
1	14.8	9.8	16.8	12.8	11.7	7.6	7.1	10.2	4.8	39.7	54.0
2	5.3	16.0	27.5	28.7	3.2	2.5	4.1	5.8	3.8	3.8	6.3
T	79.9	22.8	25.5	46.0	3.1	1.0	88.8	84.0	91.4	56.5	39.7

Conclusion:

See Test 6.

TEST 4.

To depress the sulphides by the use of Cyanide, Zinc, Sulphate and Potassium. Dichromate & float the gangue only.

CHARGE - to Pebble Mill

Ore - 1000 Grs.
Water 500 Grs.
KCN - 2#/Ton
Zinc Sulphate - 6#/Ton
Grind 60 Mins.

CELL

Concentrate 1

Added - Pot. Dichromate - 1#/Ton
Retarder LA. - 0.98#/Ton
Cond. - 3 Mins.
Skim. - 10 Mins.
pH - 8.30

Chiefly sulphide concentrate.

Concentrate 2

Added - Retarder LA. - 0.41#/Ton
#5 Pine Oil - 0.07#/Ton
Cond. - 1 Min.
Skim. - 10 Min.
pH - 8.23

Good froth - sulphide up first.

Concentrate 3

Added - Retarder LA. - 0.41#/Ton
#5 Pine Oil - 0.07#/Ton
Cond. - 1 Min.
Skim. - 10 Min.
pH - 8.1

Good froth - little mineralization.

RESULTS

TEST No.	% Wt.	ASSAY %					RECOVERY %				
		$BaSo_4$	$CaCo_3$	Sio_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
1	1.1	15.4	34.9	15.6	6.9	3.7	0.8	1.5	0.7	1.8	18.4
2	8.3	16.6	43.9	13.3	6.8	3.0	6.6	14.8	2.7	14.0	12.0
3	6.2	22.9	30.7	22.6	5.4	1.7	6.8	7.7	3.5	8.4	5.0
T	84.4	21.0	22.2	45.0	3.6	1.6	85.8	76.0	93.5	75.8	64.6

Conclusion:

See Test 6.

TEST 5.

To inhibit the flotation of Galena & Chalcopyrite by Potassium Dichromate & Potassium Cyanide - Zinc Sulphate respectively; using Oleic Acid as the collector.

CHARGE - To Pebble Mill

Grind	-	60 Min.
Ore	-	1000 Gms.
Water	-	500 Gms.
KCN	-	2.0#/Ton.
$ZnSO_4$	-	6.0#/Ton.

CELL

Concentrate 1

Added	-	Potassium Dichromate - 2.0#/Ton. Oleic Acid - 0.22#/Ton.
Cond.	-	3 Min.
Skim.	-	10 Min.
pH	-	8.25

Least amount of sulphides in concentrate for any test up to date.

Concentrate 2

Added	-	Potassium Dichromate - 1.0#/Ton. Oleic Acid - 0.11 #/Ton.

RESULTS

TEST No.	% Wt.	ASSAY 5					RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100.0	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
C	8.3	19.8	32.5	11.1	5.5	3.8	7.9	10.8	2.0	10.6	15.7
C	6.6	16.0	29.0	15.4	5.3	2.2	5.1	7.7	2.5	8.4	7.3
T	85.1	21.0	23.9	44.5	4.0	1.8	87.0	81.5	95.5	81.0	77.0

Conclusion:

See Test 6.

TEST 6.

To inhibit the flotation of Galena & Chalcopyrite by potassium Dichromate and Potassium Cyanide - Zinc Sulphate respectively; using Lissolamine A (tri-methyl cetyl ammonium bromide) as the collector.

CHARGE - to Pebble Mill

Ore	-	1000 Grs.
Water	-	500 Grs.
KCN	-	2.0#/Ton.
$ZnSo_4$	-	6.0#/Ton.
Grind	-	60 Mins.

CELL

Concentrate 1

Added - Lissolamine A (2% Col.) - 0.60#/Ton.
Pot. Dichromate - 2.0#/Ton.
#5 Pine Oil - 0.132#/Ton.

Fairly large amount of sulphides at first - large amount of froth - then died down so more #5 Pine Oil and Lissolamine A added.

Concentrate 2

Added - Lissol. A - 0.48#/Ton
Pot. Dichromate - 1.0#/Ton
Cond. - 3 Min.
Skim. - 10 Min.

Good well mineralized froth.

RESULTS

TEST No.	% Wt.	ASSAY %					RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	Fe	$BaSo_4$	$CaCo_3$	SiO_2	S	Fe
Feed	100.0	21.0	24.9	40.6	4.2	2.0	100.0	100.0	100.0	100.0	100.0
C1	16.8	23.1	21.5	17.8	7.2	2.6	26.4	15.4	7.5	26.7	22.5
C2	47.9	26.3	12.5	15.0	5.2	1.4	60.0	25.7	59.6	55.2	29.1
T	35.3	8.1	38.8	36.8	2.3	2.7	13.6	58.9	32.9	18.1	48.4

CONCLUSIONS - for tests 1 - 6 inclusive.

(1) Regardless of the collector used, the metallic sulphides float more readily than the non-sulphides.

(2) The use of Potassium Dichromate as a depressor for galena, and a combination of Potassium Cyanide with Zinc Sulphate as the chalcopyrite depressant was moderatly successful. They did not, however, give a complete inhibition when a large amount of these depressants was used. The sulphur dropped from 25.4% to 7.2% and the iron from 14.5% to 2.6% when compared with test 1.

(3) Tri-methyl-cetyl-ammonium bromide and oleic acid have different collecting actions. This is shown in the following table which compares test 6 with test 5.

COLLECTOR	BULK	GRADE				
		Barite	Limestone	Quartz	Iron	Sulphur
Oleic	Less	Lower	Higher	Lower	Higher	Lower

RECOMMENDATIONS -

(1) The addition of a greater amount of Potassium Dichromate and Zinc Sulphate with Potassium Cyanide might help to decrease the quantity of sulphides in the first concentrate.

(2) A large amount of Sodium Sulphide might be advantageous for the inhibition of the sulphides.

(3) Hydrogen Sulphide used as the gaseous phase is known to depress sulphides. It might therefore be tried as a sulphide depressant in the flotation of non-sulphides in general.

(4) A longer conditioning time with a shorter skimming period and a slight variation of reagents, might be advantageous.

TEST 7.

To float quartz using Lead Nitrate as an activator and Tri-methyl-cetyl-ammonium bromide (Lissolamine A) as a collector.

CHARGE - to Pebble Mill

Grind - 30 Min.
Ore - 500 Grs.
Water - 500 Grs.
Lead Nitrate - 0.5#/Ton.

CELL -

Added - Lissolamine A - o.48#/Ton
Cond. - 3 min.
Skim. - 10 Min.
pH - 8.20

Sulphides floated first, quickly followed by a definite non sulphide concentrate. Froth voluminous well mineralized.

RESULTS

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100.0	100.0	100.0	100.0	
C	61.7	4.9	11.7	63.7	3.5	15.2	33.4	94.5	51.4	245.8
T	38.3	44.1	37.6	6.0	5.3	84.8	66.6	5.5	48.6	

CONCLUSION - On comparison with test 11, it is seen that a more selective flotation is possible with the use of Lead Nitrate. The comparative figures for the concentrates are -

Test No.	% wt.	%$BaSo_4$	%$CaCo_3$	%SiO_2	% Rec. SiO_2
11	67.9	22.1	17.9	57.9	94.8
7	61.7	4.9	11.7	63.7	94.5

TEST 8.

To float Quartz using Copper Sulphate as activator and trimethyl-cetyl-ammonium bromide as collector -

CHARGE - to Pebble Mill

Grind	-	30 Min.
Ore	-	500 Grs.
Water	-	500 Grs.
$CuSo_4$	-	0.5#/Ton.
pH	-	8.50

CELL - Added - Lissolamine A - 0.48#/Ton

Cond.	-	3 min.
Skim.	-	10 min.
pH	-	8.31

Froth same as in previous test but stronger and more lasting in the final addition of Lissolamine A.

RESULTS

Test No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100.0	100.0	100.0	100.0	
C	60.7	5.0	8.4	65.1	3.7	14.7	23.7	94.8	50.9	256.4
T	39.3	44.3	41.5	5.5	5.5	85.3	76.3	5.2	49.1	

CONCLUSION -

Copper sulphate is a better activator for Quartz than Lead Nitrate when Lissolamine A is used as a collector.

TEST 9.

To float quartz using a relatively large amount of Lead Nitrate as an activator and Lissolamine A as a collector.

CHARGE - to Pebble Mill

Grind	-	30 min.
Ore	-	500 gms.
Water	-	500 gms.
Lead Nitrate		1.0#/Ton.

CELL -

Added	-	Lissolamine A - o.48#/Ton
Cond.	-	3 min.
Skim.	-	10 min.
pH	-	8.30

Froth same as in correcponding Test 7.

RESULTS

TEST No.	% Wt.	ASSAY %				RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	INDEX
Feed	100.0	21.0	24.9	40.6	4.2	100.0	100.0	100.0	100.0	
C	63.9	6.8	11.0	63.6	4.0	21.1	32.9	96.8	53.0	242.8
T	36.1	45.2	39.8	3.9	6.3	78.9	67.1	3.2	47.0	

CONCLUSION -

There is little difference between the results obtained in this test and test 7, in which a smaller amount of Lead Nitrate was used. A smaller bulk was obtained in the latter, but this can be accounted for principally by the lower Barite recovery.

TEST 10.

To compare the collecting actions of Retarder L.A., with Lissolamine A in the flotation of quartz when using Lead Nitrate as an activator.

CHARGE - To Pebble Mill

Grind	-	30 Min.
Ore	-	500 Grs.
Water	-	500 Grs.
Lead Nitrate		0.5#/Ton.

CELL -

Concentrate 1

Added	-	Retarder L.A. - 0.33#/Ton
		Terpineol - 0.16#/Ton
Cond.	-	3 Min.
Skim.	-	10 Min.
pH	-	8.30

Sulphides came up first. Froth not quite as heavy as that produced with Lissolamine A on the first addition but more durable.

Concentrate 2

Added	-	Retarder L.A. - 1.15#/Ton
Cond.	-	3 min.
Skim.	-	10 min.
pH	-	8.36

Froth good. Bubbles heavily loaded for a short period after each addition of collector.

RESULTS

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	Ba So_4	$CaCo_3$	Sio_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100.0	100.0	100.0	100	
C1	17.2	13.8	21.2	8.7	12.2	11.6	16.8	3.6	42.3	246.5
C2	43.1	1.9	6.7	85.6	0.9	4.0	13.3	88.6	7.8	
T	39.7	43.3	38.2	8.2	6.2	84.4	69.9	7.8	49.9	

CONCLUSION:

There appears to be a slight difference between the action of tri-methyl-cetyl-ammomium-bromide and Retarder L.A. as quartz collectors. In the following table the tailings are compared -

COLLECTOR	% Wt.	% $BaSo_4$	%$CaCo_3$	%SiO_2	% Rec. SiO_2
Lissol. A.	38.3	44.1	37.6	6.0	5.5
Retarder LA	39.7	43.3	38.2	8.2	7.8

From the above it may be inferred that the Lissolamine A is a more satisfactory collector for quartz than the Retarder LA.

TEST 11.

To study the use of Lissolamine A (Tri-methyl-cetyl-ammonium-bromide) as a collector with no depressor or collector in the flotation of quartz.

CHARGE - to Pebble Mill

Grind	-	30 Min.
Ore	-	500 gms.
Water	-	500 gms.

CELL -

Added	-	Lissolamine A - 0.60 #/Ton
		Terpineol - 0.49#/Ton
Cond.	-	3 min.
Skim.	-	10 min.
pH	-	8.3

Frother required when using Lissolamine A as a collector of quartz. On addition of Terpineol the froth became well mineralized tough and persistent.

RESULTS

TEST No.	% Wt.	ASSAY %			RECOVERY %			Index
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	67.9	22.1	17.9	57.9	54.5	41.7	94.8	198.6
T	32.1	39.3	53.9	6.6	45.5	58.3	5.2	

CONCLUSION

This collector has a definite collecting action for quartz, but at the same time floats too large a percentage of the other components when no further reagents are added.

TEST 12.

To investigate the effect of a low pH value on the flotation of quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Copper Sulphate - 0.5#/Ton
pH - 8.50

CELL

Added - Lissolamine A - 0.48"/Ton
Sulphuric Acid - 2.06#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 7.55

Sulphide up first. Froth strong. Slight effervescence of pulp on addition of sulphuric acid.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Head	100	21.0	24.9	40.6	4.2	100	100	100	100	
C	58.2	4.9	11.6	65.0	3.8	13.9	27.0	92.5	43.3	251.6
T	41.8	42.7	44.0	7.5	5.1	86.1	73.0	7.5	56.6	

CONCLUSION -

The lower pH had little effect other than slightly lowering the bulk of the concentrate.

TEST 13.

To investigate the effect of a high pH value on the flotation of quartz.

CHARGE - Pebble Mill.

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Copper Sulphate - 0.5#/Ton
pH - 8.50

CELL

Added - Lissolamine A - 0.48#/Ton
Sodium Hydroxide 0.80#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 9.75
Tails pH - 9.10

Sulphides floated first. Froth weaker than in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100	21.0	24.9	40.6	4.2	100	100	100	100	
C	56.4	6.1	12.7	63.5	3.9	16.6	28.3	88.0	56.0	243.1
T	43.6	40.0	41.8	11.7	4.0	83.4	71.7	12.0	44.0	

CONCLUSION -

The higher pH had little effect other than to slightly lower the concentrate bulk.

TEST 14.

To investigate the action of Sodium Metaphosphate as a Limestone depressant.

CHARGE - to Pebble Mill

Grind	-	30 min.
Ore	-	500 gms.
Water	-	500 gms.
$CuSo_4$	-	0.5#/Ton
pH	-	8.5

CELL

Added	-	Lissolamine A - 0.48#/Ton Sodium Metaphosphate - 2.0#/Ton.
Cond.	-	3 min.
Skim.	-	10 min.
pH	-	8.15
Tails pH	-	8.15

Froth weaker & less mineralized than in previous tests with Lissolamine A.

RESULTS -

TEST No	% Wt.	ASSAY %				RECOVERY %				
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	INDEX
Feed	100.0	21.0	24.9	40.6	4.2	100	100	100	100	
C	66.1	7.7	14.4	60.5	3.6	25.5	38.3	98.0	60.8	234.2
T	33.9	43.7	45.1	2.9	4.5	74.5	61.7	2.0	39.2	

CONCLUSION -

Copper sulphate is not successful as a barite activator. The Sodium Metaphosphate is not as good a depressor of limestone when in the presence of Copper Sulphate as it is when used alone.

TEST 15.

To compare the effectiveness of Sodium Hexametaphosphate with Sodium Metaphosphate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Copper Sulphate - 0.5#/Ton
pH - 8.5

CELL

Added - Sodium Hexametaphosphate - 2.0#/Ton.
Lissolamine A - 0.48"/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.30

Froth poor - sulphides did not come up directly as in previous tests. The bubbles were large and fragile. Some sulphides remained in the tailing.

RESULTS -

TEST No.	Wt. %	ASSAY %				RECOVERY %				INDEX
		[illegible]	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100	100	100	100	
C	19.0	14.0	21.8	29.7	8.0	13.0	16.4	13.6	36.8	184.2
T	81.0	21.9	25.9	43.9	3.2	87.0	83.6	86.4	63.2	

CONCLUSION -

Sodium Hexametaphosphate has a general depressing action for sulphides and non-sulphides when used in the above concentration.

TEST 16.

To study the collecting action of Emulsol X-1 Reagent, when not in the presence of an activator depressor or frother.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.

CELL

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.31

Well mineralized copious froth. Very little mineralization of bubbles during last 5 minutes of skimming period.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	Sio_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.9	58.8	32.0	9.6	90.2	43.8	9.6	236.8
T	59.1	4.4	28.4	63.0	9.8	56.2	90.4	

CONCLUSION -

Emulsol X-1 has a good collecting action for barite and limestone but not for quartz. Its collecting action is slightly stronger for barite than for limestone.

TEST 17.

To float barite, inhibiting the quartz with sodium silicate.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton.

CELL

Added - Emulsol X-1 = 0.49#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.18

Copious froth - slightly less mineralized than usual.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	Sio_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100	100	100	100	
C	39.5	41.2	27.2	7.8	8.9	77.6	43.8	7.6	81.4	226.2
T	60.5	7.8	22.8	61.8	1.4	22.4	56.2	92.4	18.6	

CONCLUSIONS -

Sodium silicate in small quantities has only a slight inhibiting action on quartz.

TEST 18.

To investigate the use of Sodium Silicate and Aluminum Chloride as quartz depressors.

CHARGE - to Pebble Mill.

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton.

CELL

- Added - Emulsol X-1 - 0.48#/Ton
  Aluminum Chloride - 0.20 #/Ton
  Cond. - 3 min.
  Skim. - 10 min.
  pH - 7.3
  Tails pH - 7.6

Sulphides floated first in good froth.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100	100	100	100	
C	38.2	41.2	26.9	7.2	8.3	74.4	41.0	6.8	78.8	226.6
T	61.8	8.8	24.0	60.9	1.4	25.6	59.0	93.2	21.2	

CONCLUSION -

The combination of Sodium Silicate and Aluminum Chloride has a slightly better inhibiting action on quartz than Sodium Silicate alone, but when used in small quantities has not a very great inhibiting action.

TEST 19.

To float barite using Oleic acid as a collector, and citric acid as a depressor for quartz (and limestone).

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Citric Acid - 0.10#/Ton

CELL

Added - Oleic Acid - 0.28#/Ton
Terpineol - 0.16#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.15

Very slight froth without terpineol. On addition of frother resulting bubbles were heavily loaded. Sulphides came up first. Tailing pH - 8.10.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100	21.0	24.9	40.6	4.2	100	100	100	100	
C	61.7	32.1	36.6	11.5	6.3	92.6	91.3	17.4	94.2	183.9
T	38.3	24.2	25.7	87.0	0.7	7.4	8.7	82.6	5.8	

CONCLUSION -

Citric acid has slight depressing action on quartz and limestone when used in small amounts.

TEST 20.

To investigate the feectiveness of a higher concentration of citric acid (compared to test 19) as a depressor for quartz and limestone, in the flotation of barite.

CHARGE - to Pebble Mill.

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Citric Acid - 0.4 #/Ton.

CELL -

Added - Oleic Acid - 0.28#/Ton
Terpineol - 0.16#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 7.0

Froth more mineralized than usual. Skimming time of 10 minutes insufficient for recovery of all the concentrate.

RESULTS -

TEST No.	% Wt.	ASSAY %				RECOVERY %				INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	S	$BaSo_4$	$CaCo_3$	SiO_2	S	
Feed	100.0	21.0	24.9	40.6	4.2	100	100	100	100	
C	53.8	35.8	36.6	6.9	7.0	91.7	78.0	9.2	90.0	204.5
T	46.2	3.8	12.0	79.0	0.9	8.3	22.0	90.8	10.0	

CONCLUSION -

Citric Acid in moderate quantities has a slight general depressing action, but when used in high concentrations has a very strong general depressing action. A test was conducted using 1.5#/Ton of Citric Acid produced no concentrate, hence was discarded.

TEST 21.

To float barite using Emulsol X-1 as a collector, with Sodium Silicate and Citric acid as depressors for limestone and quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Citric Acid - 0.80 #/Ton
Sodium Silicate - 0.50#/Ton.

CELL

Added - Emulsol X-1 - 0.48#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.35

Froth weak. Bubbles very slightly loaded.
Ph of tails - 8.30

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	5.5	63.4	22.8	13.9	12.7	4.2	2.1	206.4
T	94.5	25.2	29.7	40.2	87.3	95.8	97.9	

CONCLUSION -

The combination of Sodium Silicate and Citric Acid had a very great depressing action, probably due to the presence of a large quantity of Citric Acid. Citric Acid shows a differential action in depressing limestone preferentially.

TEST 22.

To investigate the use of Sodium Aluminate as a quartz depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Aluminate - 0.2 #/Ton.

CELL

Added - Emulsol X-1 = 0.48#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.10
Tails pH - 7.90

Concentrate same as in previous test.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	21.0	24.9	40.6	100	100	100	
C	35.3	42.9	26.4	4.1	71.4	37.1	3.5	230.8
T	64.7	9.3	24.4	61.0	28.6	62.9	96.5	

CONCLUSION -

This test indicates that Sodium Aluminate has a relatively good depressing action on quartz and could therefore replace Sodium Silicate in many instances.

TEST 23.

To investigate the use of Copper Sulphate as an activator for Barite and Sodium Silicate as a quartz depressant.

CHARGE - to pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25 #/Ton
$CuSo_4$ - 0.5 #/Ton.

CELL

Added - Emulsol X-1 - 0.48#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 6.92 (?)
Tails pH - 8.10

Concentrate similar to that of previous test.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	21.0	24.9	40.6	100	100	100	
C	42.3	40.5	29.9	8.2	81.3	49.8	8.6	222.9
T	57.7	6.8	22.0	64.0	18.7	50.2	91.4	

CONCLUSION -

Copper Sulphate appears to have no activating action on barite but rather it has a depressing action. The depression of the quartz is probably due to the Sodium Silicate.

TEST 24.

To investigate the use of Copper Sulphate and Sodium Aluminate as Barite activator and quartz depressor respectively.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
$CuSo_4$ - 0.5#/Ton
Sodium Aluminate - 0.2#/Ton

CELL

Added - Emulsol X-1 = 0.48#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.20
Tails pH - 8.05

Froth similar to previous test.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	21.0	24.9	40.6	100	100	100	
C	38.3	40.0	30.9	8.2	73.8	47.1	7.6	219.1
T	61.7	9.0	21.9	63.0	26.2	52.9	92.4	

CONCLUSION -

The test indicates that the combination of Sodium Aluminate and Copper Sulphate has less depressing action on quartz than Sodium Aluminate alone, due to the activating action of the copper sulphate.

TEST 25.

To duplicate test 17 with a new batch of ore.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton.

CELL -

Added - Emulsol - 0.49#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.4

Froth same as in test 17. Bubbles slightly loaded at the end of the 10 minutes skim time.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	33.8	64.0	27.8	10.4	78.7	30.7	9.1	238.9
T	66.2	8.8	30.9	53.4	21.3	69.3	90.9	

TEST 26.

To investigate the flotation of barite with a very coarse cell feed and no reagents in the mill.

CHARGE - to Pebble Mill

Grind - 5 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 - 0.60 #/Ton
Cond. - 3 min.
Skim. - 6 min.
pH - 8.35

Froth same as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	Sio_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	28.1	67.3	28.5	3.7	68.8	27.6	2.6	238.6
T	71.9	15.5	29.2	58.2	31.2	72.4	97.4	

CONCLUSION -

The results of grinding tests are as follows:

Time of Grind Mins.	% Wt.	GRADE %			RECOVERY %		
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2
5	28.1	67.3	28.5	3.7	68.8	27.6	2.6
15	36.3	63.6	30.4	6.7	86.6	37.0	5.9
30	40.9	58.8	32.0	9.6	90.2	43.8	9.6
60	42.8	45.5	38.2	16.4	72.8	55.8	17.1

It is obvious from the above table that an increased grinding time decreases the average size of the particles until they are small enough to allow flotation. Evidently Barite is sufficiently soft to break easily before the limestone & quartz

with further grinding, the limestone, and lastly quartz, can be floated with increasing efficiency, and at the expense of the barite. The recovery of the barite increases, however, due to the increased bulk of the concentrate, in all cases, except the finest grind, where the decrease in grade more than offsets the increased bulk, resulting in a lower overall recovery.

The results also show that the Barite floats more readily, and that Emulsol X-1 is a fairly rapid-acting reagent.

TEST 27.

To investigate the flotation of bariet with a coarser cell feed and no reagents in the ball mill.

CHARGE - To Pebble Mill

Grind - 15 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 9 min.
pH - 8.31

Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29. 5	43.6	100	100	100	
C	36.3	63.6	30.4	6.7	86.6	37.0	5.9	243.7
T	63.7	5.6	29.5	61.1	13.4	63.0	94.1	

CONCLUSION -

See Test 26.

TEST 28.

To investigate the flotation of barite with a finer cell feed and no reagents in the mill.

CHARGE - to Pebble Mill

Grind - 60 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.25

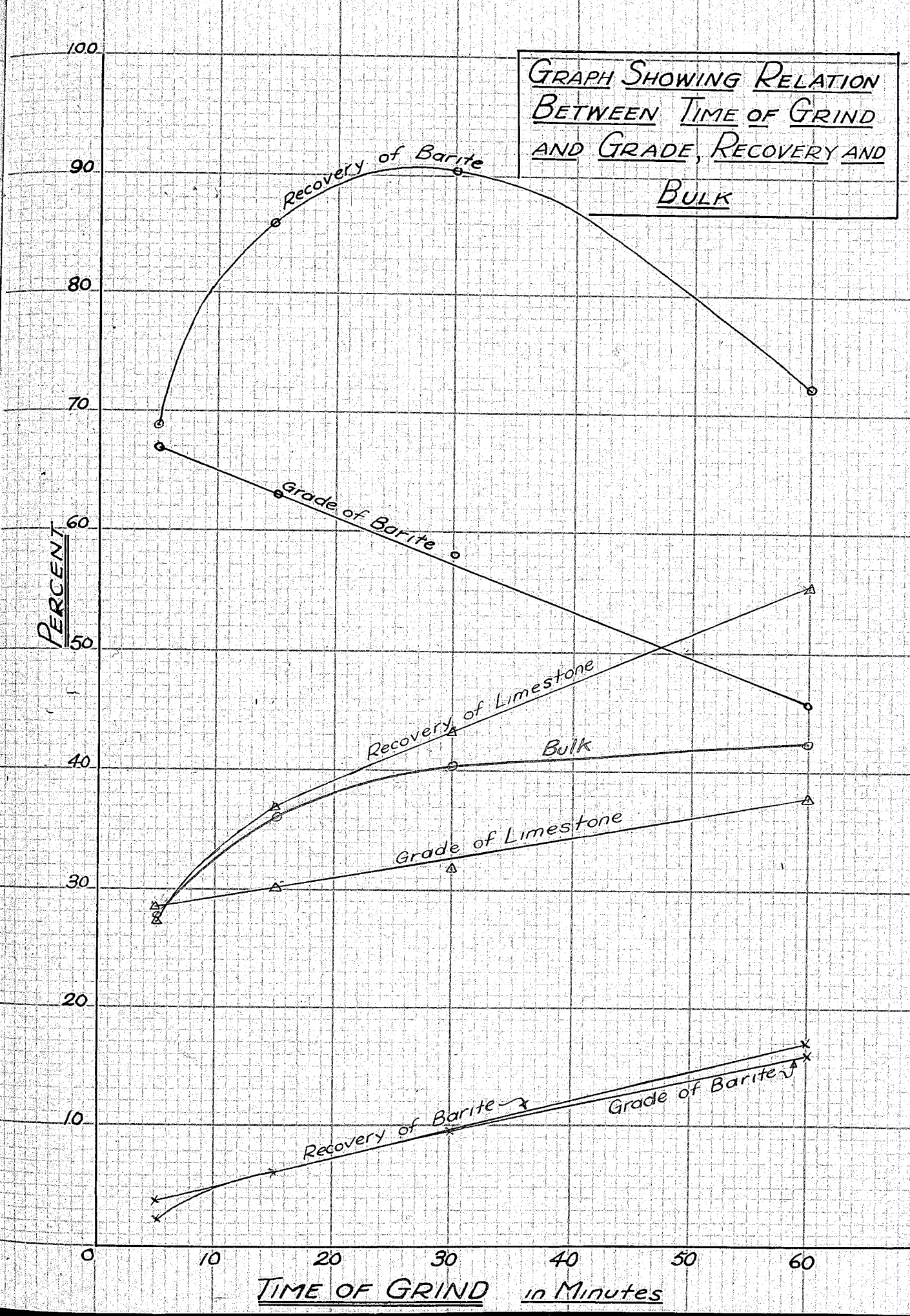
Frothas usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	42.8	45.5	38.2	16.4	72.3	55.8	17.1	199.4
T	57.2	13.0	22.6	59.5	27.7	44.2	82.9	

CONCLUSION -

See Test 27.


GRAPH SHOWING RELATION BETWEEN TIME OF GRIND AND GRADE, RECOVERY AND BULK
Recovery of Barite
Grade of Barite
Recovery of Limestone
Bulk
Grade of Limestone
Recovery of Barite
Grade of Barite
PERCENT
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
TIME OF GRIND in Minutes

TEST 29.

To investigate the flotation of Barite using a low pulp dilution of 2.5:1.

CHARGE - to Pebble Mill

Two standard charges of 500 grams were ground individually in the mills. One charge was dried, the required portion - 150 grs. was taken, added to the other charge, and the whole added to the cell.

CELL -

Ore	-	650 grs.
Water	-	1625 grs.
Pulp Density	-	2.5:1
Added	-	Emulsol X-1 0.6#/Ton
Cond.	-	1 min. with no reagent 3 mins. with reagent.
Skim	-	10 mins.
pH	-	8.25

Froth much more mineralized than usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	53.4	50.0	35.6	14.2	95.7	64.6	18.0	213.1
T	46.6	2.6	22.3	74.3	4.3	35.4	82.0	

CONCLUSION -

The following table shows results obtained for three variations in pulp dilution.

Pulp Density	% Wt.	GRADE %			RECOVERY %		
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2
2.5:1	53.4	50.0	35.6	14.2	95.7	64.6	18.0
4:1	40.9	58.8	32.0	9.6	90.2	43.8	9.6
6:1	45.4	61.0	31.1	9.0	98.0	49.1	9.6

CONCLUSIONS -

It would be advantageous to run a series of tests varying the pulp dilution in a range of 2.0 to 8.0. Although either extreme would not be economically or metallurgically efficient, a compromise might be reached within these limits.

The lowest pulp density herein gives too large a concentrate with a low barite grade, at the same time undesireably increasing the grades of the limestone and quartz respectively.

The highest pulp density, on the other hand, gives the highest barite grade and recovery; at the same time causing a desireable lowering of the limestone and quartz recoveries.

TEST 30.

To investigate the possibilities of barite flotation using a higher pulp dilution.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Ore 350 grams
Water 2150 grams
Pulp density - 6:1
Emulsol X-1 - 0.60#/Ton

Cond. - without collector - 2 min.
with collector - 3 min.
Total - 5 min.

Skim - 7 min.
pH - 8.34

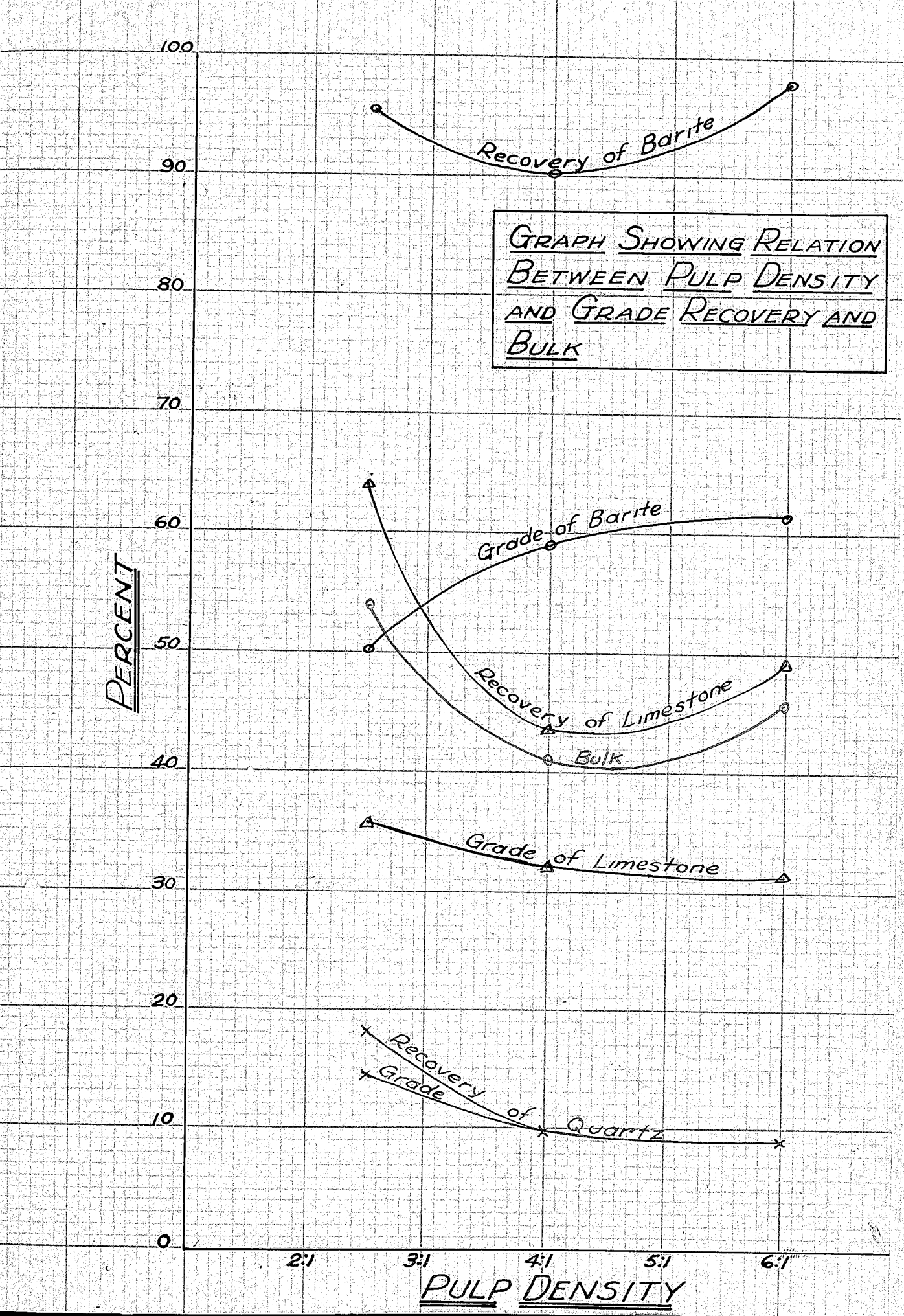
Froth as usual. Well mineralized during first 3 min.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	45.4	61.0	31.1	9.0	98.0	49.1	9.6	239.3
T	54.6	1.1	26.8	70.2	2.0	50.9	90.4	

CONCLUSION -

See test 29.


GRAPH SHOWING RELATION BETWEEN PULP DENSITY AND GRADE RECOVERY AND BULK
Recovery of Barite
Grade of Barite
Recovery of Limestone
Bulk
Grade of Limestone
Recovery of Quartz
Grade
PERCENT
100
90
80
70
60
50
40
30
20
10
0
2:1
3:1
4:1
5:1
6:1
PULP DENSITY

TEST 31.

To investigate the advantages of a shortened and variable skimming period.

CHARGE - to Pebble Mill

Grind	-	30 min.
Ore	-	500 gms.
Water	-	500 gms.
Sodium Silicate	-	0.50#/Ton

CELL -

Concentrate 1

Added	-	Emulsol	-	0.24#/Ton
Cond.	-	3 min.		
Skim.	-	1 min.		
pH	-	8.70		

Froth heavily mineralized and copious.

Concentrate 2

Added	-	Emulsol	-	0.12#/Ton
Cond.	-	1 Min.		
Skim.	-	2 Min.		
pH	-	8.70		

Froth less mineralized but still copious.

Concentrate 3

Added	-	Emulsol	-	0.24#/Ton
Cond.	-	1 min.		
Skim.	-	5 min.		
pH	-	8.70		

Froth slightly mineralized at end of 5 min. skimming period.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C1	23.9	65.5	25.3	10.3	56.5	20.8	5.9	
C2	10.6	62.5	27.6	10.0	23.7	10.0	2.5	224.2
C3	12.6	25.5	48.9	23.5	11.5	21.2	7.1	
T	52.9	4.2	26.3	66.1	8.3	48.0	84.5	

CONCLUSION -

The results from this test confirm those of Test 26, in which it is indicated that the Barite is more easily floatable with the collector Emulsol X-1. Most of it is floated at once, followed by the remainder in decreasing grades. The Limestone and Quartz grade, however, increase successively with each concentrate.

TEST 32.

To investigate the effectiveness of a low pH value in the flotation of barite.

CHARGE - to Pebble Mill.

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton.

CELL -

Added - Emulsol - 0.6#/Ton.
Sulphuric Acid - 2.94#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 7.68
pH Tails - 7.78

Froth same as in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.8	53.6	32.8	11.5	79.2	45.9	11.6	221.7
T	59.2	9.8	26.7	60.3	20.8	54.1	88.4	

CONCLUSION -

The lowered hyrdrogen ion concentration had little effect other than lowering considerably the barite recovery.

TEST 33.

To investigate the action of Oleic acid as a collector in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton.

CELL -

Added - Oleic Acid - 0.14#/Ton
Terpineol - 0.16#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.12

Froth well mineralized throughout, but particularly well mineralized during the first quarter of the skimming period.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	69.6	38.1	41.7	19.4	98.6	97.8	33.0	167.8
T	30.4	1.3	2.2	90.3	1.4	2.2	67.0	

CONCLUSION -

Oleic Acid reduced the grade of the barite concentrate but increased the grade of the limestone and quartz. The recoveried for each mineral were increased considerably due to the large bulk. This is compared with Test 17.

This test indicates that Oleic acid would be a good reagent for a bulk flotation in a rougher cell.

TEST 34.

To investigate the action of Fish Oil as a collector for non sulphides, using sodium silicate as a depressor for quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton.

CELL -

Added - Fish Oil - 0.60#/Ton
Terpineol - 0.49#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.3

Fish Oil alone has only slight frothing action necessitating use of a frother. Bubbles heavily loaded.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	20.6	42.5	42.7	14.0	33.3	29.6	7.3	206.4
T	79.4	23.2	26.3	45.9	67.7	70.4	92.7	

CONCLUSION -

Concentrate grades of all minerals are higher, limestone in particular. Due to a lower bulk, however, the recoveries in each case are lower; when compared to Test 17.

TEST 35.

To investigate the use of Sulphonated Castor Oil as a collector for non sulphides, using Sodium Silicate as a depressor for quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25"/Ton.

CELL -

Added - Sulphonated Castor Oil - 0.63#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.34

Bubbles fairly well loaded. No frother required.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	57.3	44.4	46.3	8.0	94.5	89.6	10.9	194.0
T	42.7	3.5	7.1	86.9	5.5	10.4	89.1	

CONCLUSION -

Concentrate grades of all minerals are higher, limestone in particular, indicating that the collecting action of Sulphonated Castor Oil and Fish for limestone is stronger than that of Emulsol X-1 as used in Test 17.

Recoveries also increased due to the larger bulk.

TEST 36.

To float barite using Sulphonated Cod Oil as a collector; with sodium silicate as a depressor for quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton.

CELL -

Added - Sulphonated Cod Oil - 1.47#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.35

Most heavily laden froth of tests carried out to this point. At end of 10 minutes skimming period the large bubbles were well drained - clean on top but slightly loaded on the sides. Froth not persistent - terpineol recommended for future tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	38.1	54.9	42.5	4.6	77.5	53.9	4.5	219.1
T	61.9	9.8	21.7	60.0	22.5	46.1	95.5	

CONCLUSIONS -

The test indicates that Sulphonated Cod Oil increases the recoveries of barite and limestone as compared to Test 17.

TEST 37.

To use Sodium Silicate and Sulphonated Cod Oil as depressor for quartz and collector for barite respectively.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.5#/Ton.

CELL -

Added - Sulphonated Cod Oil -1.76#/Ton
Terpineol - 0.82#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.7

Well mineralized fine bubble froth. Bubbles became much larger by end of 10 minute skimming period.
At end of 6 minutes water was added to bring the level up to that necessary for satisfactory skimming. This dilution had no apparent effect on the mineralization of the bubbles.

RESULTS -

Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	85.2	32.5	32.8	32.4	98.0	94.5	68.1	135.4
T	14.8	5.0	1.1	94.1	2.0	5.5	31.9	

CONCLUSION -

This test is essentially the same as the previous test except that it shows the effect of a large froth. The frother (Terpineol) has no collecting action, its mechanism being purely physical in forming more bubbles which present a greater adhesion surface.

TEST 38.

To float barite with Sulphonated Cod Oil, using Sodium Metaphosphate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 2.0#/Ton.

CELL -

Added - Sulphonated Cod Oil - 1.32#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.41

Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	45.0	55.5	39.9	5.7	93.8	60.9	6.2	226.7
T	55.0	3.0	20.8	70.2	6.2	39.1	93.8	

CONCLUSION -

As compared with Tests 65 -

	GRADE	RECOVERY	BULK
Barite	Better	Same	Less
Limestone	Tails higher	Smaller	Less
Quartz	Lower	Better	Less

TEST 39.

To float barite using Sulphonated Cod Oil as a collector, and a relatively large amount of Sodium Metaphosphate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 2.5#/Ton.

CELL -

Added - Sulphonated Cod Oil - 1.32#/Ton
Sodium Metaphosphate - 0.5#/Ton
Cond. - 5 min.
Skim. - 10 min.
pH - 8.32

Additional Sodium Metaphosphate to cell due to decision that 2.5# was insufficient.
Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	43.2	58.9	32.8	9.5	91.0	49.7	9.8	231.5
T	56.8	4.4	25.3	65.2	9.0	50.3	90.2	

CONCLUSION -

The Sodium Metaphosphate had little effect other than to reduce the bulk, by its general depressing action - particularly in the case of limestone.

TEST 40.

To compare Silicic Acid with Sodium Silicate as a depressor for quartz.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Silicic Acid - 0.5#/Ton

CELL -

Added - Emulsol X-1 - 0.72#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.5

Froth similar to previous tests. Small fragile bubbles at first, which later developed into the relatively strong type as in other tests.

RESULTS -

Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	39.7	59.6	30.4	9.4	86.8	41.3	9.1	236.4
T	60.3	6.0	28.8	62.3	13.2	58.7	90.9	

CONCLUSION -

Silicic Acid appears to be less efficient as a quartz depressant but apparently raises the grade of the barite.

TEST 41.

To investigate the effectiveness of Sodium Sulphate as depressant for Limestone.

CHARGE - Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Sulphate - 1.0#/Ton.

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.38

Froth same as in previous tests.

RESULTS -

Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	42.6	55.2	34.0	9.1	86.1	49.0	9.6	227.5
T	57.4	6.6	26.2	63.8	13.9	51.0	90.4	

CONCLUSION -

According to theories sponsored by I. W. Wark, calcium sulphate, being more soluble than barium sulphate, should be less amenable to flotation. This test does not support that theory but shows that Sodium Sulphate has a slight activating action for barite when using Emulsol X-1 as a collector.

TEST 42.

To investigate the use of Sodium Sulphate as a depressor for Limestone when Palmitic Acid is used as a collector.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Sulphate - 1.0"/Ton

CELL -

Added - Palmitic Acid - 0.16#/Ton
Terpineol - 0.49#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.32

Froth copious and well mineralized initially but on second and third portions of palmitic acid became considerably less mineralized. On the third addition of palmitic acid the froth became very shallow so that water had to be added to bring the froth up to a practical skimming level.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	37.9	39.7	48.2	10.2	55.9	62.7	9.5	183.7
T	62.1	19.5	17.5	58.8	44.6	37.3	90.5	

CONCLUSION -

This test does not support the theory of Gaudin and Hansen who state that sodium sulphate is a depressant for calcite when collectors of the type Heptylic Acid are used.

Note - Palmitic Acid is four members higher than Heptylic Acid in the same homologeous series.

The test shows that Sodium Sulphate is an activator rather than a depressor for limestone.

TEST 43.

To float barite using ferric Sulphate as a limestone activator.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Ferric Sulphate - 1.0#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.33

Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	44.3	56.1	34.5	8.3	90.8	50.2	8.9	230.7
T	55.7	4.2	26.4	67.5	9.2	49.8	90.1	

CONCLUSION -

This test indicates that Ferric Sulphate has the same action as that of Sodium Sulphate (Test 41) i.e., as an activator for limestone

TEST 44.

To investigate the use of Sodium Oxalate as a Limestone depressant when Palmitic Acid is used as the collector.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Oxalate - 1.0#/Ton

CELL -

Added - Palmitic Acid - (dissolved in ethyl alcohol)-0.16#/Ton
Terpineol - 0.33#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.39

Froth initially well mineralized. Addition of second portion of palmitic acid destroyed froth. This appeared to be a result of a greatly lowered surface tension causing rupture of bubbles. With a frother (terpineol) the froth became copious and well mineralized.

RESULT -

Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	42.1	41.2	45.4	11.5	63.6	65.9	13.6	184.1
T	57.9	17.2	17.1	61.5	36.4	34.1	86.4	

CONCLUSION -

This test does not support the theory of reduced floatability due to increased solubility of mineral films. Calcium Oxalate is more soluble than Barium Oxalate according to the solubility tables.

TEST 45.

To investigate the effectiveness of Oxalic Acid as a depressor of calcite, in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 2.0#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Oxalic Acid - in two parts of 0.5#/Ton each total - 1.0#/Ton.
Cond. - 3 min.
Skim. - 10 min.
pH - 8.30

Froth same as in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	43.8	55.5	32.5	11.1	89.6	48.5	12.0	229.1
T	56.2	5.0	26.9	63.4	10.4	51.5	88.0	

CONCLUSION -

Oxalic Acid is a better activator of barite than Sodium Oxalate - (Test 44)

TEST 46.

To investigate the effectiveness of Lead Chromate as a depressor for limestone (calcite) and Silicic Acid as a depressor for quartz, in barite flotation.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Silicic Acid - 0.5#/Ton
Lead Chromate - 0.8#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.25

Froth similar to that produced in previous tests - well mineralized small bubble froth.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	Sio_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	43.0	57.2	33.2	9.5	87.2	49.3	10.2	228.7
T	57.0	6.4	26.0	63.5	12.8	50.7	90.8	

CONCLUSION -

The use of Chromates was suggested by the solubility of Calcium and Barium Chromates, the former being more soluble than the latter. There is no apparent effect.

TEST 47.

To compare the use of Sodium Oleate with Emulsol X-1 as a collector for barite, using Lead Chromate and Silicic Acid as depressors for Limestone and Quartz. As in preceeding test -

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Silicic Acid - 0.5#/Ton
Lead Chromate - 0.8#/Ton

CELL -

Added - Sodium Oleate - 0.24#/Ton
Terpineol - 0.16#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.30

Froth same as in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29. 5	43.6	100	100	100	
C	67.5	37.8	41.2	19.9	95.0	94.4	32.0	168.6
T	32.5	6.3	4.4	88.0	5.0	5.6	68.0	

CONCLUSION -

Sodium Oleate gave a larger bulk, under the same conditions as Emulsol X-1. The barite grade was lower while that of limestone and silica was higher. Recoveries in all cases were higher due to the increased bulk.

TEST 48.

To investigate the flotation of barite using Silicic Acid as a quartz depressant and Lead Chromate in an Acetic acid solution.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Silicic Acid - 0.5#/Ton
Lead Chromate - 0.8#/Ton
Acetic Acid - 8.0#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 7.62
Tails pH - 7.70

Some reaction between acid and limestone visible.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.0	57.0	34.6	8.6	84.5	48.0	8.5	228.0
T	60.0	7.0	25.3	62.0	15.5	52.0	91.5	

CONCLUSION -

The use of a weak Acetic Acid solution was suggested by Scott's "Metallurgical Analysis" which states that Barium Chromate was less soluble than Calcium Chromate in an Acetic Acid solution.

A slight difference in bulk and limestone grade was noted when compared with Test 46.

TEST 49.

To float barite using an increased amount of Lead Chromate as a limestone depressant, and Silicic Acid as a quartz depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Silicic Acid - 0.5#/Ton
Lead Chromate - 1.6#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.28

Froth same as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	43.1	56.3	33.5	11.7	87.6	49.5	12.4	235.7
T	56.9	6.2	26.2	63.5	12.4	50.5	87.6	

CONCLUSION -

An increased amount of Lead Chromate has apparently no effect.

TEST 50.

To investigate the advantages of shortening the skimming time in the flotation of barite when using Lead Chromate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 Min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 1.0#/Ton
Lead Chromate - 0.8#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 5 min.
pH - 8.45

Froth same as in previous tests.

RESULTS -

Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	39.6	59.7	30.0	11.3	84.0	41.0	11.0	233.0
T	60.4	7.6	28.3	60.0	16.0	59.0	89.0	

CONCLUSION -

A short skim time increases the grade of the barite concentrate but decreases the recovery approximately ten percent.

TEST 51.

To investigate the effectiveness of Potassium Chromate as a depressor for limestone and Silicic Acid as a depressor for quartz in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Silicic Acid - 0.5#/Ton
Potassium Chromate - 0.8#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.2

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	41.0	55.9	33.3	8.3	79.0	47.0	8.5	223.5
T	59.0	10.4	26.2	61.5	21.0	53.0	91.5	

CONCLUSION -

There is little difference between the effectiveness of Potassium and Lead Chromates as limestone depressants except that the grade of barite and quartz dropped slightly along with the bulk.

TEST 52.

To investigate the effectiveness of Sulphonated Cod Oil as a collector of barite, employing sodium Silicate and Potassium Chromate as depressors for quartz and limestone.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.25#/Ton
Potassium Chromate - 0.8#/Ton

CELL -

Added - Sulphonated Cod Oil -1.47#/Ton
Terpineol - 0.66#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.45

Well mineralized fine bubble froth for first 5 minutes - subsequently poor, irrespective of amount of Cod Oil or Terpineol added.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	Sio_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	59.6	42.4	45.7	10.9	93.8	93.0	15.7	185.1
T	40.4	4.2	5.2	86.6	6.2	7.0	84.3	

CONCLUSION -

Sulphonated Cod Oil has a good collecting action for both barite and calcite with no evident selective action. It confirms previous statements regarding increased limestone grade with the use of Fish Oils as collectors.

TEST 53.

To investigate the effectiveness of Chromium Oxide (Cr_2O_3) as a depressor for limestone in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Chromium Oxide (Cr_2O_3) - 3.2#/Ton
Sodium Silicate - 2.0#/Ton

CELL - Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 10.32
Tails pH - 9.80

Frothas usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY%			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	46.6	53.7	29.5	16.9	89.7	47.4	19.3	223.0
T	53.4	5.3	28.6	62.8	10.3	52.6	80.7	

CONCLUSION -

Chromium Oxide (Cr_2O_3) has a slight general activating action particularly towards barite and quartz, thereby increasing the bulk.

Note - The high pH value is inexplicable as Chromic Oxide should hydrolyze to Chromic Acid.

TEST 54.

To float barite using Chromic Acid as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Chromic Acid - 1.0#/Ton

CELL - Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.21

Pulp appeared yellow when taken from mill. Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCo_3$	SiO_2	$BaSo_4$	$CaCo_3$	SiO_2	
Feed	100.0	77.4	29.5	43.6	100	100	100	
C	37.5	53.2	36.0	9.0	73.9	46.0	8.2	219.7
T	62.5	11.2	25.4	59.2	26.1	54.0	91.8	

CONCLUSION -

Chromic Acid has a general activating action, particularly towards barite and limestone. Compared to Chromic Oxide, Chromic Acid is a stronger activator of limestone.

TEST 55.

To float barite using Aluminum Nitrate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Aluminum Nitrate - 0.2#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.48

Froth as usual

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSo_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.9	58.3	31.2	9.1	93.9	42.7	9.2	242.0
T	59.1	2.7	29.0	62.5	6.1	57.3	90.8	

CONCLUSION -

Aluminum Nitrate is a stronger activator for barite than for limestone.

This test was suggested by a statement of Gaudin that salts which form colloidal hydroxides act as limestone depressants.

TEST 56.

To investigate the effectiveness of Aluminum Nitrate as a depressor for limestone.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Silicic Acid - 0.5#/Ton
Aluminum Nitrate - 0.5#/Ton

CELL -

Added - Emulsol X-1. 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.32

Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.5	59.3	29.4	11.4	86.8	40.7	10.3	235.8
T	59.5	6.5	30.0	62.0	13.2	59.3	89.7	

CONCLUSION -

Increased amount of Aluminum Nitrate gives an increased selectivity between barite and limestone.

TEST 57.

To investigate the effectiveness of a higher concentration of Aluminum Nitrate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Sodium Silicate - 0.5#/Ton
Aluminum Nitrate - 1.0#/Ton

CELL -

Added - Emulsol X-1. 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.41

Froth same as in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	48.2	53.4	34.5	9.0	96.2	56.3	10.5	229.4
T	51.8	2.0	24.7	70.8	3.8	43.7	89.5	

CONCLUSION -

This test illustrates the principle that an excess of activator usually leads to a depressing action.

TEST 58.

To investigate the effectiveness of Lead Nitrate as a depressor of limestone in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Lead Nitrate - 1.25#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.4

Froth similar to previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	44.8	56.4	32.8	11.5	92.0	49.6	12.5	230.9
T	55.2	3.9	26.8	64.8	8.0	50.4	87.5	

CONCLUSION -

Lead Nitrate has little effect other than to slightly increase the bulk.

TEST 59.

To investigate the effectiveness of Argols (Potassium bitartrate) as a depressor for quartz in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 grs.
Water - 500 grs.
Argols - 0.5#/Ton

CELL -

Added - Emulsol X-1 - 0.72#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.5

Well mineralized fine bubble froth - much same as in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	41.7	58.9	28.7	10.3	90.3	41.0	10.3	239.0
T	58.3	4.5	29.5	64.1	9.7	59.0	89.7	

CONCLUSION -

Argols has little effect.

TEST 60.

To investigate the flotation of Barite using Sodium Metaphosphate as a Limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 0.5#/Ton

CELL -

Added - Emulsol - 0.6#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.5

Froth as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	40.1	62.9	26.8	10.9	92.3	36.5	10.7	245.1
T	59.9	3.6	31.1	60.6	7.7	63.5	89.3	

CONCLUSION -

See Test 64.

TEST 61.

To investigate the consumption of Sodium Metaphosphate when used as a depressor of limestone in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Metaphosphate - 1.0#/Ton
Sodium Silicate - 0.5#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.30

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	35.4	66.4	22.5	10.2	87.9	26.6	8.9	252.4
T	64.6	5.0	33.9	57.4	12.1	73.4	91.1	

CONCLUSION -

See Test 64.

TEST 62.

To investigate the consumption of Sodium Metaphosphate when used as a depressor of limestone, in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Metaphosphate - 1.5#/Ton
Sodium Silicate - 0.5#/Ton

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Cond. - 3 min.
Skim. - 7 min.
pH - 8.4

Smaller concentrate than usual, due to the general depressing action of the sodium metaphosphate.

RESULT -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	25.1	82.7	12.6	6.7	75.9	10.7	4.1	261.1
T	74.9	8.8	35.1	53.0	24.1	89.3	95.9	

CONCLUSION -

See Test 64.

TEST 63.

To investigate the effectiveness of a high concentration of Sodium Metaphosphate as a depressor of limestone in the flotation of barite.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.50#/Ton
Sodium Metaphosphate - 2.0#/Ton

CELL -

Added - Emulsol - 0.60#/Ton
Cond. - 3 min.
Skim. - 6 min.
pH - 8.11

Mineralization of froth very slight, becoming negligible after 6 minutes of skimming.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	19.7	87.1	8.2	3.7	62.9	5.5	1.8	255.6
T	80.3	12.5	34.8	49.8	37.1	94.5	98.2	

CONCLUSION -

See Test 64.

TEST 64.

To float barite using a large amount of Sodium Metaphosphate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 2.5#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.35

Froth strong but poorly mineralized. Bubble column shorter than usual. Bubbles larger and very persistent. Small amount of concentrate.

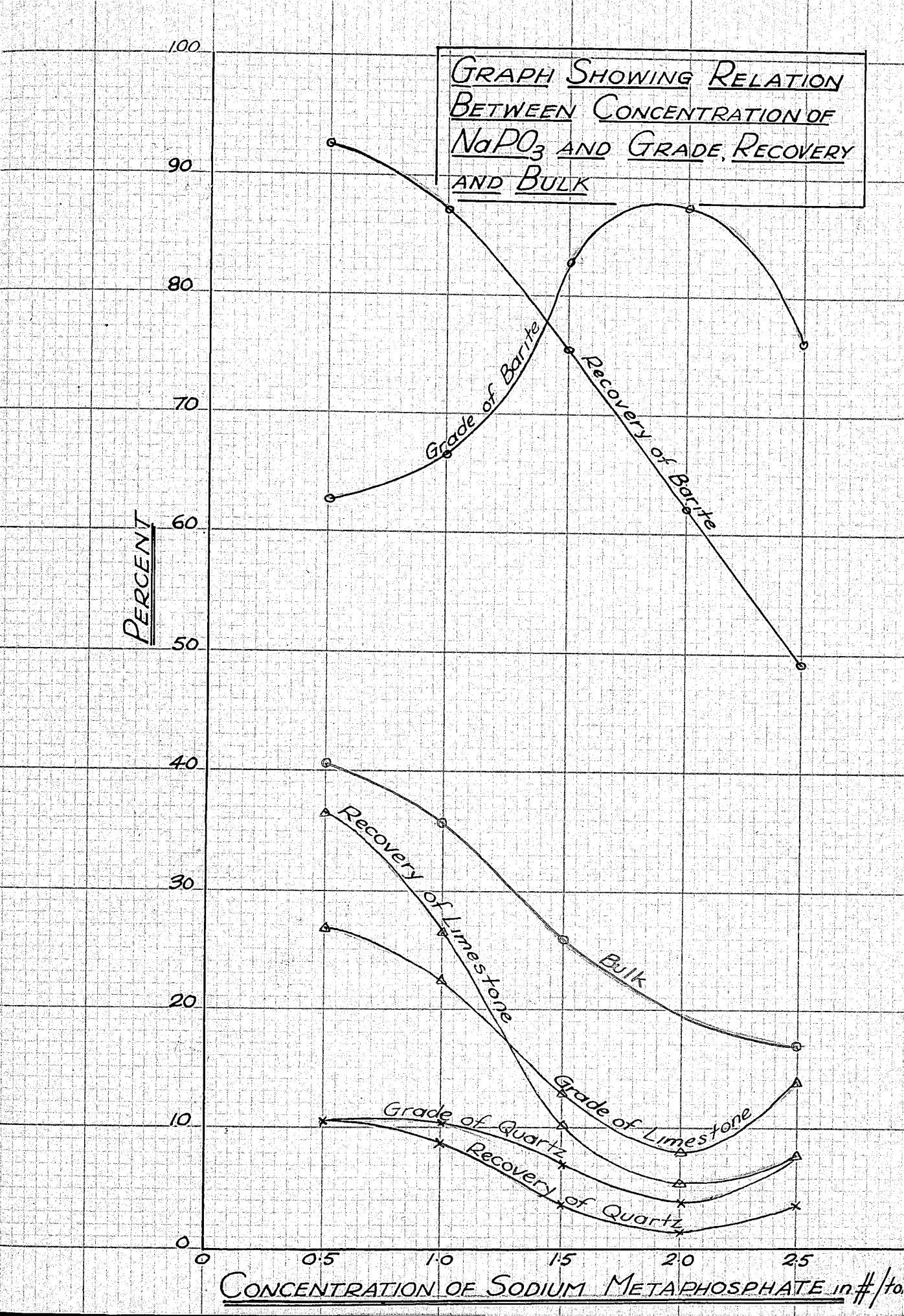
RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	16.9	75.8	13.9	8.0	49.0	7.9	3.3	237.8
T	83.1	16.0	32.7	48.4	51.0	92.1	96.7	

CONCLUSION -

The following table summarizes the results of varying amounts of Sodium Metaphosphate as a limestone depressant

AMOUNT $NaPO_3$	% Weight	ASSAY %			RECOVERY %		
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2
0.5	40.1	62.9	26.8	10.9	92.3	36.5	10.7
1.0	35.4	66.4	22.5	10.2	87.9	26.6	8.9
1.5	25.1	82.7	12.6	6.7	75.9	10.7	4.1
2.0	19.7	87.1	8.2	3.7	62.9	5.5	1.8
2.5	16.9	75.8	13.9	8.0	49.0	7.9	3.3


GRAPH SHOWING RELATION BETWEEN CONCENTRATION OF $NaPO_3$ AND GRADE, RECOVERY AND BULK
PERCENT
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1.0
1.5
2.0
2.5
CONCENTRATION OF SODIUM METAPHOSPHATE in #/to
Grade of Barite
Recovery of Barite
Recovery of Limestone
Bulk
Grade of Limestone
Grade of Quartz
Recovery of Quartz

TEST 65.

To float barite with Oleic Acid using Sodium Metaphosphate as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 2.0#/Ton

CELL -

Added - Oleic Acid - 0.11#/Ton
Terpineol - 0.33#/Ton

Cond. - 3 min.
Skim. - 10 min.
pH - 8.30

Well mineralized froth.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.4	29.5	43.6	100	100	100	
C	63.8	39.5	40.4	18.1	95.5	87.8	27.8	179.9
T	36.2	3.3	10.3	82.6	4.5	12.2	72.2	

CONCLUSION -

Oleic Acid is useful mainly as a collector in a rougher cell, as it tends to float the entire pulp.

TEST 66.

To investigate the flotation of barite with a coarser cell feed and Sodium Metaphosphate to depress the limestone.

CHARGE - to Pebble Mill

Grind - 15 min.
Ore - 500 gms.
Water - 500 gms.
Sodium Silicate - 0.5#/Ton
Sodium Metaphosphate - 1.0#/Ton

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.36

Concentrate and froth same as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	30.8	73.6	20.8	7.0	79.5	22.2	5.0	252.3
T	69.2	8.4	32.5	58.6	20.5	77.8	95.0	

CONCLUSION -

The coarser cell feed gives a better selective flotation by increasing the grade of the barite and decreasing the grade of the limestone. Recoveries are lower due to the smaller bulk.

TEST 67.

To float barite using a deslimed cell fee, and no reagents in mill.

FEED - Two standard 500 gram charges were individually deslimed after the usual grind.

Loss due to slimes - 18.15%
Assay of deslimed ore
Barite - 25.0%
Limestone - 28.5%
Quartz - 46.5%

The ore was dried and 500 grams used as cell charge.

CELL - Added - Emulsol X-1 0.48#/Ton
Cond. - (a) Before adding collector - 5 min
(b) With collector - 3 min
Skim. - 5 min.
pH - 8.35

Froth same as usual.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	25.0	28.5	46.5	100	100	100	
C	33.0	66.5	25.2	8.2	88.0	29.0	6.4	252.6
T	67.0	4.5	30.6	59.4	12.0	71.0	93.6	

CONCLUSION -

A deslimed cell feed results in a greater selectivity between the flotation of barite and limestone than that found in a standard cell feed.

slimes might be evolved but this point was not investigated by the authors.

TEST 68.

To float barite using a deslimed cell feed, with Sodium Metaphosphate as a limestone depressant.

FEED - Two standard 500 gram charges were individually deslimed after the usual grind.

Loss due to Slimes - 19.1%
Assay of deslimed ore
Barite - 26.5%
Limestone - 25.6%
Quartz - 47.9%

The ore was dried and 500 grams used as the cell charge.

CELL -

Added - Emulsol X-1 - 0.60#/Ton
Sodium Metaphosphate - 1.0#/Ton
Cond. (a) With Sodium Metaphosphate but no collector - 10 min.
(b) With collector - 3 min.
13 min.
Skim. - 5 min.
pH - 8.30

Most of concentrate came up in the first minute. Good froth throughout, but no mineralization in latter stages.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	26.5	25.6	47.9	100	100	100	
C	23.1	88.5	7.4	4.9	76.8	6.7	2.7	267.4
T	76.9	8.0	30.5	57.0	23.2	93.3	97.3	

CONCLUSION -

This test has given the best selective action between the flotation of barite and limestone to date. However, it may be noted that this test may not be practical due to the loss of slimes; A satisfactory method of treatment of the

TEST 69.

To investigate the flotation of Barite at a temperature of 40 degrees Centigrade.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 7.95
Temp. - 40° C.

Froth much same as usual. Larger bulk of concentrate.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	53.4	50.7	36.2	13.7	97.9	67.1	17.3	213.3
T	46.6	1.7	20.4	75.2	2.1	32.9	82.7	

CONCLUSION -

See Test 70.

TEST 70

To investigate the flotation of Barite at a temperature of 60 degrees Centigrade.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 0.60#/Ton
Cond. - 3 min.
Skim. - 10 min.
pH - 8.40
Temp. - 60° C.

Concentrate much same as usual. Froth appeared to be lighter texture than in previous tests.

RESULTS -

TEST No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	52.3	50.4	36.6	11.5	96.0	65.7	14.3	216.0
T	47.7	2.2	21.1	76.1	4.0	34.3	85.7	

CONCLUSION -

The following table summarizes the results of varying temperature on the flotation of barite limestone and quartz.

Temp. °C.	% Weight	ASSAY %			RECOVERY %		
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2
20	40.9	58.8	32.0	9.6	90.2	43.8	9.6
40	53.4	50.7	36.2	13.7	97.9	67.1	17.3
60	52.3	50.4	36.6	11.5	96.0	65.7	14.3

Temperature has little effect above 40° C. The most noticeable effect of increased temperature is the relatively large increase in the recovery of limestone.

TEST 71.

To investigate the flotation of Barite at a temperature of 40 degrees Centigrade using Sodium Metaphosphates as a limestone depressant.

CHARGE - to Pebble Mill

Grind - 30 min.
Ore - 500 gms.
Water - 500 gms.

CELL -

Added - Emulsol X-1 0.60#/Ton
Sodium Metaphosphate - 1.0#/Ton
Cond. - 5 min.
Skim. - 10 min.
pH - 7.95
Temp - 40°

Froth very much the same as usual during the first half of skimming period. Later froth was lighter in texture & more copious.

RESULTS -

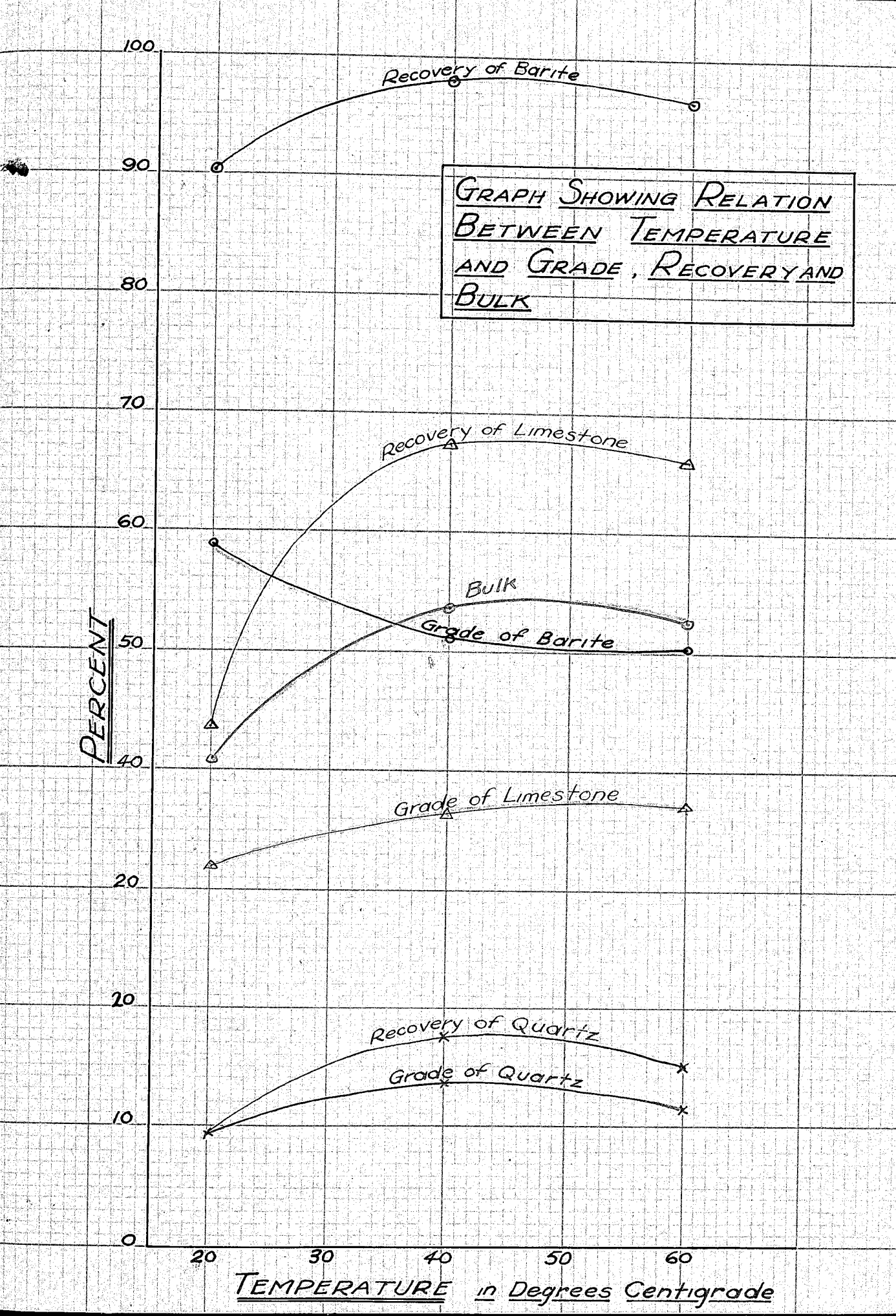
Test No.	% Wt.	ASSAY %			RECOVERY %			INDEX
		$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2	
Feed	100.0	27.9	29.4	42.7	100	100	100	
C	31.8	76.9	16.2	7.0	86.8	17.4	5.2	264.0
T	68.2	6.0	35.7	59.7	13.2	82.6	94.8	

CONCLUSION -

The following table summarizes the results of flotation of barite silica and quartz using Sodium Metaphosphate as a depressor of limestone under temperature conditions of 20° C. and 40° C.

Temp °C.	REAGENT	% Weight	ASSAY %			RECOVERY %		
			$BaSO_4$	$CaCO_3$	SiO_2	$BaSO_4$	$CaCO_3$	SiO_2
20	Na PO_3	35.4	66.4	22.5	10.2	87.9	26.6	8.9
40	Na PO_3	31.8	76.9	16.2	7.0	86.8	17.4	5.2
40	———	53.4	50.7	36.2	13.7	97.9	67.1	17.3

At 40° C. a better selective flotation between barite and calcite is obtained than that at 20° C. Both tests conducted with use of Sodium Metaphosphate are better than that conducted at 40° C. without Sodium Metaphosphate.


GRAPH SHOWING RELATION BETWEEN TEMPERATURE AND GRADE, RECOVERY AND BULK
Recovery of Barite
Recovery of Limestone
Bulk
Grade of Barite
Grade of Limestone
Recovery of Quartz
Grade of Quartz
PERCENT
100
90
80
70
60
50
40
20
20
10
0
20
30
40
50
60
TEMPERATURE in Degrees Centigrade

- ASSAY METHODS -

The unique character of the ore allowed developement of original assay procedures based on standard commercial methods. Results obtained were recorded to the nearest tenth only - further figures would have been meaningless.

The methods outlined are divided into two parts, one for each type of ore:

9 (1) Part A - Assay of ore containing

(a) Barite

(b) Calcite

(c) Quartz

(d) Sulphides.

(2) Part B - Assay of ore containing

(a) Barite

(b) Calcite

(c) Quartz

PART A -

ASSAY OF ORE CONTAINING BARITE CALCITE QUARTZ AND SULPHIDES

Section (1)

Weigh out one half gram of ore into a 120 c.c. beaker; add 10 cc HCl, cover with a watch glass and place on hot plate. When violent action ceases, add 5 cc HNO_3 and boil until brown fumes are all off. Place beaker on a low plate, rinse off cover glass, and take assay to dryness.

Bake at 120°C for 1/2 hour, cool, add 10 cc HCI and 40 cc water, boil till clear, filter through a 12 1/2 cm rapid filter and wash alternating with boiling water and 1:1 HCL until yellow ferric chloride is all out of the paper; then with water four times. Reserve the residue for determination of silica and barium.

Section (2) - (a) Determination of Iron.

Make the filtrate ammoniacal; then 5 cc in excess. Boil, filter and wash with boiling water.

Reserve the filtrate for determination of calcium as in section (3).

Dissolve the precipitate of iron hydroxide with 1:1 HCL; then 5 cc in excess. Add 25 cc water and boil till clear. While still hot add Sn CL_2 drop by drop until the yellow color of Fe_2 CL_6 disappears and add one drop in excess. Cool thoroughly add 10-15 cc of mercuric chloride to neutralize excess Sn CL_2, and titrate with standard potassium dichromate solution, - using potassium ferricyanide (K_3Fe $(CN)_6$) as an indicator.

Section (3)

Determination of Calcium.

To the from the iron hydroxide precipitate (Section 2), add HCL till acid, then 1 cc in excess. Add 3 gms. ammonium oxalate, bring to boil and add ammonia drop by drop till alkaline. (The calcium oxalate will be coarse and easily washed). Allow the precipitate to settle out for 1/2 hour, decant the solution through the filter, wash precipitate into

filter and rinse beaker out well to remove any remaining ammonium oxalate. (at least 8 times) Wash precipitate into original beaker, fold paper over edge of beaker, add 100 cc hot water and 5 cc 1:1 H_2SO_4. Heat to about 60°C, titrate to pink color with $KMnO_4$, add the filter paper and finish titration.

Section (4) - Determination of Barium.

Thoroughly mix the final residue from Section (1) with 3 grams of Na_2CO_3 in a platinum crucible and fuse at 950°C till the melt is clear. Pour the fused material into the cover of the crucible immerse both crucible and cover, together with the contents, in a beaker of hot water. Digest for 10 min., remove cover and crucible, scrub and rinse well. When solution is complete, filter through 12 1/2 cm #1 Whatman filter, wash well with hot water. Reserve the filtrate for determination of Silica.

Wash the residue back into original beaker. Dissolve cautiously with 1:1 HCL adding 10 cc of free HCL in excess. Boil for 10 min. Add 4 cc of H_2SO_4 in 20 cc of H_2O to the hot barium chloride solution. Cover the beaker, place on a medium plate and allow to settle for 20-45 min. Decant the solution into a filter, wash the precipitate in beaker with hot water, wash into filter, wash the precipitate at least 8 times with boiling water. Ignite and weigh as barium sulphate.

Section (5)- Determination of Silica

Acidify filtrate of Section 4 as there identified,

with HCL; then 20 cc in excess. Evaporate to dryness and bake for 1/2 hour at 120°C. Add 15 cc 1:1 HCL, 150 cc water, digest 10 min. Filter, and wash the residue. To the filtrate, add 10 cc HCL and again evaporate to dryness. Filter through the same filter paper. Wash 6 times with boiling water. Ignite and weigh as SiO_2.

PART B -

ASSAY OF ORE CONTAINING BARITE CALCITE AND QUARTZ

Section (1) - Determination of Barite and Quartz.

Fuse 1 gram of the ore with 3 gms of Na_2CO_3 in a platinum crucible at 950°C, and proceed as in Section 4 and subsequently in Section 5 for quartz determination.

Section (2) - Determination of Calcite.

The determination of lime may be made from either the filtrate from Section 4 Part A after removal barite as barium sulphate precipitate or may be made on a separate sample. The latter procedure was used for the sake of speed.

Weigh out 1 gram of ore into a beaker, bring into solution as in Section 1 Part A, remove iron as a hydroxide as in Section 2 Part A, and proceed, as in Section 3 Part A.

(Notes) (1) Some silica may be contained in the barium carbonate residue, hence in the high silicas such as the tailings, the filtrate from the barium sulphate filtration is best further acidified and taken to dryness, dissolved in 15 cc 1:1 HCL made up to 150 cc with water,

filtered ignited and the result silica obtained, added to the regular silica assay.

(2) Large excesses of sodium carbonate should be avoided in fusions.

SULPHUR:

Weigh out 1/2 gram of sample into a 150 cc beaker. Wet with 40 cc water and 30 cc nitric chlorate mixture. Keep on a low plate until the solution is complete - preferably over night. Take to dryness and bake at 120°C for 10 minutes. Cool, add 5 cc water and 1 cc HCL, digest for a few minutes. Add excess Na_2CO_3 and 25 cc water. Boil for 10 minutes. Make up to 75 cc with water and boil again, taking care to avoid heating too fast lest bumping results.

Filter using #1 Whatman paper. Wash 4 or 5 times with hot water. Add 2 drops of phenolphthalien to filtrate.

Redissolve precipitate with water and HCL. Digest till clear. Add $Na_2 CO_3$ until brown precipitate is reformed. Filter into first filtrate. Acidify filtrate with HCL adding 3 cc in excess. Boil. Add boiling $Ba CL_2$ in excess and boil for 10 minutes or until $Ba SO_4$ precipitates settles out. Filter through #1 F paper. Wash 10 times with boiling water and 4 times with cold water. Ignite, slowly at first, then at a high temperature. Cool and weigh.

$$\frac{\text{Wt of } Ba\,SO_4 \times 0.1373}{\text{Wt. of sample}} \times 100\% = \quad \%s.$$

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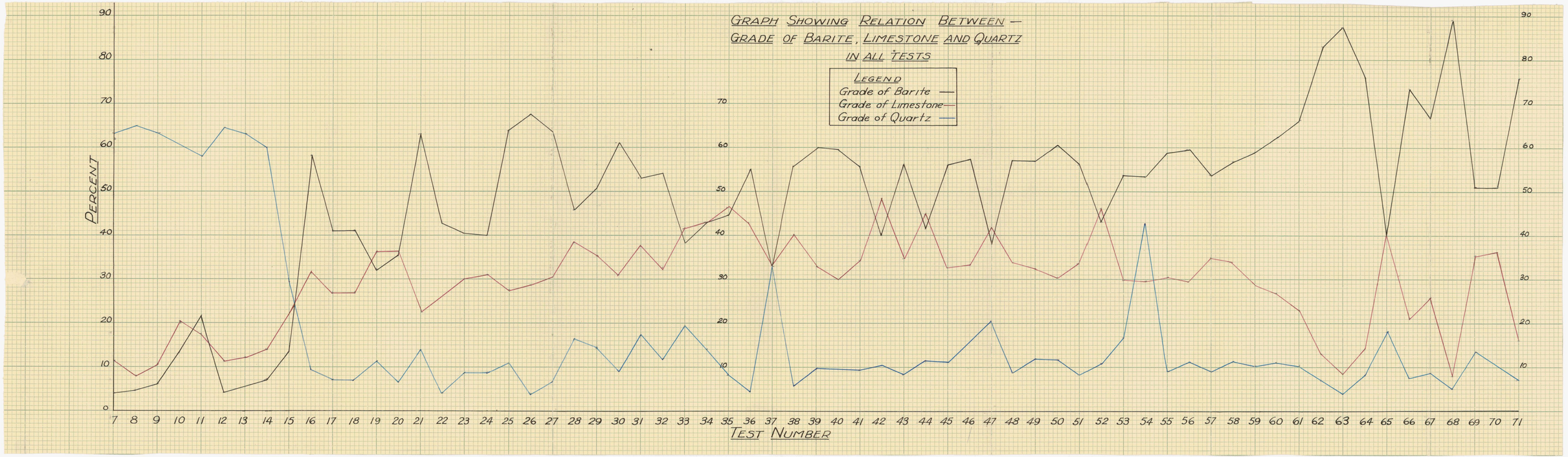
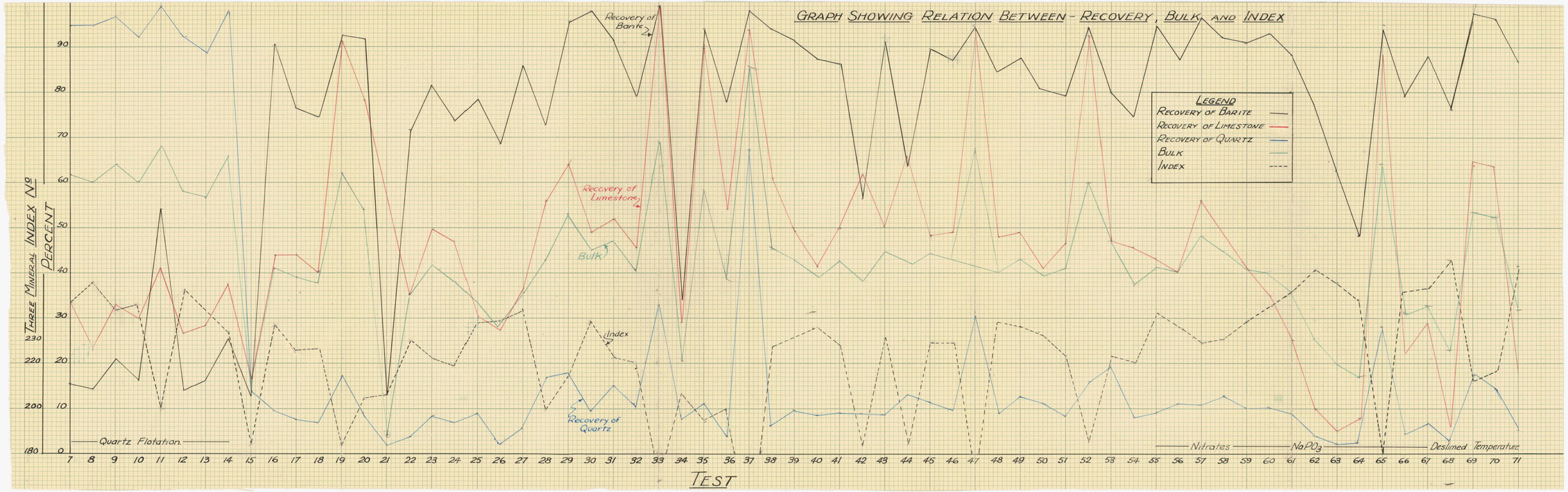

GRAPH SHOWING RELATION BETWEEN —
GRADE OF BARITE, LIMESTONE AND QUARTZ
IN ALL TESTS
LEGEND
Grade of Barite
Grade of Limestone
Grade of Quartz
PERCENT
TEST NUMBER


GRAPH SHOWING RELATION BETWEEN - RECOVERY, BULK AND INDEX
LEGEND
RECOVERY OF BARITE
RECOVERY OF LIMESTONE
RECOVERY OF QUARTZ
BULK
INDEX
Recovery of Barite
Recovery of Limestone
Bulk
Index
Recovery of Quartz
THREE MINERAL INDEX No
PERCENT
TEST
Quartz Flotation
Nitrates
NaPO3
Deslimed Temperature

Test No	Wt. of Ore (Gms.)	Wt. of Water (Gms.)	Wt. of Conc. (Gms.)	% Weight	Grind (Minutes)	Condition (Mins.)	Skim. (Minutes)	Temperature °C	Pulp Density	pH	Cu SO_4	KCN	Zn SO_4	Na_2SiO_3	Citric Acid	$Na_2Al_2O_4$	Pb NO_3	Lissolamine A	Retarder LA	Oleic Acid	#5 Pine Oil	$K_2Cr_2O_7$	Emulsol X-1	Terpineol	$AlCl_3$	$NaPO_3$	$Na_2B_4O_{18}$	H_2SO_4	NaOH	Barite	Limestone	Quartz	Sulphur	Iron	Barite	Limestone	Quartz	Sulphur	Iron	Index	Remarks
Head																														21.0	24.9	40.6	4.2	2.0								
1	1000	500			60					8.63																																
C1			86.4	8.6		3	10	20	4:1	8.30								0.16												2.5	9.5	20.8	25.4	14.5	1.0	9.3	4.5	28.5	57.5		
C2			42.6	4.2		1	5			8.50								0.08												5.9	15.6	36.4	13.3	5.9	1.2	2.7	8.8	5.0	10.3		
C3			45.7	4.6		1	6			8.15								0.08												13.2	29.7	25.5	6.2	2.7	2.9	4.3	2.9	5.7	5.7		
T			825.7	82.6																										24.0	27.5	42.8	2.7	0.7	94.9	89.7	98.8	60.8	26.5		
2	1000	500			60																																					
C1			116.8	11.6		3	10	20	4:1	8.35									0.41		0.07									12.2	23.8	6.9	12.3	7.4	6.9	11.3	1.8	33.3	38.5		
C2			10.2	1.0		1	5			8.20									0.16											21.5	36.4	17.8	4.0	1.3	1.1	1.5	0.4	0.9	0.6		
T			874.8	87.4																										21.3	24.7	44.9	3.2	1.4	92.0	87.2	97.8	65.8	60.9		
3	1000	1000			10																																					
C1			150.0	14.8		3	10	20	4:1	8.27									0.41		0.07									9.8	16.8	12.8	11.7	7.6	7.1	10.2	4.8	39.7	54.0		
C2			53.5	5.3		1	5			8.10									0.16											15.9	27.5	28.7	3.2	2.5	4.1	5.8	3.8	3.8	6.3		
T			811.1	79.9																										22.8	25.5	46.0	3.1	1.0	88.8	84.0	91.4	56.5	39.7		
4	1000	500			60							2.0	6.0																													
C1			10.5	1.1		3	10	20	4:1	8.30									0.98			1.0								15.4	34.9	15.6	6.9	3.6	0.8	1.5	0.7	1.8	18.4		
C2			83.3	8.3		1	10			8.23									0.41		0.07									16.6	43.9	13.3	6.8	3.0	6.6	14.8	2.7	14.0	12.0		
C3			61.7	6.2		1	10			8.10									0.41		0.07									22.9	30.7	22.6	5.5	1.7	6.8	7.7	3.5	8.4	5.0		
T			843.4	84.4																										21.0	22.2	45.0	3.6	1.6	85.8	76.0	93.5	75.8	64.6		
5	1000	500			60							2.0	6.0																													
C1			83.0	8.3		3	10	20	4:1	8.25										0.22		2.0								19.8	32.5	11.1	5.5	3.8	7.9	10.8	2.0	10.6	15.7		
C2			66.0	6.6		1	10			8.17										0.11		1.0								16.0	29.0	15.4	5.3	2.2	5.1	7.7	2.5	8.4	7.3		
T			853.3	85.1																										21.0	23.9	44.5	4.0	1.8	87.0	81.5	95.5	81.0	77.0		
6	1000	500			60							2.0	6.0																													
C1			168.3	16.8		3	10	20	4:1	8.32								0.60			0.19	2.0								23.1	21.5	17.8	7.2	2.6	26.4	15.4	7.5	26.7	22.5		
C2			482.7	47.9		1	10			8.23								0.48				1.0								26.3	12.5	50.0	5.2	1.4	60.0	25.7	59.6	55.2	29.1		
T			956.1	95.3																										8.1	38.8	36.8	2.3	2.7	13.6	58.9	32.9	18.1	48.4		
7	500	500			30			20		8.23						0.5																								245.8	
C			307.9	61.7		3	10		4:1	8.20								0.48												4.9	11.7	68.7	3.5		15.2	33.4	94.5	51.4			
T			191.7	38.3						8.15																				44.1	37.6	6.0	5.3		84.8	66.6	5.5	48.6			
8	500	500			30					8.5	0.5																															
C			302.0	60.7		3	10	20	4:1	8.31								0.48												5.0	8.4	65.1	3.7		14.7	23.7	94.8	50.9		256.4	
T			196.0	39.3																										44.3	41.5	5.5	5.5		85.3	76.3	5.2	49.1			
9	500	500			30	3				8.30							1.0																									
C			318.6	63.8			10	20	4:1	8.30								0.48												6.8	11.0	63.6	4.0		21.1	32.9	96.8	53.0		242.8	
T			179.8	36.1																										45.2	39.8	3.9	6.3		78.9	67.1	3.2	47.0			
10	500	500			30					8.30							0.5													21.0	24.9	40.6	4.2								
C1			86.4	17.2		3	10	20	4:1	8.43									0.33					0.16						13.8	21.2	8.7	12.2		11.6	16.8	3.6	42.3			
C2			216.2	43.1		3	10			8.36									1.15											1.9	6.7	85.6	0.9		4.0	13.3	88.6	7.8		246.5	
T			199.5	39.7																										43.3	39.2	8.2	6.2		84.4	69.9	7.8	43.9			
11	500	500			30																									27.4	29.5	43.6									
C			337.6	67.9		3	10	20	4:1	8.30								0.60						0.49						22.1	17.9	57.9			54.5	41.7	94.8			198.6	
T			158.7	32.1																										39.3	53.9	6.6			45.5	58.3	5.2				
12	500	500			30					8.5	0.5																			21.0	24.9	40.6	4.2								
C			290.9			3	10	20	4:1	7.55								0.48										2.06		4.9	11.6	65.0	3.8		13.9	27.0	92.5	43.3		251.6	
T			206.9																											42.7	44.0	7.5	5.1		86.1	73.0	7.5	56.7			
13	500	500			30					8.50	0.5																		0.80	6.1	12.7	63.5	3.9		16.6	28.3	88.0	56.0		243.1	
C			282.2	56.4		3	10	20	4:1	9.75								0.48												40.0	41.8	11.7	4.0		83.4	71.7	12.0	44.0			
T			218.7	43.6						9.10																																
14	500	500			30					8.50	0.5																															
C			331.2	66.1		3	10	20	4:1	8.15								0.48								2.0				7.7	14.4	60.5	3.6		25.5	38.3	98.0	60.8		234.2	
T			170.2	33.9						8.15																				43.7	45.1	2.9	4.5		74.5	61.7	2.0	39.2			
15	500	500			30					8.50	0.5																			21.0	24.9	40.6	4.2								
C			94.7	19.0		3	10	20	4:1	8.30								0.48									2.0			14.0	21.8	29.7	8.0		13.0	16.4	13.6	36.8		184.2	
T			405.0	81.0						8.30																				21.9	25.9	43.9	3.2		87.0	83.6	86.4	63.2			
16	500	500			30																									27.4	29.5	43.6									
C			204.8	41.0		3	8	20	4:1	8.31													0.60							58.8	32.0	9.6			90.2	43.8	9.6			236.8	
T			295.7	59.0																										4.4	28.4	63.0			9.8	56.2	90.4				
17	500	500			30																									21.0	24.9	40.6	4.2								
C			199.5	39.5		3	10	20	4:1	8.20				0.25									0.49							41.2	27.2	7.8	8.9		77.6	43.8	7.6	81.4		226.2	
T			305.5	60.5						8.18																				7.8	22.8	61.8	1.4		22.4	56.2	92.4	18.6			
18	500	500			30																																					
C			191.7	38.2		3	10	20	4:1	7.8				0.25									0.49		0.2					41.2	26.9	7.2	8.3		74.4	41.0	6.8	78.8		226.6	
T			309.8	61.8						7.6																				8.8	24.0	69.0	1.4		25.6	59.0	93.2	21.2			
19	500	500			30					8.30																														183.9	Low Citric
C			308.2	61.7		3	10	20	4:1	8.15					0.1					0.28				0.16						32.1	36.6	11.5	6.3		92.6	91.3	17.4	94.2			
T			192.2	38.3						8.10																				4.2	5.7	87.0	0.7		7.4	8.7	82.6	5.8			
20	500	500			30																									21.0	24.9	40.6	4.2							204.5	High Citric
C			269.5	53.8		3	10	20	4:1	7.0					0.4					0.28				0.16						35.8	36.6	6.9	7.0		91.7	78.0	9.2	90.0			
T			231.5	46.2						7.2																				3.8	12.0	79.0	0.9		8.3	22.0	90.8	10.0			
21	500	500			30									0.50	0.80															27.4	29.5	43.6									
C			27.5	5.5		3	10	20	4:1	8.35													0.48							63.4	22.8	13.9			12.7	4.2	2.1			206.4	
T			475.5	94.5						8.30																				25.2	29.7	40.2			87.3	95.8	97.9				
22	500	500			30											0.2														21.0	24.9	40.6	4.2								
C			175.6	35.3		3	10	18	4:1	8.1													0.49							42.9	26.4	4.1	8.0		71.4	37.1	3.5	68.3		230.8	
T			323.6	64.7						7.9																				9.3	24.4	61.0	1.5		28.6	62.9	96.5	31.7			
23	500	500			30						0.5			0.25																21.0	24.9	40.6									
C			211.5	42.3		3	10	18	4:1	6.9													0.48							40.5	29.9	8.2			81.3	49.8	8.6			222.9	
T			287.7	57.7						8.1																				6.8	22.0	64.0			18.7	50.2	91.4				
24	500	500			30											0.2														21.0	24.9	40.6									
C			192.6	38.3		3	10	18	4:1	8.20	0.5												0.48							40.0	30.9	8.2			73.8	47.1	7.6			219.1	
T			305.2	61.7						8.05																				9.0	21.9	68.7			26.2	52.9	92.4				
25	500	500			30									0.25																27.4	29.5	43.6									
C			170.5	33.8		3	10	18	4:1	8.4													0.48							64.0	27.8	10.4			78.7	30.7	9.1			238.9	
T			332.5	66.2						8.4																				8.8	30.9	53.4			21.3	69.3	90.9				

Sulphide Inhibition

Quartz Flot N

Flotation

Barite

Test No	Wt. of Ore (Gms)	Wt. of Water (Gms)	Wt. of Conc. (Gms)	% Weight	Grind (Mins)	Condition (Mins)	Skim (Mins)	Temperature °C	Pulp Density	pH	Reagents to Mill #/Ton: Na_2SiO_3	H_2SiO_3	$NaPO_3$	Na_2SO_4	$Fe_2(SO_4)_3$	Na Oxalate	$PbCrO_4$	H.Ac.	Reagents to Cell #/Ton: Emulsol X	Na Oleate	Terpineol	Oleic Acid	Fish Oil	Sulphonated Castor Oil	Sulphonated Cod Oil	$NaPO_3$	Palmitic Acid	Oxalic Acid	H_2SO_4	Assay %: Barite	Limestone	Quartz	Recovery %: Barite	Limestone	Quartz	Index	Remarks
Head																														27.9	29.4	42.7					
26	500	500			5																																	
C			137.8	28.1		3	6	20	4:1	8.35									0.60											67.8	28.5	3.7	68.8	27.6	2.6	238.6	Variable Grind
T			352.2	71.9																										15.5	29.2	58.2	31.2	72.4	97.4		
27	500	500			15																																	
C			180.6	36.3		3	9	20	4:1	8.31									0.60											63.6	30.4	6.7	86.6	37.0	5.9	243.7	
T			317.0	63.7																										5.6	29.5	61.1	13.4	63.0	94.1		
16	500	500			30																																	
C			204.8	40.9		3	10	20	4:1	8.31									0.60											58.8	32.0	9.6	90.2	43.8	9.6	236.8	
T			295.7	59.1																										4.4	28.4	63.0	9.8	56.2	90.4		
28	500	500			60																																	
C			216.7	42.8		3	10	20	4:1	8.25									0.60											45.5	38.2	16.4	72.3	55.8	17.1	199.4	
T			289.7	57.2																										13.0	22.6	59.5	27.7	44.2	82.9		
29	650	1625			30																																	
C			349.1	58.4		4	10	20	25:1	8.25									0.60											50.0	35.6	14.2	95.7	64.6	18.0	213.1	Pulp Dil.n
T			304.5	46.6																										2.6	22.3	74.3	4.3	35.4	82.0		
30	340	2040			30																																	
C			154.5	45.4		5	7	20	6:1	8.34									0.60											61.0	31.1	9.0	98.0	49.1	9.6	239.3	
T			186.0	54.6																										1.1	26.8	70.2	2.0	50.9	90.4		
31					30																									27.4	29.5	43.6					
C1	500	500	119.0	23.9		3	1	20	4:1	8.70	0.5								0.24											65.5	25.3	10.3	56.5	20.8	5.9		
C2			52.7	10.6		1	2			8.70									0.12											62.5	27.6	10.0	23.7	10.0	2.5	234.2	
C3			62.4	12.6		1	5			8.70									0.24											25.5	48.9	23.5	11.5	21.2	7.1		
T			263.2	52.9																										4.2	26.3	66.1	8.3	48.0	84.5		
32	500	500			30																																	
C			204.4	40.8		3	10	20	4:1	7.68	0.50								0.60										2.94	53.6	32.8	11.5	79.2	45.9	11.6	221.7	
T			296.7	59.2						7.78																				9.8	26.7	60.3	20.8	54.1	88.4		
33	500	500			30																																	
C			350.5	69.6		3	10	20	4:1	8.12	0.50										0.16	0.14								38.1	41.7	19.4	98.6	97.8	33.0	167.8	
T			152.6	30.4																										1.3	2.2	90.3	1.4	2.2	67.0		
34	500	500			30																																	
C			103.8	20.6		3	10	20	4:1	8.30	0.25										0.49		0.60							42.5	42.7	14.0	33.3	29.6	7.3	206.4	Oils
T			399.2	79.4																										23.2	26.3	45.9	67.7	70.4	92.7		
35	500	500			30																																	
C			287.4	57.3		3	10	20	4:1	8.34	0.25													0.63					44.4	46.3	8.0	94.5	89.6	10.9	194.0	
T			214.5	42.7																										3.5	7.1	86.9	5.5	10.4	89.1		
36	500	500			30						0.25																											
C			191.9	38.1		3	10	20	4:1	8.35															1.47					54.9	42.5	4.6	77.5	53.9	4.5	219.1	
T			312.0	61.9																										9.8	21.7	60.0	22.5	46.1	95.5		
37	500	500			30						0.50																											
C			429.2	85.2		3	10	20	4:1	8.70											0.82				1.76					32.5	32.8	32.4	98.0	94.5	68.1	135.4	
T			72.9	14.8																										5.0	1.1	94.1	2.0	5.5	31.9		
38	500	500			30						0.50		2.0																									
C			225.1	45.0		3	10	20	4:1	8.41															1.32					53.5	39.9	5.7	93.8	60.9	6.2	226.7	
T			276.6	55.0																										3.0	20.8	70.2	6.2	39.1	93.8		
39	500	500			30						0.50		2.5																	27.9	29.4	42.7					
C			217.9	43.2		5	10	20	4:1	8.32															1.32	0.50				58.9	32.8	9.5	91.0	49.7	9.8	231.5	
T			287.3	56.8																										4.4	25.3	65.2	9.0	50.3	90.2		
40	500	500			30							0.50																										
C			201.7	39.7		3	10	20	4:1	8.50									0.72											59.6	30.4	9.4	86.8	41.3	9.1	236.4	
T			301.2	60.3																										6.0	28.8	62.3	13.2	58.7	90.9		
41	500	500			30						0.50			1.0																27.4	29.5	43.6					
C			213.4	42.6		3	10	20	4:1	8.38									0.60											55.2	34.0	9.1	86.1	49.0	9.6	227.5	Sulphates
T			288.5	57.4																										6.6	26.2	63.8	13.9	51.0	90.4		
42	500	500			30						0.50			1.0																27.4	29.5	43.6					
C			190.5	37.9		3	10	20	4:1	8.32											0.49						0.16			39.7	48.2	10.2	55.9	62.7	9.5	183.7	
T			312.9	62.1																										19.5	17.5	58.8	44.6	37.3	90.5		
43	500	500			30						0.50				1.0																							
C			222.8	44.3		3	10	20	4:1	8.33									0.60											56.1	34.5	8.3	90.8	50.2	8.9	230.7	
T			278.7	55.7																										4.2	26.4	67.5	9.2	49.8	90.1		
44	500	500			30						0.50						1.0																					
C			211.8	42.1		3	10	20	4:1	8.39											0.33						0.16			41.2	45.4	11.5	63.6	65.9	13.6	184.1	
T			291.0	57.9																										17.2	17.1	61.5	36.4	34.1	86.4		
45	500	500			30						2.0																											
C			220.0	43.8		3	10	20	4:1	8.30									0.60										1.0	55.5	32.5	11.1	89.6	48.5	12.0	229.1	
T			282.4	56.2																										5.0	26.9	63.4	10.4	51.5	88.0		
46	500	500			30							0.50						0.80																				
C			215.4	43.0		3	10	20	4:1	8.25									0.60											57.2	33.2	9.5	87.2	49.3	10.2	228.7	
T			284.0	57.0																										6.4	26.0	63.5	12.8	50.7	90.8		
47	500	500			30							0.50								0.24	0.16																	
C			338.8	67.5		3	10	20	4:1	8.30																				37.8	41.2	19.9	95.0	94.4	32.0	168.6	Chromates
T			163.2	32.5																										6.3	4.4	88.0	5.0	5.6	68.0		
48	500	500			30							0.50						0.80	8.0																			
C			201.6	40.0		3	10	20	4:1	7.62									0.60											57.0	34.6	8.6	84.5	48.0	8.5	238.0	
T			301.9	60.0						7.70																				7.0	25.3	62.0	15.5	52.0	91.5		
49	500	500			30							0.50						1.6																				
C			217.6	43.1		3	10	20	4:1	8.28									0.60											56.3	33.5	11.7	87.6	49.5	12.4	235.7	
T			284.4	56.9																										6.2	26.2	63.5	12.4	50.5	87.6		
50	500	500			30						1.0							0.80																				
C			199.1	39.6		3	10	20	4:1	8.45									0.60											59.7	30.0	11.3	84.0	41.0	11.0	233.0	
T			303.0	60.4																										7.6	28.3	60.0	16.0	59.0	89.0		

Test No	Wt of Ore (Grs)	Wt of Water (Grs)	Wt of Conc (Grs)	% Weight	Grind (Mins)	Condition (Mins)	Skim (Mins)	Temperature °C	Pulp Density	pH	Reagents to Mill #/ton: Na_2SiO_3	H_2SiO_3	K_2CrO_4	Cr_2O_3	H_2CrO_4	$Al(NO_3)_3$	$PbNO_3$	Argols	$NaPO_3$	Reagents to Cell #/ton: Emulsol X-1	Sulph Coo Oil	Terpineol	Oleic Acid	$NaPO_3$	Assay % Barite	Limestone	Quartz	Recovery % Barite	Limestone	Quartz	Index	Remarks
																									27.4	29.5	43.6					
51	500	500			30																											
C			206.6	41.0		3	10	20	4:1	8.20		0.5	0.8							0.6					55.9	33.3	8.3	79.0	47.0	8.5	223.5	
T			297.2	59.0																					10.4	26.2	61.5	21.0	53.0	91.5		
52	500	500			30						0.25		0.8																			
C			298.4	59.6		3	10	20	4:1	8.45											1.47	0.66			42.4	45.7	10.9	93.8	93.0	15.7	185.1	
T			202.5	40.4																					4.2	5.2	86.6	6.2	7.0	84.3		
53	500	500			30						2.0			3.20																		
C			233.2	46.6		3	10	20	4:1	10.32										0.6					53.7	29.5	16.9	89.7	47.4	19.3	223.0	
T			266.8	53.4						9.8															5.3	28.6	62.8	10.3	52.6	80.7		
54	500	500			30						0.5				1.0																	
C			187.2	37.5		3	10	20	4:1	8.21										0.6					53.2	36.0	9.0	73.9	46.0	8.2	219.7	
T			312.1	62.5																					11.2	25.4	59.2	26.1	54.0	91.8		
55	500	500			30						0.5					0.2																
C			207.8	40.9		3	10	20	4:1	8.48										0.6					58.3	31.2	9.1	93.9	42.7	9.2	242.0	
T			299.5	59.1																					2.7	29.0	62.5	6.1	57.3	90.8		
56	500	500			30							0.5				0.5																
C			202.9	40.5		3	10	20	4:1	8.32										0.6					59.3	29.4	11.4	86.8	40.7	10.3	235.8	
T			288.2	59.5																					6.5	30.0	62.0	13.2	59.3	89.7		
57	500	500			30						0.5					1.0																
C			240.4	48.2		3	10	20	4:1	8.41										0.6					53.4	34.5	9.0	96.2	56.3	10.5	229.4	
T			259.5	51.8																					2.0	24.7	70.8	3.8	43.7	89.5		
58	500	500			30						0.5						1.25															
C			223.9	44.8		3	10	20	4:1	8.40										0.6					56.4	32.8	11.5	92.0	49.6	12.5	230.9	
T			278.8	55.2																					3.9	26.8	64.8	8.0	50.4	87.5		
59	500	500			30													0.5														
C			208.5	41.7		3	10	20	4:1	8.50										0.72					58.9	28.7	10.3	90.3	41.0	10.3	239.0	
T			292.7	58.3																					4.5	29.5	64.1	9.7	59.0	89.7		
16	500	500			30																											
C			204.8	40.9		3	10	20	4:1	8.31										0.60					58.8	32.0	9.6	90.2	43.8	9.6	236.8	ST'D TEST
T			295.7	59.1																					4.4	28.4	63.0	9.8	56.2	90.4		
60	500	500			30						0.5								0.5													
C			201.2	40.1		3	10	20	4:1	8.50										0.60					62.9	26.8	10.9	92.3	36.5	10.7	245.1	
T			301.6	59.9																					3.6	31.1	60.6	7.7	63.5	89.3		
61	500	500			30						0.5								1.0													
C			177.3	35.4		3	10	20	4:1	8.30										0.6					64.4	22.5	10.2	87.9	26.6	8.9	252.4	
T			323.9	64.6																					5.0	33.9	57.4	12.1	73.4	91.1		
62	500	500			30						0.5								1.5													
C			125.6	25.1		3	7	20	4:1	8.40										0.6					82.7	12.6	6.7	75.9	10.7	4.1	261.1	
T			373.2	74.9																					8.8	35.1	53.0	24.1	89.3	95.9		
63	500	500			30						0.5								2.0													
C			98.1	19.7		3	6	20	4:1	8.11										0.6					87.1	8.2	3.7	62.9	5.5	1.8	255.6	
T			400.0	80.3																					12.5	34.8	49.8	37.1	94.5	98.2		
64	500	500			30						0.5								2.5													
C			84.4	16.9		3	10	20	4:1	8.35										0.6					75.8	13.9	8.0	49.0	7.9	3.3	237.8	
T			416.6	83.1																					16.0	32.7	48.4	51.0	92.1	96.7		
65	500	500			30						0.5								2.0						27.4	29.5	43.6					
C			319.1	63.8		3	10	20	4:1	8.30											0.33	0.11			39.5	40.4	18.1	95.5	87.8	27.8	179.9	
T			181.3	36.2																					3.3	10.3	82.6	4.5	12.2	72.2		
66	500	500			15						0.5								1.0						27.9	29.4	42.7					
C			151.3	30.8		3	10	20	4:1	8.36										0.6					73.6	20.8	7.0	79.5	22.2	5.0	252.3	
T			340.7	69.2																					8.4	32.5	58.6	20.5	77.8	95.0		
67	500	500			30																				25.0	28.5	46.5					
C			163.8	33.0		8	5	20	4:1	8.35										0.48					66.5	25.2	8.2	88.0	29.0	6.4	252.6	
T			332.0	67.0																					4.5	30.6	59.4	12.0	71.0	93.6		
68	500	500			30																				26.5	25.6	47.9					
C			114.9	23.1		13	5	20	4:1	8.30										0.60				1.0	88.5	7.4	4.9	76.8	6.7	2.7	267.4	
T			384.2	76.9																					8.0	30.5	57.0	23.2	93.3	97.3		
69	500	500			30																				27.9	29.4	42.7					
C			267.1	53.4		3	10	40	4:1	7.95										0.6					50.7	36.2	13.7	97.9	67.1	17.3	213.3	
T			232.7	46.6																					1.7	20.4	75.2	2.1	32.9	82.7		
70	500	500			30																											
C			261.5	52.3		3	10	60	4:1	8.40										0.6					50.4	36.6	11.5	96.0	65.7	14.3	216.0	
T			237.6	47.7																					2.2	21.1	76.1	4.0	34.3	85.7		
71	500	500			30																											
C			156.7	31.8		5	10	40	4:1	7.95										0.6				1.0	76.9	16.2	7.0	86.8	17.4	5.2	264.0	
T			336.3	68.2																					6.0	35.7	59.7	13.2	82.6	94.8		

Remarks: CHROMATES; NITRATES; ST'D TEST; SODIUM METAPHOSPHATE; DE-SLIMED; TEMPERATURE