R E S E A R C H

O N

NEW FROTHING AGENTS

b y

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A Thesis submitted for the Degree of

MASTER OF APPLIED SCIENCE

In the Department

o f

METALLURGY

The University of British Columbia

April 1938.

"accepted"

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T he writer wishes to thank Professor G.A. Gillies for his help in performing this work, also W. Bishop and F.A. Forward for their assistance and suggestions regarding the assaying.

INTRODUCTION

During recent years there has been extensive investigation on both the theoretical and practical aspects of flotation. In the theoretical investigations, the aim has been to increase the knowledge of the chemistry of the reactions involved in the flotation processes, and thereby to aid in the control of these processes, while in the practical investigations the aim has been to improve, and reduce the costs of, existing operations and to extend the process to hitherto unamenable ores.

Most of the practical investigation so far has dealt with the action of collectors in an attempt to increase the knowledge of preferential flotation. As a result, many new collecting agents have been discovered, some of which are not entirely satisfactory with the existing frothing agents. As an example, when X anthates are used as collectors for sulphides, pine oil is an excellent frother. But when soap is used as a collector for non-sulphides, a delicate balance must be set between the amount of soap and pine-oil present, or the pine oil interferes with the action of the soap.

The investigations recorded in this paper are a continuation of work started the previous year[1], and deal with new reagents which have been suggested as Frothers.[2]

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[1] Bianco, R.H., and Pothins, J.E.
"New Frothing Agents for Flotation"
B.A.Sc. Thesis, University of B.C. April, 1937.

[2] Dean, R.S., and Hersberger, A.D.
"New Flotation Reagents" A.I.M.M.E. Tech. Pub. No. 605, 1935.

The tests were made under conditions comparable with those encountered in actual mill operation. Machine, pulp density and amount of reagent used are typical of those in common practise, and to give a basis of comparison, quantative analysis of the concentrates were made.

In the first part of the paper, an outline of the history of flotation, and a brief discussion on the theory of the process as shown by a consideration of the reagents used therein, is given. In the second part the tests are outlined, and the results discussed and recorded.

HISTORY OF FLOTATION

The earliest recorded attempts[3] to concentrate ores by flotation were in 1860 when a patent was issued to Haynes. His process consisted in mixing the ore with one fifth to one ninth as much fatty or oily agent, agitating the mass with water and so segregating the oiled sulphides from the earthy material. This process was known as the bulk-oil process.

Opposed to that process was the skin-flotation method, which made use of the different wettabilities of sulphide and non-sulphide particles. Separation was effected by having a free water surface approach the dry, or drying minerals.

The period from 1901 to 1905 marked the introduc-

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[3] Gaudin, A.M. 'Flotation' Chap. I. McGraw-Hill, New York, 1932.

tion of gas as the buoyant medium. Delpratt and Potter produced gas by the effect of acid on carbonates: other investigators used electrolysis, vacuum generator, or direct introduction of gas. In the latter case, the gas was usually air, introduced either by agitation, or by direct application of compressed air through nozzles. ,One of the main results of the use of a gas was a very large reduction in the amounts of oil necessary for sulphide flotation. With the bulk-oil method, oil consumption was between 250 and 400 lbs/ton of orewhich was reduced to between .3 and 2.0 lbs/ton with the introduction of gas.

The next step forward was the discovery by Perkins in 1921, of the collecting properties of various organic compounds which contained nitrogen in the trivalent state or sulphur in the divalent state. This was followed by the introduction of X anthates in 1924, and the change from an acid to an alkaline circuit. These developments marked the beginning of 'chemical flotation', as opposed to the 'oil-flotation', which preceeded it.

THEORY OF FLOTATION AS SHOWN BY A STUDY OF THE REAGENTS INVOLVED

The chemical reagents used in modern flotation practise may be grouped under four general headings:

1. Frothers.
2. Collectors or promotors.
3. Activators, deactivators, and depressors.
4. P H regulators and Miscellaneous Reagents.

Each of these will be dealt with in order.

Frothers

(a) Definition and character of frothers.

The purpose of frothers is to make the bubbles in the flotation pulp more elastic and persistant than those obtained with a pure liquid. They are organic substances characterized by a heteropolar structure in their molecule, i.e. one part of the molecule is polar, or water avid, and the others part is non polar or water repellant. These parts will be denoted by (x) and (R) respectively. It is this dual character of the molecules that the frothers owe their power. Both affinities can be satisfied when the molecules are oriented at a gas-water interface, and so bubbles in a liquid containing a frother are partially lined with a layer of frother molecules, the polar part being absorbed in the water, and the non polar part sticking out into the air in the bubble. When the bubble film starts to stretch, more liquid must come from the bulk of the solution and so the solution at the interface is diluted. Accordingly, the surface tension is raised, and the tendency to stretch is counteracted. This gives the bubble the needed elasticity and persistance.

The orientation of the frother molecules at a gas-water interface is well illustrated in the following sketch.[4]

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[4] Gillies, G.A., "The Story of the Bubble". Annual Meeting, C.I.M.M. Vancouver, B.C. Nov. 1937.

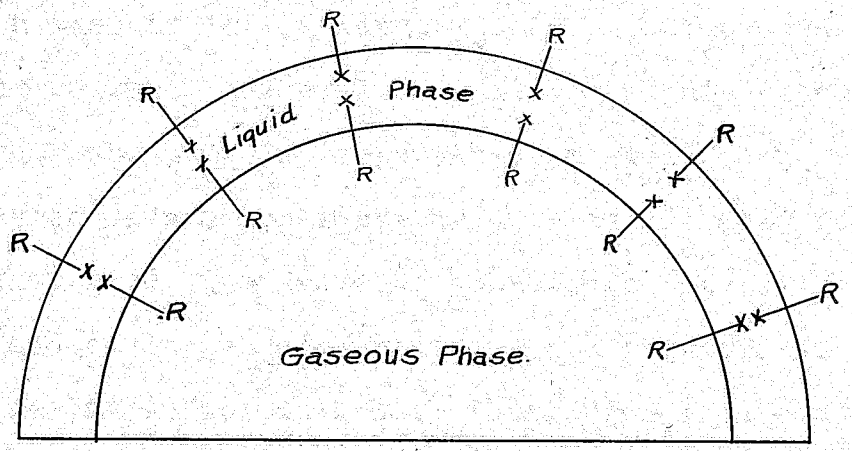

Fig. I.

In such a lined bubble, the (X) portion absorbed in the water will lower the surface tension of the water and so give the bubble the desired elasticity, while the (R)part, sticking out into the air presents an inactive surface to adjacent bubbles and so tends to prevent coalescence of the bubbles. Thus the above combination of (R) and (X) gives the stability to a froth which is required in the flotation process.

(b) Relation between Frothers and Surface Tension.

The relation between surface tension and dilution is shown by Gibbs adsorption equation.

$$a = -\frac{c}{RT} \cdot \frac{dr}{dc}$$

where a = amount of material adsorbed at the interface.

c = concentration in the bulk of the liquid.

R = a constant

$\frac{dr}{dc}$ = rate of change of surface tension with concentration.

It is seen that if 'a' is large, $\frac{dr}{dc}$ is correspondingly large, and if 'a' is small, $\frac{dr}{dc}$ will be small. Organic compounds are strongly adsorbed, $\frac{dr}{dc}$ is large and so a small change in concentration causes considerable drop in surface tension. On the other hand, inorganic compounds are only slightly adsorbed and so large concentrations are required to give much change in surface tension. Therefore organic substances are favored as frothers. Another conclusion from the above equation is that if a solution has a lower surface tension than the water, there will be an excess of solute present in the surface layer, over that in the bulk of the solution. Conversely when the concentration of the surface layer is decreased by dilution, the surface tension will be raised.

The change of surface tension with respect to concentration of a soluble organic substance is shown in the following sketch.

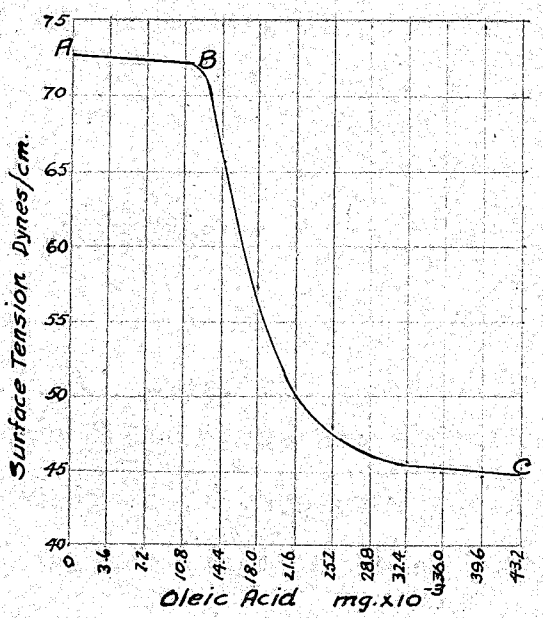

Fig. 2.

The level portion of the curve, from A to B, corresponds to a small concentration of the solute, and the molecules are arranged haphazardly on the surface of the solvent with the soluble polar part (X) dissolved in the water, and the insoluble, non polar (R) part lying on the surface. At point B, there is a sufficient concentration of the solute molecules to cause them to arrange themselves in an orderly manner at the interface, as shown in Figure 3. Further increases in the amount of solute, crowd them closer together, until at the point C, a closely packed monomolecular layer of the solute is formed at the interface. The affect of greater concentrations of the solute is not so marked, since the excess molecules can only be piled up on the surface layer, and their polar parts do not have an opportunity to exert their full effect in lowering the surface tension by increasing the concentration of (X) in the interfacial layer of water.

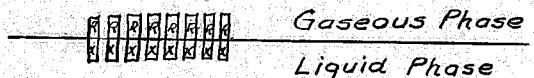

Fig. 3.

(c) Relation between Structure and efficiency of frothers.

According to Traubes rule there is a definite relationship between the length of the hydrocarbon chain, the solubility of the compound and the lowering of the surface

tension of the solution. For each (CH_2) added, the solubility is cut approximately 1/3 and the surface tension is increased by 3, for equimolar amounts of the solute added. Accordingly when the higher homologues of a series are used, the solute will be nearly all at the surface, and when two bubbles coelesce, the decrease in the area of the interface will cause local supersaturation and disappearance of the froth. This would indicate that the intermediate homologues should be more favorable for frothers.

Dean and Hersberger[5] believe that the above consideration, re length of hydrocarbon chain and insolubility, applies only if the polar part is restricted to a simple hydroxyl or carboxyl group, and that if suitable polar groups are chosen to give the proper balance between the polar and non-polar parts, hydrocarbon chains of much greater length can be used. It is along the lines suggested by them, that the compounds under consideration in this paper were formed.

(d) Summary of requirements for Frothers.

The requirements of a frother have been summarized by G.A. Gillies,[6] as follows:

1. It must be an organic substance.

2. Its molecules must be heteropolar and consist of one

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[5] Dean, R.S., and Hersberger, A.D. "New Flotation Reagents" A.I.M.M.E. Tech. Pub. No. 605, 1935.

[6] Gillies, G.A., "The Story of the Bubble" Annual Meeting, C.I.M.M. Vancouver, B.C. Nov. 1937.

or more hydrocarbon radicals attached to a polar group.

3. There should be only one polar group, and it should preferably contain oxygen in the (OH) (COOH) or (CO) form, or nitrogen in the (NH_2) or (CN) form.

4. It must not ionize materially.

5. Its solubility must be neither large nor very small, with a range of from 0.2 to 5.0 gms per litre.

6. It must be reasonable in cost and easily obtained.

The above has been supplemented by Dean and Hersberger[7] with the following:

"The properties of an ideal frother may be set down as follows:

1. It must form in low concentrations copious but not too persistent froth.

2. It must be insensitive to hydrogen-ion concentration of the pulp: that is it must froth equally well in an acid or alkaline medium.

3. It must be insensitive to salts, even in high concentrations.

4. It must be absolutely non collecting to both sulphides and non sulphides.

5. Its frothing properties must not be affected by collecting agents, including soap, the most generally used non-sulphide collector.

6. It must readily emulsify and disperse any insoluble

[7] Dean, R.S. and Hersberger, A.D. "New Flotation Reagents" A.I.M.M.E. Tech.Pub. No. 605, 1935.

collecting agent that is likely to be used."

The reagents tested in this work were ones outlined by Dean and Hersberger as fulfilling most of these requirements.

Collectors

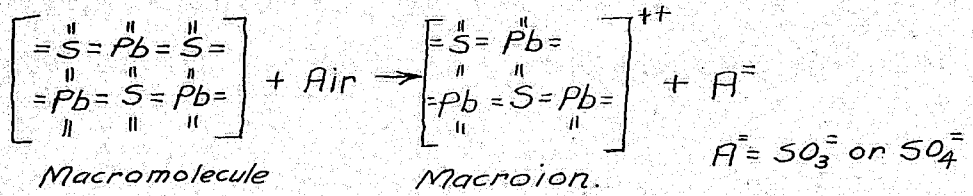
(a) Definition and character of collectors.

The basic principle of mineral flotation is that if a mineral particle is insoluble in water, it is water-repellant and air-avid. The more insoluble the mineral is, the greater the ease with which it can be floated, and the more soluble it is, the more difficult it is to float, or the easier it is to depress. The purpose of collectors is to render the mineral particles insoluble in the solution; hence they will be attracted to the air bubbles and floated to the surface. They are heteropolar compounds, but unlike frothers, the polar part must be active and ionize appreciably. The polar part is attached to the mineral particle, leaving the non polar part sticking out from the surface. This gives a hydro phobe coating to the mineral surface and renders it air-avid.

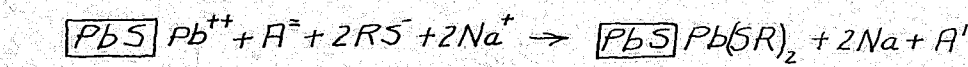
(b) Reaction between collectors and mineral particles.

The exact nature of the chemical reaction whereby the collector is attached to the mineral surface is still a matter of discussion. In some cases, such as the flotation of copper carbonate by amyl X anthate, there is definite evidence to show that copper X anthate is formed by metathesis or double decomposition. However there is just as much evidence that

pyrite does not form iron X anthate, but that the collector is attached to the pyrite particles by adsorption, which is reaction between the polar part of the collector molecules, and the residual surface valence of the particles. Christman[8] suggests that certain sulphides, when subject either to oxidation or adsorption of ions, form macroions, as seen the following example of galena.



These charged particles tend to repel each other by reason of the like charges they carry and so are dispersed throughout the pulp. When the collector is added, it combines with the charged macroin and forms a hydrophobe organic coating on the particle.



The collector shown above is of the mercaptan type

R-S-Na.

(c) Gas-Solid attachment

There is a difference of opinion among investiagators as to the exact nature of the process whereby mineral particles, coated with collectors, are bound to the bubbles

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[8] Christman. "Chemistry and the Flotation Process" American Cyanamid Co. Tech. Paper, No. 17, Nov. 1930.

in the pulp and froth. According to Gaudin[9] it is the polarity of the surface of the mineral which determines whether a particle will remain attached to a bubble after an encounter between the two. A study of the contact angle shows that if the surface of the particle is non-polar, there is a tendency for the gas to displace the water at the surface of the solid, (Fig. 4(a).) but if the surface of the particle is polar, the water will tend to displace the gas, and the particle will be returned to the liquid phase. (Fig. 4(b).)

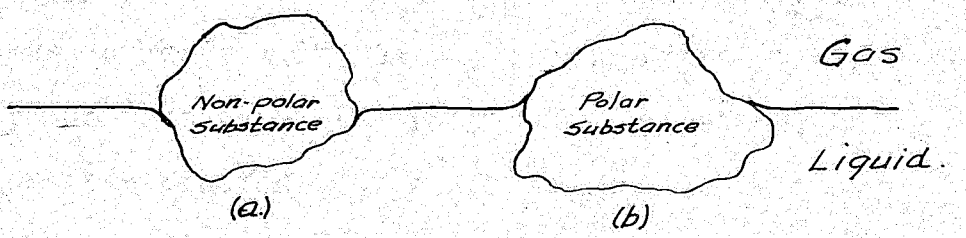

Fig. 4.

Christman[10] suggests that the (R) of the collector is absorbed by the (R) of the frother, and so fastened to the bubble. In the opinion of the writer there are two factors opposing the latter viewpoint. Firstly the (R) portion of the frother and collector molecules is a hydrocarbon chain, -- a very inactive substance, and it is practically impossible for there to be any reaction or adsorption between two such

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9 Gaudin, A.M. "Flotation" P.98. McGraw Hill, New York. 1932.

10 American Cynamid Co. Tech. Paper No. 17 Nov. 1930.

chains. Secondly the (R) of the frother is not presented to a particle as that particle approaches a bubble. When a bubble is in the pulp, the conditions are as in Fig. 5.

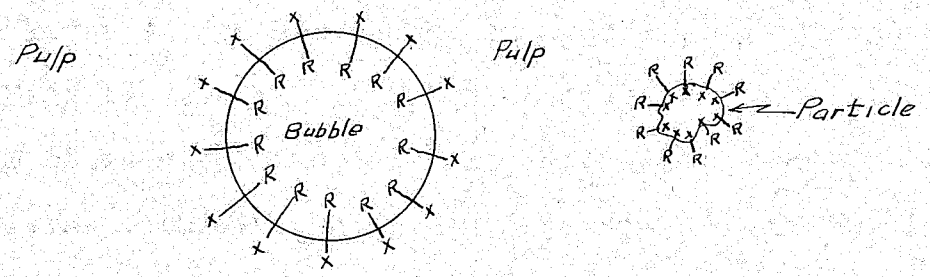
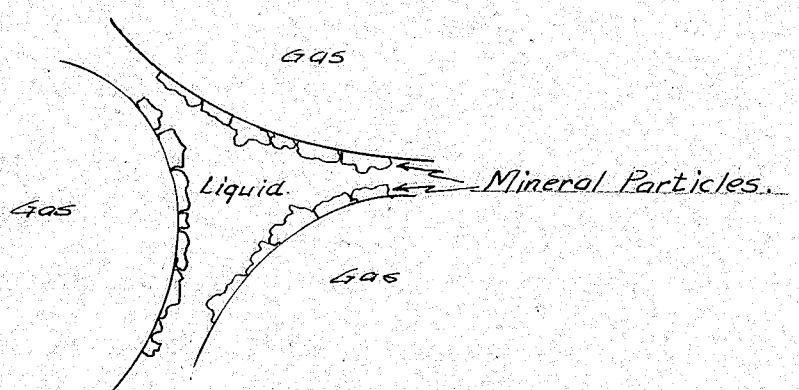


Fig 5.

The polar part (X) of the frother is in the water and the non polar part (R) is in the air. Hence when the particle approaches the bubble, the (R) of the collector would have to react with the (X) of the frother, or as is probably the true case, the (R) of the collector, being water repellant is attracted to the air in the bubble and thus fastens the particle to the bubble.

That such a state, as shown by Fig. 5, exists also in the froth, is shown by Gaudins picture of polygonal bubbles in his discussion of pulp drainage from froths.[11] (Fig. 7)



[11] Gaudin, A.M. 'Flotation'. P.109. McGraw Hill, New York. 1932.

When the bubble is in the pulp or the froth (excepting the surface layer of the froth), there is only one skin or wall to each bubble, and hence there is only one layer of frother molecules present, as opposed to two in Fig. 1. The mineral particles are contained in the water film between the bubbles, and fastened to the bubbles as explained above. Fig. 1. is true for the surface layer of bubbles of a frother; such a bubble must have two skins or interfaces since it is composed of a film of water, with air on both sides of it.

(d) Preferential Collectors.

Preferential flotation depends upon the collector acting preferentially with the desired sulphide, or else forming the most insoluble coating with the desired sulphide. The following are typical examples:
X anthates collect Pb minerals in preference to Cu or Hg minerals: Lower X anthates collect Cu, Fe or Pb minerals in preference to Zn or Co minerals: substituted dithiophosphates collect the Cu minerals, soaps collect minerals of divalent and trivalent metals, and fatty acids, such as oleic, collect the carbonates and oxides of the metallic minerals.

The use of fatty acids gives a preferential separation between the non-sulphides and sulphides, but among the non-sulphides, such as carbonates and oxides, it is practically a universal collector. To modify this action special reagents

must be used.[12] By the use of hydrated phosphates, such as sodium metaphosphate, and soluble metallic salts, chromite was separated from limestone, and fluorspar (calcium fluoride) from limestone (calcium carbonate). In the first case, the soluble salts used were lead nitrate and ferrous sulphate, which resulted in coating the limestone with iron carbonate and the chromite with lead chromite. The former is depressed by the metaphosphate while the latter is not, and so the separation was effected. In the fluorspar, limestone separation, ferrous sulphate was again used. As before it coated the limestone, but did not affect the fluorspar, since calcium fluoride is less soluble than either ferrous fluoride or calcium sulphate. When the metaphosphate was added, the limestone, with its coating of ferrous carbonate was depressed, while the fluorspar was not, and so could be floated off as the concentrate.

(e) Types of Collectors.

The types of collectors in general use are

1. X anthates — R = Aliphatic group.
2. Dithiophosphates (Aerofloat) — R= Aliphatic or aromatic group.
3. Mercaptans R-S-H
4. Fatty and Aromatic carboxylic acids
5. X anthate derivatives - dixanthogen $R-O-\overset{\overset{S}{\|}}{C}-S-S-\overset{\overset{S}{\|}}{C}-O-R$
   monoxanthogen $R-O-\underset{\underset{S}{\|}}{C}-S-\underset{\underset{S}{\|}}{C}-O-R$

[12] Rose E.H. and MacDonald, W.T. U.S. Patent No. 2,040,187.

Activators

Activating agents are compounds which react with a non floatable substance and so alter its surface as to render it floatable. This is achieved by forming such a coating on the particle that reaction between this coating and the collector will result in the formation of a less soluble compound than that formed between the collector and the mineral. As an example, sphalerite will not float when treated with ethyl xanthate because zinc ethyl xanthate is relatively soluble. However, when copper sulphate is added, it reacts with the sphalerite forming a coating of copper salt on the particles, and this, with ethyl xanthate forms insoluble copper ethyl xanthate, which is readily floatable.

The most effective activating agents are copper, lead or mercury since their organic salts are the least soluble.

Deactivators

The purpose of deactivators is to undo any accidental activation which has occurred in the mill circuit, and so prevent the flotation of some undesired sulphides. In complex copper zinc ores, the sphalerite becomes activated by the copper which is dissolved in the mill solutions, and would float with the chalcopyrite unless it is deactivated. The deactivator used is cyanide, which dissolves the coating of copper previously formed on the sphalerite, and hence renders it unfloatable.

Depressors.

The action of depressors is to prevent the flotation of certain undesired minerals. This is achieved by forming a coating on the particles which is non soluble in the collector molecules. As an example, the action of potassium chromate on lead carbonate is to form a layer of lead chromate at the surface on the particles which is less soluble in the collector than the original lead carbonate.

Wark and Cox[13] studied the action of alkali and cyanide on pyrite and concluded that their depressing action was due to prevention of absorption of xanthate by the pyrite, rather than to any coating formed by the alkali or cyanide on the pyrite. Without the alkali and cyanide in the solution, the xanthate absorbed readily on the pyrite particles and collected them in the froth.

The effect of temperature on the depressing action of cyanide on certain sulphides is shown in Figs. 8 and 9[14]. It is seen that at the higher temperature there is a large increase in the amount of cyanide necessary to depress the pyrite, but only a very small increase in the amount necessary to depress the sphalerite and chalcopyrite.

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13 Wark, I.W. and Cox, A.B.
Principles of Flotation III.
A.I.M.E. "Milling Methods." 1934.

14 Wark, I.W. and Cox, A.B.
Principles of Flotation VI
Mining Technology. Jan. 1938.

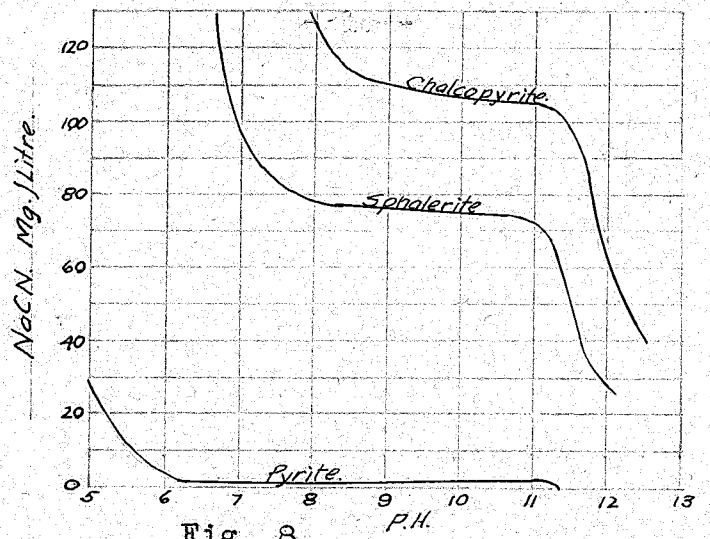

Fig. 8.

$CuSO_4$ 5 H_2O = 150 mg / litre

K Et X = 25 mg / litre

Temp. = 10°C

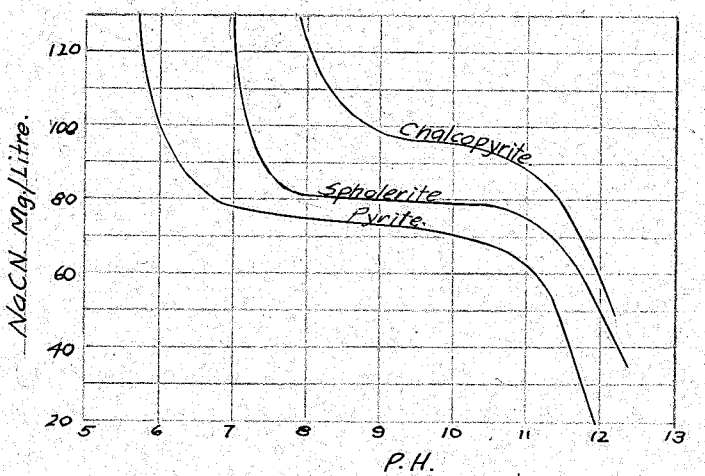

Fig. 9.

$CuSO_4$ 5 H_2O = 150 mg/litre

K Et X = 25 mg/litre

Temp. = 35°C

(In fig. 8, 9, and 10 the curves indicate the termination of the air-mineral contact, i.e. the point at which flotation of the mineral will cease. Thus the area below the curve is where flotation is possible, and the area

above, where it is not)

P H Regulators.

These reagents are added to control the P H of the flotation pulps. Since the advent of 'chemical flotation', all pulps, except for a few special processes, have been alkaline, mainly because the alkaline reagents remove certain soluble salts in the ores which would otherwise precipitate the organic collecting agents. Lime is the commonest reagent for P H control. By the use of Sodium carbonate or sodium sulphide, the p H may be buffered between 8 - 9.5 and and 8.5 - 10 respectively.

The importance of p H control on certain separations has been shown by Wark and Cox.[15] In the following graph the critical p H's for pyrite and sphalerite with varying amounts of lime and sodium cyanide, have been plotted. It is seen that the most favorable conditions for separation would be with a p H of between 6 and 8, while it would be very difficult to obtain a separation at a p H of 11.

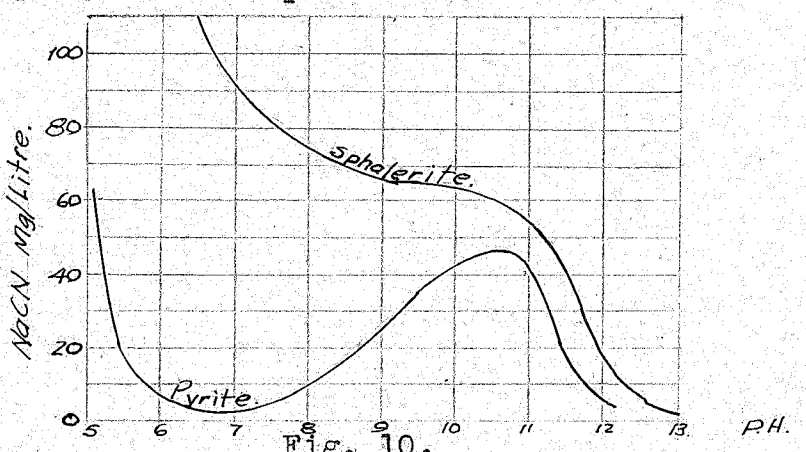

Fig. 10.

15 Wark, I.W. and Cox, A.B. Mining Technology, Jan. 1938.

Fig. 10.

$CuSO_4$ $5H_2O$	=	150 mg/litre
K Et X	=	5 mg/litre
Temp	=	35°C

Miscellaneous reagents.

In this class are certain reagents which are only used when certain peculiarities in the ore require modification. As an example, when there is much chloritic material present in an ore, it is usually ground to colloidal size, and comes up into the froth in the flotation cells, causing a tough froth, and a lower grade recovery. To overcome this, a dispersing agent, such as sodium silicate is used. This coagulates the colloidal particles, and they remain with the other gaugue minerals.

PART II

The tests were carried out in the Ore Dressing laboratory at the University of British Columbia, by Professor G.A. Gillies and G.H. Gwyn.

CHARACTER OF THE ORE

The ore used for the tests was a nickel-copper ore supplied by the B.C. Nickel Mine, Choate, B.C. The ore bearing rock is a hornblende-pyroxenite with varying amounts of hypersthene. The minerals are pentlandite, chalcopyrite, pyrrhotite, chromite, and several others in minor amounts. The high grade ore carries up to 50% sulphides.

The sulphides occur:

1. as grains varying in size from 14 to - 200 mesh
2. as veins in fractures of the hornblendite, and filling of intercrystalline spaces.
3. as massive sulphides, up to 1½ inches in diameter.

The chalcopyrite and pentlandite are intimately mixed. A small amount of the pentlandite, in minute grains, is locked in the pyrrhotite, or lies in bays along the borders of the latter. In two places was observed what was apparently a eutectic alloy.

A partial chemical analysis of the ore gave the following results.

	%
Ni	1.39
Cu	.29

	%
Fe	11.73
S	7.65
Mgo	17.15
ALO	12.25
CaO	1.24
SIO	39.00

Two different samples of the ore, both however from the same section of the mine, were used in these tests. The first sample, used for tests 22 to 36 inclusive assayed 1.12% Ni and .35% Cu, while the second sample, used in tests 37 to 54 inclusive assayed .92% Ni and .26% Cu.

DESCRIPTION OF THE MACHINES

A laboratory rod mill (10" diam by 11½" long) containing 24 steel rods ($\frac{15}{16}$" diam by 11$\frac{3}{16}$" long) was used to grind the ore. It was driven at 44 R.P.M.

The flotation cell was a Ruth laboratory machine, of 1000 gm size. It is an agitation type machine, driven by an electric motor at the top of the spindle.

For measuring the p H of the solutions, a Leeds and Northrup glass electrode machine was used.

DESCRIPTION AND LIST OF THE REAGENTS

The reagents tested were of the form suggested by Dean and Hersberger[18] as being suitable for frothing agents, and were synthesized in the chemical Laboratory at the

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18 Dean, R.S., and Hersberger, A.D. "New Flotation Reagents" A.I.M.M.E. Tech. Pub. No. 605, 1935.

University of British Columbia.[19] They are organic compounds: the number of carbon atoms in the hydrocarbon chains varying from 8 to 27, and the polar groups are sulphate, phosphate, pyridinium, or quinaldinium derivatives. Most of them are difficultly soluble in water, so solutionswith pure ethyl alcohol were made, and standard amounts of these solutions added to the pulp. The strength of the solution is recorded as a percentage: $\frac{\text{weight of reagent}}{\text{total weight of solvent and reagent}} \times 100 = \%$ soln.

The drops of each solution were calibrated, and the weight of the reagent added to the pulp was calculated. It is this solution of the reagents to which reference is made in this paper, and which the conclusions are drawn from.

To give a basis of comparison, tests were run using terpineal and pine oil as the frothing agents. These are the closest approach to ideal frothers of any that are in commercial use today. No collecting agents were added.

Following is a list of the organic reagents, with their chemical formula, the weight of a drop of the solution, and the strength of the solution.

REAGENT A - Potassium salt of Monocetyl phosphate

$C_{16}H_{33} - O - \overset{O}{\overset{\|}{P}}\!\!<^{OH}_{OK}$

10.7 % soln 1 drop = .0617 gms.

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[19] Pyle, J.J. "The Synthesis of New Flotation Agents" M.A. Thesis University of B.C. April 1937.

REAGENT F - Carbo octoxy methyl pyridinium chloride

11.3% soln 1 drop = .018 gms.

" G - Carbo lauryloxy methyl pyridinium chloride

11.2% soln 1 drop = .0169 gms.

" I - Carbo chloresteroxy methyl quinaldinium bromide

7.8% soln 1 drop = .0187 gms.

" J - Carbo chloresteroxy methyl pyridinium chloride

5.97% soln 1 drop = .0172 gms.

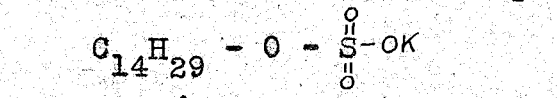
" P - ∝ stearin di hydrogen phosphate

4.06% soln 1 drop = .0165 gms.

" Z - Myristyl Ammonium sulphate

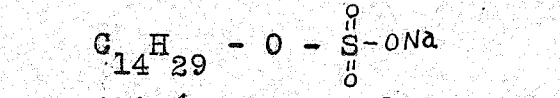
" 4.06% soln 1 drop = .0192 gms.

" R - Myristyl Potassium Sulphate



4.06% soln 1 drop = .0196 gms.

" S - Myristyl Sodium Sulphate



4.06% soln 1 drop = .0192 gms.

REAGENT Q - stearin ammonium sulphate

$$C_{17}H_{35} - \overset{O}{\overset{\|}{C}} - OCH_2 - CHOH - CH_2 - SO_3 - NH_4$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad NH_4$$

4.06% soln. 1 drop = .0165 gms.

TEST ROUTINE

1000 gms of ore and 1000 gms of water were placed in the rod mill, and ground for 15 minutes at 44 R.P.M. The pulp was then transferred to the flotation cell, and the pulp dilution increased to 4:1. Six drops of the solution being tested, were added, the pulp mixed for one minute, and agitated and skimmed for 10 minutes; this gave the first concentrate. Then sufficient water was added to bring the pulp depth back to the original level of 4:1 dilution, another 6 drops of the solution were added, the pulp mixed for 1 minute and agitated and skimmed for 10minutes; this gave the second concentrate. Five such concentrates were taken off in each test. In the case where the circuit was to be acid or alkaline, the required amount of acid or alkali was added and mixed for 3 minutes, previous to the addition of the first six frops of the frothing agent.

The p H of each concentrate and the tailings was taken.

After being dried in an electric oven, the concentrates and tailings were weighed, and sacked, and samples taken for assaying. The nickel was assayed by the dimethyl-glyoxime precipitation method, the concentrate coppers by Lord and Demorests fluoride-iodide method, and the tailing coppers by electrolytic analysis.

Each reagent was tested in a natural, acid and alkaline pulp. 1:2 H_2SO_4 was used to obtain an acid circuit,

and N a O H pellets to obtain an alkaline circuit.

DISCUSSION ON THE TESTS

(a) Individual Reagents.

Tests No. 22 and 23
Reagent - Terpineol.

Standard Test Conditions.

These two tests were run to obtain a comparison of performance between the new Ruth Flotation Machine (Test No.23), and the Ruth Flotation Machine in which previous tests[20] had been made.

The froth was a little deeper in test 23, and slightly tougher, showing that there was more agitation in the Denver machine.

Six drops of the reagent were added for each concentrate, and this appeared to be more than was necessary. Accordingly the amount was reduced to one drop per concentrate in the next set of tests.

Tests No. 24, 25 and 26.
Reagent - Terpineol

Standard Test Conditions

In these tests, one drop of reagent per concentrate was added, and after the second addition there was just enough froth to fill the machine - $2\frac{1}{2}$ - 3" deep. In test 25, in the acid circuit, the froth of the first concentrate was very dark, due, probably, to the action of the acids on the sulphides.

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[20] Bianco and Potkins, "New Frothing Agents for Flotation." B.A.Sc. Thesis University of B.C. April 1937.

The subsequent froths were progressively lighter in color.

With this reagent, the recovery of copper was higher in the natural pulp circuit than in either the acid or alkaline circuits, but the recovery of nickel was lower in the natural pulp circuit than in the other two.

Tests No. 27, 28 and 29.
Reagent - #5 Pine oil. G.N.S.

Standard Test Conditions

In each of these tests, the first concentrate did not have as satisfactory a froth as the following ones, showing that a sufficient amount of the reagent had not yet been added.

The froth produced by this reagent was very similar to that of the terpineol, both in quantity and persistancy. However, with it, both acid and alkaline circuits gave a higher recovery of sulphides than did the natural pulp circuit; the assays for Cu and Ni for the no.1. concentrate in both cases were 80 - 100% higher than in the natural pulp.

A comparison of tests No. 24 and 27, shows that pine oil exhibits less collecting properties, in the natural pulp circuit, than does terpineol.

Tests No. 30, 31 & 32

Reagent A - Potassium salt of Monocetyl phosphate

$C_{16}H_{33} - O - \overset{O}{\overset{\|}{P}}\begin{matrix} -OH \\ \diagdown OK \end{matrix}$

10.7% Solution

Standard Test Conditions

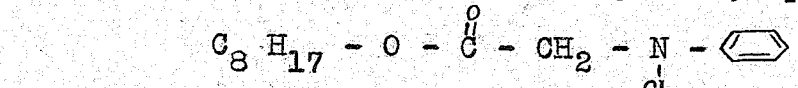
This solution did not give as satisfactory a froth as the standard oils (pine oil and terpineol) -- the maximum depth being in the natural pulp where it reached 1½ inches. In each test, there was a decrease in the depth of froth in the 4th and 5th concentrate, indicating that too much frother had been added. In a number of the runs, it was noted that the froth increased slightly towards the end of the skimming period, showing that a longer conditioning period would be beneficial.

There was a decided collecting action in the acid and alkaline circuits, as shown by graph No. 4. In all cases, the first two concentrates contained practically all the sulphides brought up. The p H of the circuit has a decided effect on the collecting properties of this solution. The recovery was less in the natural pulp circuit, than for the standard oils, but was considerably higher in the acid and alkaline circuits.

Note should be taken that in the acid circuit a cumulative recovery of 95.3% Ni was obtained, with a concentration ratio of 1:3.2

Test No. 33, 34 and 35

Reagent F - Carbo octoxy methyl pyridiniumchloride



11.3% solution

Standard Test Conditions

This solution gave a very good type of froth: of satisfactory depth and consistancy. In the 4th concentrate, the depth of froth suddenly decreased, showing that too much reagent had been added.

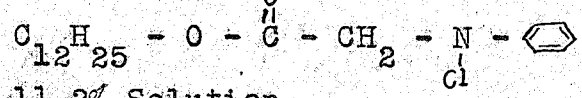
In the natural circuit, there was less collecting of both copper and nickel, than in the tests of terpineol or pine oil, while the froth was just as satisfactory. However, the affect of acid and alkali on the collecting action of the solution was quite startling; especially that of the former. In this test, an overall recovery of 99.36% Nickel and 93.1% copper was obtained. None of the concentrate assays were very high, because a large bulk was floated.

This frother might be satisfactory in both acid and alkaline circuits within a small range of the neutral point, since the concentration of acid and alkali employed in the tests was quite high. viz.

P.H. of No. 1 conc. Test No. 35 = 1.6

P.H. of No. 1 " Test No. 34 = 11.0

Tests No. 36, 37 and 38
Reagent G - Carbo Lauryloxy Methyl Pyridiniumchloride



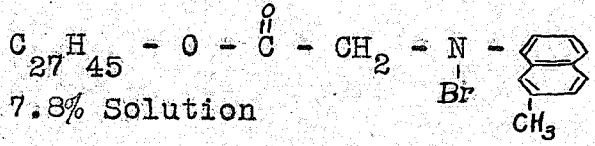
11.2% Solution

Standard Test Conditions

This reagent gave a very satisfactory froth in both quantity and consistancy. In test No. 37, with an alkaline circuit, there was a sudden decrease in the froth after the second concentrate. There must have been some reaction between the reagent and the alkali, because in both the other tests it wasn't until the fifth concentrate was taken that a slight decrease in the froth indicated that an excess of the frother had been added.

This reagent gave an unusually high recovery of copper in the natural pulp circuit, but the change in the p H of the circuit affected the copper recovery only slightly.

Tests No. 39, 40 and 41
Reagent I - Carbo cholesteroxy Methyl Quinaldinium Bromide.



7.8% Solution

Standard Test Conditions

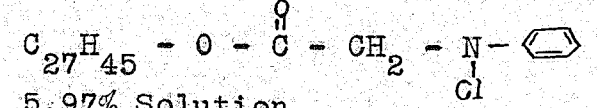
This reagent gave a very poor froth in the natural pulp circuit; only very little was formed and it was coarse and brittle. However, it gave a satisfactory froth in the acid and alkaline circuits.

The affect of p H of the pulp on this reagent is very marked. Both acid and alkaline circuits gave much higher recovery than the natural pulp circuit.

The solubility of this reagent is very low, and it was difficult to form the solution with the ethyl alcohol.

Test No. 42, 43, and 44

Reagent J - Carbo chloresteroxy Methyl Pyridinium Chloride



$C_{27}H_{45} - O - C(=O) - CH_2 - N(Cl) -$

5.97% Solution

Standard Test Conditions

This reagent did not give a satisfactory froth in any of the circuits. In the natural and alkaline circuits it was coarse, brittle and in small quantities, and although there was considerably more froth in the acid circuit, it was still very brittle.

In the natural pulp, this reagent exhibited less collecting action than the standard oils, but, appreciably more in the acid and alkaline circuits, indicating sensitivity of the reagent to the p H of the pulp.

In the acid circuit, a very high nickel assay was obtained (7.03%). This would indicate a decided preference for pentlandite under the test conditions, since the copper assay - (3.15%) was not as high as that obtained in other tests.

This reagent was the longest chain compound of the homologous series, F.G. and J, and the least satisfactory, as regards condition of froth.

Test No. 48, 49 and 50

Reagent P - α stearin di hydrogen phosphate

$C_{17}H_{35} - C(=O) - OCH_2CHOHCH_2 - O - P(=O)(OH)(OH)$

4.06% solution

Standard Test Conditions

In the acid and alkaline circuits this solution gave a satisfactory froth, but in the natural circuit, the froth was very coarse and brittle and only of medium quantity.

In the natural circuit, this solution showed collecting powers of about the same order as the standard oils, but in the others collection was greatly increased, especially so in the acid circuit.

It was noted in these tests that the maximum froth was not produced until about half the skimming time was over, indicating that a longer conditioning time would be beneficial.

Test No 51.

Reagent Q - α stearin ammonium sulphate

$$C_{17}H_{35} - \overset{O}{\overset{\|}{C}} - OCH_2CHOH - CH_2 - \underset{NH_4}{SO_3} - NH_4$$

4.06% Solution

Standard Charge and dilution

This solution gave quite an abundant froth but it was very unstable and brittle. The froth did not indicate any collecting action; the bubbles were not mineralized. Subsequent analysis showed quite low collecting action.

This solution compares closely with solution P. test 48, in both frothing characteristics and collecting action. Both reagents have the same hydrocarbon chain but differ in the polar part of the molecule.

This solution was tested only in the natural pulp circuit.

Test No. 52

Reagent R. Myristyl Potassium Sulphate

$C_{14}H_{29} - O - \overset{O}{\underset{O}{\overset{\|}{\underset{\|}{S}}}} - OK$

4.06% Solution

Standard Test Conditions

It was not until the fourth addition of reagent that the maximum depth of froth was reached. At this point the froth compared favorably with that of the standard oils, both in quantity and persistancy.

The collecting properties of this solution also compared favorably with those of the standard oils. The recovery of copper was lower than that obtained in the natural pulp test with terpineol, and just slightly higher than with pine oil.

Test No 53.

Reagent S - Myristyl Sodium Sulphate

$C_{14}H_{29} - O - \overset{O}{\underset{O}{S}} - ONa$

4.06% Solution

Standard Test Conditions

This solution did not give a satisfactory froth, either in quantity or persistancy. The bubbles appeared to be quite well mineralized, indicating that the solution had decided collecting powers. This was borne out by subsequent analysis.

Test No. 54.

Reagent Z - Myristyl ammonium Sulphate

$C_{14}H_{29} - O - \overset{O}{\underset{O}{S}} - ONH_4$

4.06% Solution

Standard Test Conditions

This solution gave a very poor froth; there was only a small quantity and the bubbles were large and brittle.

The collecting properties of this solution were of the same order as those of the standard oils.

(b) General Discussion

It will be noted that in the acid and alkaline circuits, there was a gradual change in p H towards the neutral point, in consecutive conts.. The amount of acid or alkali removed by each concentrate, and the amount of water added to bring the pulp depth back to the same point, would bring the p H closer to neutrality.

When the acid was added to the pulp to give an acid circuit, H_2S gas was given off. This would indicate that there was a certain amount of reaction between the acid and the sulphides in the ore. The higher recoveries of the metals obtained in the acid circuits were probably due in part to this change in the character of the ore.

Reagents with the long hydrocarbon chains, noteably reagents I and J, gave a very brittle froth. This was probably due to their slight solubility, and correspondingly slight lowering of the surface tension. The polar groups on these reagents were not sufficiently soluble to balance the insolubility of the long hydrocarbon chains.

Reagents Q, S, R and Z were tested only in the natural pulp circuit, and so can only compare with the other reagents on that basis.

Since there wasn't any collecting agent added, any concentration which is effected will be due to the collecting action of the frother. This is assuming that there is no 'native flotability' of the sulphides, which is allowable,

because the theory of 'native flotability' has lost favor during recent years. If the frothers used were 'ideal frothers', the assays of the concentrates taken off should be the same as the original head assay. It is seen that none of the solutions that were tested fulfilled this ideal condition, but the collecting properties of several of them compared favorably with those of the Standard oils, pine oil, and terpineol.

Tests No. 45 and 46 and 47 were run using reagent I, and so duplicated tests No. 39, 40 and 41. Accordingly they are omitted from the records and discussions.

SUMMARY

A study has been made of the frothing powers of certain organic compounds, in natural, acid and alkaline pulp. The number of carbon atoms in the hydrocarbon chain of the various compounds range from 8 to 27. The polar groups are phosphates, sulphates, pyridinium and quinaldinium derivatives.

1. The most satisfactory froths were obtain with reagents F and G. These are members ofahomologeous series, with 8 and 12 carbon atoms, respectively, in their hydrocarbon chain. Reagent J belongs to the same series, but it gave a very brittle froth, due, doubtlessly, to its lower solubility.

2. In the natural pulp circuit, reagent R gave a satisfactory froth, but reagents S and Z, compounds with the same non-polar part, but different polar parts, did not do so.

3. A comparison of tests 52, 53 and 54 showed that reagent S possessed the greatest collecting powers of any of the analogous reagents, S, R and Z.

4. In an acid circuit, reagent F exhibited very marked collecting powers for the sulphides.

5. With all the solutions tested, higher recoveries were obtained in the acid and alkaline circuits, than in the natural pulp circuit. This indicates sensitivity of the solution to the P H of the pulp.

CONCLUSIONS

1. Reagents composed of pyridinium chloride, and a hydrocarbon chain, with carbon atoms up to 12 in number appear to be the most promising frothing reagents.

2. The parallel action of quinaldinium and pyridinium compounds, in reagents I and J, indicates that the lower homologues of the quinaldinium series should give satisfactory frothing action.

3. Compounds with more than 16 carbon atoms in the hydrocarbon chain, do not appear to be satisfactory frothing agents.

4. Polar groups, of pyridinium or quinaldinium derivatives do not appear to be sufficiently soluble to counteract the insolubility of hydrocarbon chains with 27 carbon atoms.

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Test No. 22

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu. gms.	Weight Ni. gms	Percent Rec. Cu%	Percent Rec. Ni%
1	24.3	2.4	3.87	5.16	.94	1.25	27.1	10.5
2	25.0	2.5	2.08	2.60	.52	.65	15.0	5.5
3	51.7	5.2	1.17	3.12	.60	1.61	17.4	13.6
4	34.4	3.4	.55	2.16	.19	.74	5.4	6.2
5	30.8	3.1	.95	2.24	.29	.69	8.5	5.8
Tails	835.1	83.5	.11	.83	.92	6.93	26.5	58.4
	1001.3				3.46	11.87		

Test No. 23

1	31.8	3.0	3.34	2.38	1.06	.76	30.0	6.6
2	87.3	8.3	1.25	3.54	1.09	3.07	30.9	26.7
3	36.4	3.5	.57	2.37	.21	.86	5.7	7.5
4	25.0	2.5	.46	1.84	.11	.46	3.3	4.0
5	40.8	3.9	.38	2.00	.15	.82	4.3	7.1
Tails	826.5	79.0	.11	.67	.91	5.53	25.7	48.1
	1047.8				3.53	11.50		

Test No. 24

1	32.0	3.2	3.91	2.20	1.25	.70	33.8	5.4
2	26.2	2.6	1.86	2.04	.49	.53	12.2	4.0
3	20.1	2.0	1.43	1.45	.29	.29	7.8	2.2
4.	11.2	1.1	1.28	1.37	.14	.15	3.8	1.2
5	10.0	1.0	1.58	1.12	.16	.11	4.3	.8
Tails	912.0	90.1	.15	1.24	1.37	11.30	37.1	86.4
	1011.6				3.70	13.08		

Test No. 25

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	23.3	2.2	2.85	2.98	.66	.69	17.6	6.6
2	38.1	3.7	2.60	3.34	.99	1.27	26.4	12.1
3	29.1	2.8	1.06	1.95	.31	.57	8.3	5.4
4	17.3	1.7	.59	1.38	.10	.24	2.7	2.3
5	15.3	1.5	.35	1.01	.05	.15	1.3	1.4
Tails	912.8	88.05	.18	.83	1.64	7.58	43.7	72.2
	1035.9				3.75	10.50		

Test No.26

1	19.1	1.9	1.16	1.88	.22	.36	5.8	3.3
2	35.4	3.5	1.97	1.72	.70	.61	18.5	5.6
3	21.7	2.1	1.79	1.52	.39	.33	10.3	3.0
4	9.8	1.0	.95	1.41	.09	.14	2.4	1.3
5	8.3	.8	.71	1.32	.06	.11	1.6	1.0
Tails	932.8	91.7	.25	1.01	2.33	9.43	61.5	86.0
	1017.1				3.79	10.98		

Test No. 27

1	35.4	3.5	1.73	1.81	.61	.64	19.1	5.3
2	12.3	1.2	3.18	1.83	.39	.22	12.2	1.8
3	19.0	1.9	1.61	1.56	.31	.30	9.8	2.5
4	9.4	.9	.87	1.41	.08	.13	2.5	1.1
5	16.8	1.6	.84	1.36	.02	.23	.6	1.9
Tails	924.7	91.1	.19	1.14	1.76	10.55	55.5	87.2
	1017.6				3.17	12.07		

Test No. 28.

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	36.8	3.5	3.51	3.22	1.30	1.20	39.7	9.6
2	47.4	4.5	1.39	2.02	.66	1.43	20.1	11.4
3	----------							
4	10.9	1.0	.36	1.21	.04	.13	1.2	.1
5	20.0	1.9	.28	.83	.06	.17	1.8	.1
Tails	940.8	89.2	.13	1.02	1.22	9.59	37.2	76.6
	1055.9				3.28	12.52		

Test No. 29.

1	37.2	3.6	3.16	3.44	1.17	1.28	34.5	10.1
2	31.5	3.1	1.56	3.88	.49	1.22	14.4	9.6
3	54.3	5.3	.62	2.64	.34	1.43	10.0	11.3
4	13.9	1.3	.39	1.18	.05	.16	1.5	1.3
5	10.8	1.0	.46	1.15	.05	.12	1.5	.9
Tails	861.7	83.8	.15	.97	1.29	8.45	38.0	66.7
	1029.4				3.39	12.66		

Test No. 30.

1	28.3	2.80	1.87	1.95	.53	.55	14.8	4.6
2	25.4	2.5	2.07	1.97	.53	.50	14.8	4.2
3	11.8	1.2	.99	1.34	.12	.16	3.3	1.3
4	7.9	.8	.90	1.31	.07	.10	2.0	.8
5.	9.7	.9	.87	1.29	.08	.12	2.2	1.0
Tails	936.5	91.9	.24	1.15	2.25	10.48	62.8	87.9
	1019.6				3.58	11.91		

Test No. 31

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	92.0	9.2	2.40	4.77	2.21	4.38	70.5	40.0
2	11.9	1.2	.71	1.65	.08	.20	2.5	1.8
3	18.9	1.9	.43	1.25	.08	.24	2.5	2.2
4	14.4	1.4	.38	.96	.05	.14	1.6	1.3
5	7.2	.7	.46	.99	.03	.07	1.0	.6
Tails	859.1 / 1003.5	85.9	.08	.73	.69 / 3.14	5.92 / 10.95	21.9	54.1

Test No. 32.

1	120.2	11.3	1.67	3.65	2.01	4.39	49.4	50.5
2	176.4	16.6	.68	1.88	1.20	3.32	29.5	38.2
3	39.5	3.7	.32	.93	.13	.37	3.2	4.3
4	27.3	2.5	.37	.56	.10	.15	2.5	1.7
5	----------							
6	10.6	1.0	.32	.47	.03	.05	.7	.6
Tails	688.5 / 1062.5	64.7	.09	.06	.60 / 4.07	.42 / 8.70	.7	.6

Test No. 33

1	26.0	2.5	3.28	1.92	.85	.50	23.2	4.0
2	21.6	2.1	1.41	1.77	.30	.38	8.3	3.0
3	12.8	1.3	.93	1.51	.12	.19	3.3	1.5
4	8.7	.8	.99	1.30	.09	.11	2.5	.9
5	6.5	.6	1.82	.89	.12	.06	3.3	.5
Tails	950.0 / 1025.6	93.0	.24	1.19	2.18 / 3.66	11.30 / 12.54	59.6	90.1

Test No. 34

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	134.5	13.0	1.77	2.68	2.38	3.63	61.8	37.6
2	23.0	2.2	1.51	2.67	.35	.61	9.1	6.3
3	14.2	1.4	.78	1.27	.11	.18	2.8	1.9
4	14.0	1.4	.83	.93	.12	.13	3.1	1.3
5	8.0	.8	.68	.87	.05	.07	1.3	.7
Tails	839.3	81.2	.10	.60	.84	5.04	21.8	52.4
	1033.0				3.85	9.66		

Test No. 35

1	280.6	27.2	1.03	3.68	2.88	10.32	82.3	93.0
2	79.5	7.7	.24	.67	.19	.53	5.4	4.8
3	48.9	4.7	.26	.28	.13	.14	3.7	1.3
4	15.2	1.5	.29	.12	.04	.02	1.1	.2
5	5.5	.5	.41	.12	.02	.01	.6	.1
Tails	600.3	58.2	.04	.016	.24	.10	6.9	.8
	1030.				3.50	11.12		

Test No. 36

1	65.9	6.5	2.60	2.67	1.71	1.76	53.7	14.7
2	43.3	4.2	1.10	2.61	.48	1.14	15.1	9.5
3	21.4	2.1	.59	1.85	.13	.40	4.7	3.3
4	11.0	1.1	.78	1.32	.09	.15	2.8	1.3
5	11.9	1.1	.64	1.38	.08	.16	2.5	1.3
Tails	879.8	85.1	.08	.95	.70	8.35	21.9	69.8
	1033.3				3.19	11.96		

Test No. 37

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	211.1	21.1	1.01	3.75	2.13	7.91	66.2	82.6
2	69.3	6.9	.49	.85	.34	.59	11.1	6.2
3	12.5	1.3	.45	.16	.06	.02	1.9	.2
4	12.3	1.2	.22	.08	.03	.01	.9	.1
5	8.0	.8	.50	.09	.04	.01	1.2	.1
Tails	694.6	69.4	.09	.15	.62	1.04	19.3	10.9
					3.22	9.58		

Test No. 38

1	105.3	9.9	1.21	5.37	1.27	5.65	55.2	56.5
1a	46.3	4.3	.45	2.47	.21	1.13	9.1	11.3
2	66.6	6.2	.40	1.40	.27	.93	11.7	9.3
3	20.6	1.9	.30	.67	.06	.14	2.6	1.4
4	22.4	2.1	.40	.62	.09	.14	3.9	1.4
5	14.3	1.3	.57	.24	.08	.03	3.5	.3
Tails	791.3	72.3	.04	.25	.32	1.97	13.9	19.7
	1067.8				2.30	9.99		

Test No. 39

1	11.4	1.1	.45	1.05	.05	.12	2.4	1.3
2	7.3	.7	2.51	1.08	.18	.08	8.6	.8
3	12.4	1.2	2.52	1.32	.31	.16	14.7	1.7
4	8.2	.8	1.49	1.10	.12	.09	5.7	.9
5	4.1	4.0	2.27	1.12	.09	.05	4.3	.5
Tails	969.2	96.0	.14	.92	1.36	8.92	64.8	94.6
	1012.6				2.11	9.42		

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu. gms.	Weight Ni. gms.	Percent Rec. Cu%	Percent Rec. Ni%
Test No. 40								
1	86.6	8.4	1.92	4.65	1.66	4.03	63.3	48.7
2	38.3	3.7	.43	4.23	.16	1.62	6.1	19.6
3	24.7	2.4	.32	2.50	.08	.62	3.1	7.5
4	9.8	1.0	.49	.77	.05	.08	1.9	.9
5	7.7	.7	.59	.46	.05	.04	1.9	.4
Tails	859.3	83.7	.07	.22	.62	1.89	23.7	22.8
	1026.4				2.62	8.28		
Test No. 41								
1	114.1	11.0	1.43	6.03	1.63	6.88	61.1	69.6
1a	93.0	8.9	.52	2.21	.48	2.05	18.0	20.7
2	34.7	3.3	.34	1.01	.12	.35	4.5	3.5
3	16.0	1.5	.26	.54	.04	.09	1.5	.9
4	32.7	3.1	.22	.22	.07	.07	2.6	.7
5	13.3	1.3	.28	.18	.04	.02	1.5	.2
Tails	737.1	70.8	.04	.06	.29	.43	10.9	4.3
	1040.9				2.67	9.89		
Test No. 42								
1	14.3	1.4	2.35	1.99	.34	.28	12.8	2.9
2	18.0	1.8	1.92	1.62	.35	.29	13.2	3.1
3	10.0	1.0	1.42	1.61	.14	.16	5.3	1.7
4	5.5	5.3	.33	1.18	.02	.06	.8	.6
5	10.7	1.0	.57	.97	.06	.10	2.3	1.1
Tails	970.1	94.3	.18	.89	1.74	8.62	65.7	90.6
	1028.6				2.65	9.51		

Test No. 43

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu. gms.	Weight Ni. gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	30.2	3.0	4.18	3.22	1.26	.97	45.7	11.6
2	26.3	2.6	.78	3.97	.21	1.04	7.6	12.4
3	9.0	.9	.79	2.64	.07	.24	2.5	2.8
4	11.0	1.1	.43	.90	.05	.10	1.8	1.2
5	14.3	1.4	.46	.65	.07	.09	2.5	1.1
Tails	914.4	91.4	.12	.65	1.10	5.93	39.9	70.9
	1005.2				2.76	8.37		

Test No. 44

1	31.3	2.9	3.15	7.03	.99	2.20	32.4	22.8
2	49.8	4.7	1.79	4.08	.89	2.03	29.1	21.1
3	43.4	4.1	1.31	1.67	.57	.72	18.6	7.5
4	13.8	1.3	.54	.64	.07	.09	2.3	.9
5	14.5	1.4	.62	.35	.09	.05	2.9	.5
Tails	910.1	85.5	.05	.50	.45	4.55	14.6	47.2
	1062.9				3.06	9.64		

Test No. 48

1	29.3	2.9	.76	1.24	.22	.36	8.4	3.8
2	41.9	4.2	1.82	1.83	.76	.77	29.1	8.1
3	29.2	2.9	.68	.93	.20	.27	7.7	2.9
4	34.0	3.4	.46	.97	.16	.33	6.1	3.5
5	24.0	2.4	.31	.81	.07	.19	2.7	2.0
Tails	856.7	84.3	.14	.88	1.20	7.54	46.0	79.7
	1015.1				2.61	9.46		

Test No. 49

Conc No.	Wt. of Conc	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	84.4	8.4	2.17	5.45	1.83	4.60	71.0	49.0
2	53.3	5.3	.31	2.74	.17	1.46	6.6	15.5
3	27.5	2.7	.25	1.32	.07	.36	2.7	3.8
4	11.7	1.2	.31	.47	.04	.05	1.6	.5
5	21.1	2.1	.30	.32	.06	.07	2.3	.7
Tails	818.9	80.7	.05	.35	.41	2.86	15.9	30.4
	1016.9				2.58	9.40		

Test No. 50

1	198.1	19.1	1.13	4.69	2.24	9.30	85.3	93.8
2	25.8	2.5	.24	.55	.06	.14	2.3	1.4
3	23.0	2.2	.13	.18	.03	.04	1.1	.4
4	22.8	2.2	.16	.12	.04	.03	1.5	.3
5	21.8	2.1	.20	.12	.04	.03	1.5	.3
Tails	746.5	71.8	.03	.05	.22	.37	8.4	3.7
	1038.0				2.63	9.91		

Test No. 51

1	29.9	3.0	1.61	1.33	.48	.40	17.1	4.9
2	35.9	3.5	1.57	1.23	.56	.44	20.0	5.3
3	31.4	3.1	.51	.94	.16	.29	5.7	3.5
4	18.3	1.8	.29	.91	.05	.17	1. 8	2.1
5	20.8	2.1	.28	.89	.06	.19	2.1	2.3
Tails	875.1	86.6	.17	.77	1.49	6.74	53.2	81.9
	1011.4				2.80	8.23		

Test No. 52

Conc. No.	Wt. of Conc.	% Wt.	Assay Cu%	Assay Ni%	Weight Cu.gms.	Weight Ni.gms.	Percent Rec. Cu%	Percent Rec. Ni%
1	21.8	2.1	2.39	2.02	.52	.44	22.1	4.9
2	15.6	1.5	2.70	1.91	.42	.30	17.9	3.3
3	11.4	1.1	1.51	1.72	.17	.20	7.2	2.2
4	12.3	1.2	.65	1.17	.08	.14	3.4	1.5
5	12.5	1.2	.15	.86	.02	.11	.8	1.2
Tails	949.7 / 1023.3	92.6	.12	.83	1.14 / 2.35	7.87 / 9.06	48.6	86.8

Test No. 53

1	14.4	1.4	5.35	3.20	.77	.46	32.0	5.1
2	20.4	2.0	2.69	4.49	.55	.92	22.8	10.2
3	21.4	2.1	.58	2.50	.12	.54	5.0	6.0
4	15.4	1.5	.63	1.99	.10	.31	4.1	3.4
5	10.2	1.0	.35	1.03	.04	.11	1.7	1.2
Tails	920.8 / 1002.6	92.1	.09	.72	.83 / 2.41	6.68 / 9.02	34.4	74.1

Test No. 54

1	25.0	2.5	3.36	2.58	.84	.65	33.0	7.4
2	19.4	1.9	1.48	2.10	.29	.41	11.4	4.6
3	30.8	3.1	.39	1.22	.12	.38	4.7	4.3
4	21.6	2.1	.33	.1	.07	.20	2.8	2.3
5	18.5	1.8	.27	.78	.05	.14	2.0	1.6
Tails	898.3 / 1013.6	88.6	.13	.79	1.17 / 2.54	7.09 / 8.87	46.1	79.9

Conc. No.	Cumulative Recovery Wt.%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 NaOH
				Test No. 22			
1	2.4	27.1	10.5	.17	4c	6.5	
2	4.9	42.1	16.0	.34	4c	7.66	
3	10.1	59.5	29.6	.51	4bc	7.8	
4	13.5	64.9	35.8	.68	4bc	7.12	
5	16.6	73.4	41.6	.85	4b	7.69	
				Test No. 23			
1	3.0	30.0	6.6	.17	6c	7.7	
2	11.3	60.9	33.3	.34	6c	7.0	
3	14.8	66.6	40.8	.51	6c	7.5	
4	17.3	69.9	44.8	.68	6bc	7.5	
5	21.2	74.2	51.8	.85	6bc	7.6	
				Test No. 24			
1	3.2	33.8	5.4	.028	6b	7.08	
2	5.8	47.0	9.4	.056	7bc	7.0	
3	7.8	54.8	11.6	.084	7bc	7.0	
4	8.9	58.6	12.8	.112	7bc	7.3	
5	.9	62.9	13.6	.140	7b	7.75	
				Test No. 25			
1	2.2	17.6	6.6	.028	5bc	5.64	50
2	5.	44.0	18.7	.056	7bc	5.30	
3	8.7	52.3	24.1	.084	7b	5.2	
4	10.4	55.0	26.4	.112	7c	4.65	
5	11.9	56.3	27.8	.140	4c	4.65	

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 1:2c.c.	NaOH gms.
				Test No. 26				
1	1.9	5.8	3.3	.028	5b	7.96		67
2	5.4	24.3	8.9	.056	7b	7.94		
3	7.5	34.6	11.9	.084	7bc	7.6		
4	8.5	37.0	13.2	.112	7bc	7.45		
5	9.3	38.6	14.2	.140	7bc	7.43		
				Test No. 27				
1	3.5	19.1	5.3	.028	7b	7.26		
2	4.7	31.3	7.1	.056	7ab	7.37		
3	6.6	41.1	9.6	.084	7b	7.46		
4	7.5	43.6	10.7	.112	7b	7.40		
5	9.1	44.2	12.6	.140	7b	7.44		
				Test No. 28				
1	3.5	39.7	9.6	.028	5b	5.59	50	
2	8.0	59.8	21.0	.056	6b	4.41		
3	----------							
4	9.0	61.0	22.0	.112	6b	4.34		
5	10.9	62.8	23.0	.140	6bc	4.34		
				Test No. 29				
1	3.6	34.5	10.1	.028	6ab	9.92		1.11
2	6.7	48.9	19.7	.056	7b	9.57		
3	12.0	58.9	31.0	.084	7b	9.10		
4	13.3	60.4	32.3	.112	7b	8.5		
5	14.4	61.9	33.2	.140	7b	8.41		

Test No. 30

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	pH.	H_2SO_4 1:2 c.c.	NaOH gms.
1	2.8	14.8	4.6	.03	5bc	7.56		
2	5.3	29.6	8.8	.078	5ab	7.20		
3	6.5	32.9	10.1	.117	4b	7.30		
4	7.3	34.9	10.9	.156	3ab	7.27		
5	8.2	37.1	11.9	.195	2ab	7.44		
			Test No. 31					
1	9.2	70.5	40.0	.039	5ab	10.59		.89
2	10.4	73.0	41.8	.078	5ab	9.40		
3	12.3	75.5	44.0	.117	5a	------		
4	13.7	77.1	45.3	.156	4ab	8.75		
5	14.4	78.1	45.9	.195	4ab	8.58		
			Test No. 32					
1	11.3	49.4	50.5	.039	1a	1.76	50	
2	27.9	78.9	88.7	.078	4b	1.99		
3	31.6	82.1	93.0	.117	2b	2.20		
4	34.1	84.6	94.7	.156	1b	2.20		
6	35.1	85.3	95.3	.196	4b	2.09	25	
			Test No. 33					
1	2.5	23.2	4.0	.012	7c	7.09		
2	4.6	31.5	7.0	.024	7c	7.22		
3	5.8	34.8	8.5	.036	7c	7.40		
4	6.7	37.3	9.4	.048	6c	7.53		
5	7.3	40.6	9.9	.060	6c	7.5		

Test No. 34

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 1:2 c.c.	NaOH gms.
1	13.0	61.8	37.6	.012	7b	11.0	11.0	1.11
2	15.2	70.9	43.9	.024	6b	9.84		
3	16.6	73.7	45.8	.036	6b	9.20		
4	18.0	76.8	47.1	.048	6b	8.75		
5	18.8	78.1	47.8	.060	5b	8.79		
			Test No. 35					
1	27.2	82.3	93.0	.012	7ab	1.6	50	
2	34.9	87.7	97.8	.024	7bc	2.2		
3	39.6	91.4	99.1	.036	7bc	2.7		
4	41.1	92.5	99.3	.048	7c	3.65		
5	41.6	93.1	99.4	.060	6c	4.15		
			Test No. 36					
1	6.5	53.7	14.7	.0115	7du	7.30		
2	10.7	68.1	24.2	.0230	7du	7.35		
3	12.8	72.8	27.5	.0345	7cu	7.53		
4	13.9	75.6	28.8	.0460	7bcu	7.52		
5	15.0	78.1	30.1	.0575	7au	7.69		
			Test No. 37					
1	21.1	66.2	82.6	.0115	4bu	12.27		2.22
2	28.0	77.3	88.8	.0230	7cu	12.37		
3	29.3	79.2	89.0	.0345	3bu	10.53		
4	30.5	80.1	89.1	.0460	3bu	9.85		
5	31.3	81.3	89.2	.0575	2abu	9.54		

Test No. 38

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 1:2 cc.	NaOH gms.
1	9.9	55.2	56.5	.0115	6cu	3.69	50	
1a	14.2	64.3	67.8			4.46		
2	20.4	76.0	77.1	.0230	6cu	4.50		
3	22.3	78.6	78.5	.0345	6ab	4.70		
4	24.4	82.5	79.9	.0460	7ab	4.72		
5	25.7	86.0	80.2	.0575	7bc	4.70		

Test No. 39

1	1.1	2.4	1.3	.009	2bx	6.85		
2	1.8	11.0	2.1	.013	2bx	7.8		
3	3.0	25.7	3.8	.027	3bx	7.92		
4	3.8	31.4	4.8	.036	2bx	8.18		
5	7.8	35.7	5.3	.045	2bx	7.86		

Test No. 40

1	8.4	63.3	48.7	.009	5abx	12.3		2.22
2	12.1	69.4	68.3	.018	7bu	11.2		
3	14.5	72.5	75.8	.027	6bx	10.5		
4	15.5	74.4	76.7	.036	6cu	9.91		
5	16.2	76.3	77.1	.045	6bcu	9.52		

Test No. 41

1	11.0	61.1	69.6	.009	6cu	2.32	50	
1a	19.9	79.1	90.3			2.64		
2	23.2	83.6	93.8	.018	6cu	3.0		
3	24.7	85.1	94.7	.027	6cu	3.65		
4	27.8	87.7	95.4	.036	7cu	4.32		
5	29.1	89.2	95.6	.045	6cu	4.35		

Test No. 42

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 NaOH gms. 1:2 cc.
.1	1.4	12.8	2.	.006	3ax	7.42	
2	3.2	26.0	6.0	.012	3ax	7.5	
3	4.2	31.3	7.7	.018	3ax	7.5	
4	4.7	32.1	8.3	.024	3ax	7.33	
5	5.7	34.3	9.4	.030	4ax	7.32	
			Test No. 43				
1	3.0	45.7	11.6	.006	3ax	10.67	2.22
2	5.6	53.3	24.0	.012	4ax	10.17	
3	6.5	55.8	26.8	.018	4ax	9.7	
4	7.6	57.6	28.0	.024	4ax	9.4	
5	9.0	60.1	29.1	.030	4ax	9.35	
			Test No. 44				
1	2.9	32.4	22.8	.006	7bx		
2	7.6	61.5	43.9	.012	6bx		
3	11.7	80.1	51.4	.018	6bx		
4	13.0	82.4	52.3	.024	6bx		
5	14.4	85.3	52.8	.030	6bx		
			Test No. 48				
1	2.9	8.4	3.8	.004	3a	7.25	
2	7.1	37.5	11.9	.008	4ax	7.26	
3	10.0	45.2	14.8	.012	4ax	7.26	
4	13.4	51.3	18.3	.016	5abx	7.35	
5	15.8	54.0	20.3	.020	5abx	7.80	

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 1:2 cc.	NaOH gms.
				Test No. 49				
1	8.4	71.0	49.0	.004	5ax	9.85		2.22
2	13.7	77.6	64.5	.008	6b	9.63		
3	16.4	80.3	68.3	.012	6b	9.43		
4	17.6	81.9	68.8	.016	6b	9.17		
5	19.7	84.2	69.5	.020	6b	9.03		
				Test No. 50				
1	19.1	85.3	93.8	.004	7du	3.16	50	
2	21.6	87.6	95.2	.008	6dx	3.18		
3	23.8	88.7	95.6	.012	6du	3.22		
4	26.0	90.2	95.9	.016	6dx	3.27		
5	28.1	91.7	96.2	.020	6dx	3.27		
				Test No. 51				
1	3.0	17.1	4.9	.004	4ax	6.31		
2	6.5	37.1	10.2	.008	5ax	7.01		
3	9.6	42.8	13.7	.012	5ax	7.08		
4	11.4	44.6	15.8	.016	5ax	7.27		
5	13.5	46.7	18.1	.020	5ax	7.36		
				Test No. 52				
1	2.1	22.1	4.9	.005	3abx	8.65		
2	3.6	40.0	8.2	.010	3ax	8.60		
3	4.7	47.2	10.3	.015	5au	8.54		
4	5.9	50.6	11.8	.020	7au	8.40		
5	7.1	51.4	13.0	.025	7bu	8.36		

Test No. 53

Conc. No.	Cumulative Recovery Wt%	Cu%	Ni%	Cum. Wt. Reagent gms.	Froth Condition	p.H.	H_2SO_4 1:2 cc.	NaOH gms.
1	1.4	32.0	5.1	.005	2bx	8.67		
2	3.4	54.8	15.3	.010	2bx	8.67		
3	5.5	59.8	21.3	.015	3abx	8.38		
4	7.0	63.9	24.7	.020	4ax	8.25		
5	8.0	65.6	25.9	.025	3ax	7.87		

Test No. 54

1	2.5	33.0	7.4	.005	3ax	7.85		
2	4.4	44.4	12.0	.010	3ax	7.85		
3	7.5	49.1	16.3	.015	2ax	7.95		
4	9.6	51.9	18.6	.020	3ax	7.97		
5	11.4	53.9	20.2	.025	4bx	7.97		

Condition of Froth

Depth of Froth

#1 - few bubbles near lip

#2 - $\frac{1}{4}$" layer

3 - $\frac{1}{4}$ - $\frac{1}{2}$" "

4 - $\frac{1}{2}$ - $\frac{3}{4}$" "

5 - $\frac{3}{4}$ - $1\frac{1}{2}$" layer

6 - $1\frac{1}{2}$ - $2\frac{1}{2}$" "

7 - $2\frac{1}{2}$" - overflowing.

Size of Bubble

a - 3/8" or over

b - 3/8 - 1/8 "

c - 1/8 - 1/16"

d - very fine

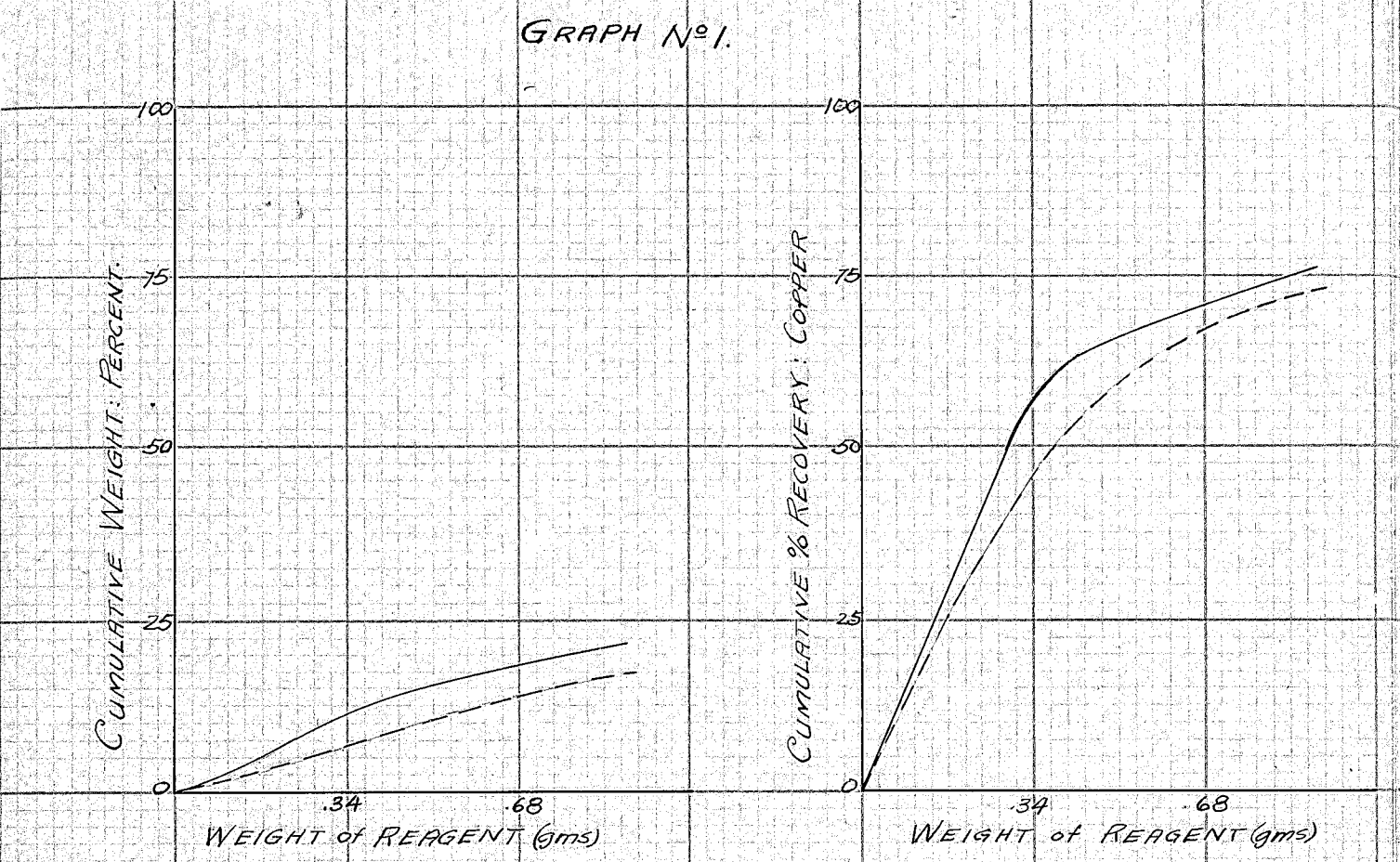
Stength and lasting power of bubble.

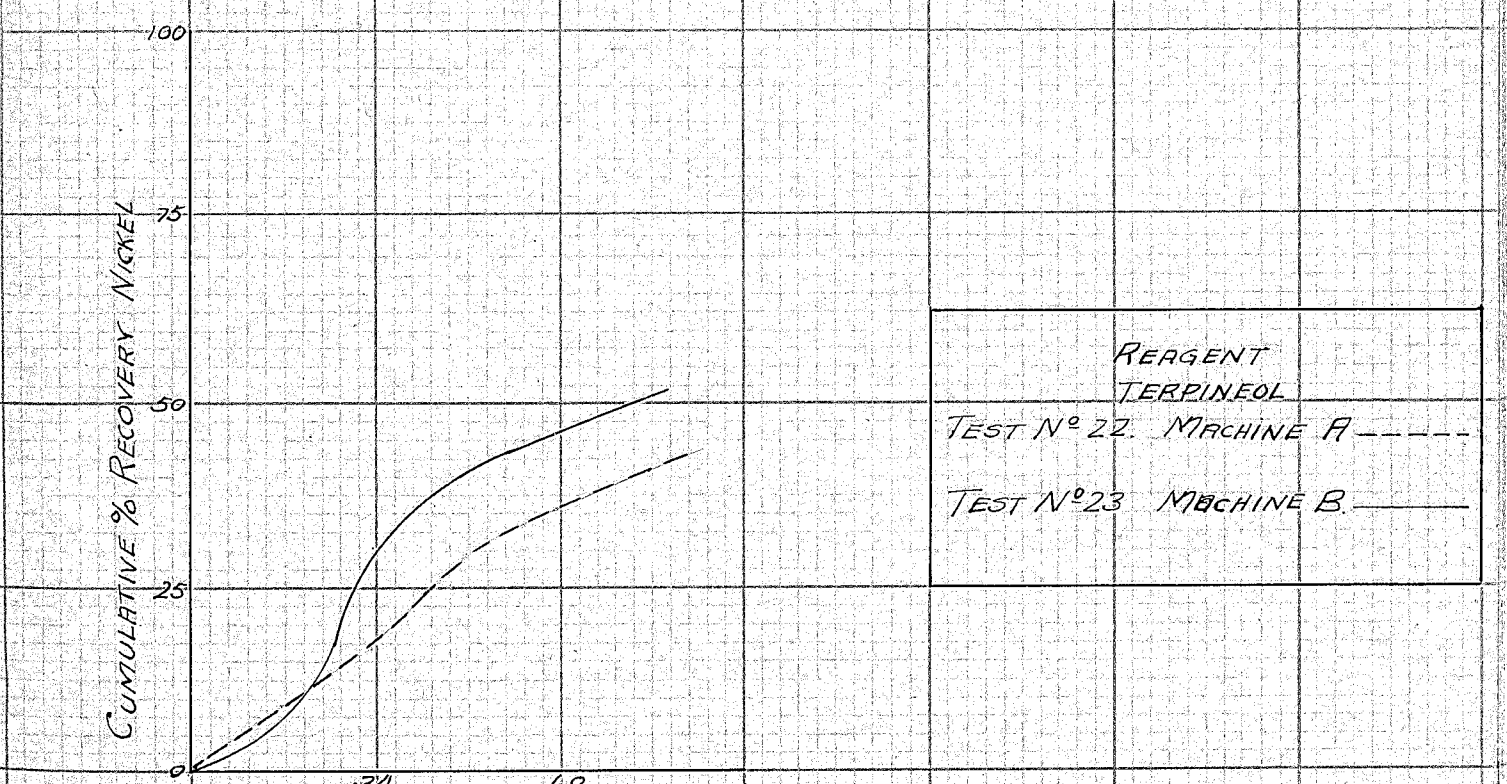
T - Tough - lasts till pan is put in oven.

U - Lasts till all froth reaches pan

X - Brittle - bursts while overflowing.

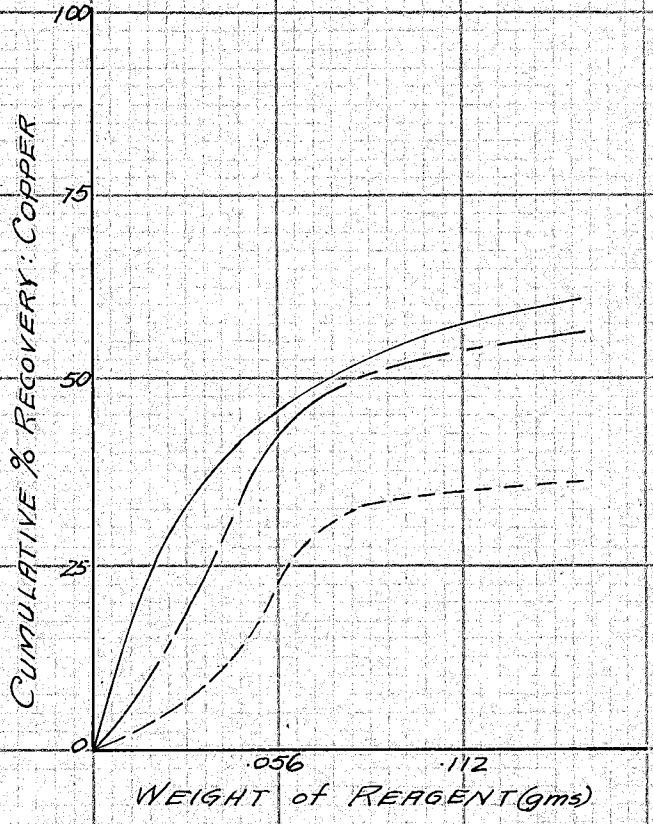
GRAPH Nº 1.

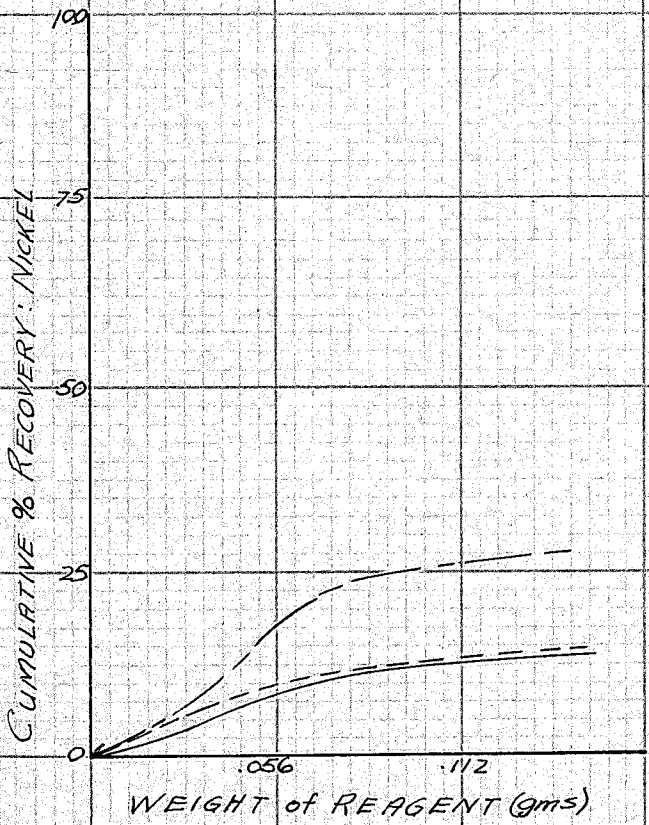




REAGENT
TERPINEOL
TEST Nº 22. MACHINE A - - - - -
TEST Nº 23 MACHINE B. ———

GRAPH Nº 2





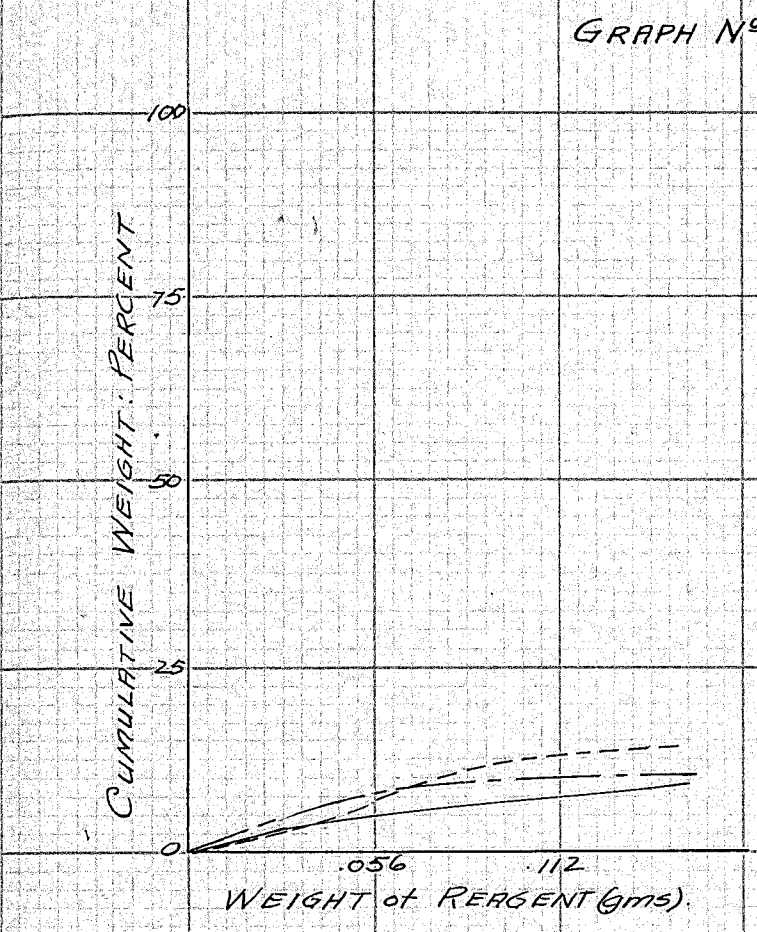
REAGENT
TERPINEOL

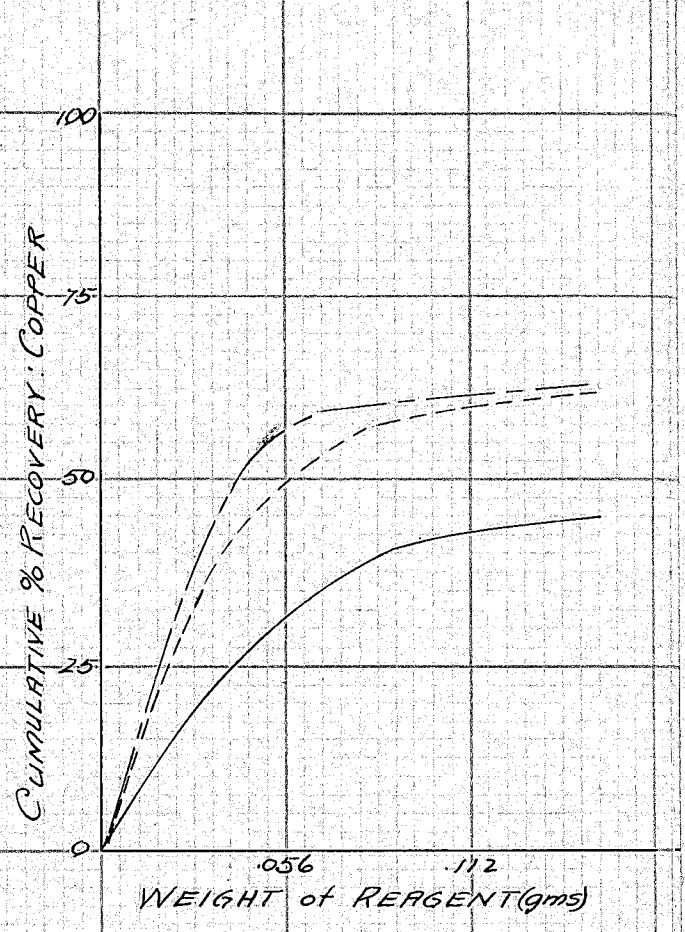
TEST Nº 24 NATURAL. ——————

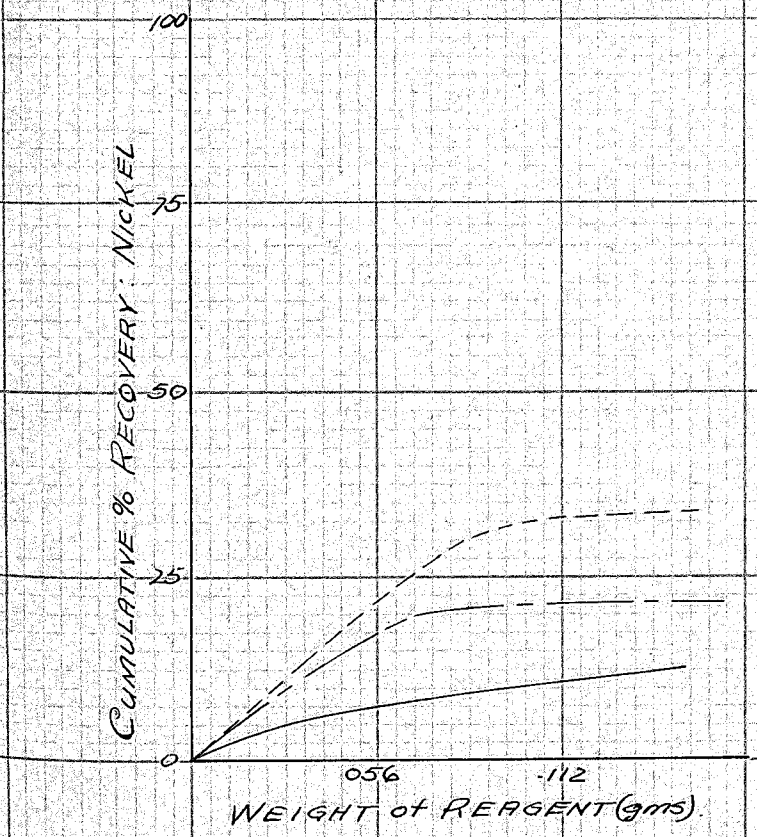
TEST Nº 25 ACID: —— - ——

TEST Nº 26 ALKALINE: - - - - - -

GRAPH Nº3







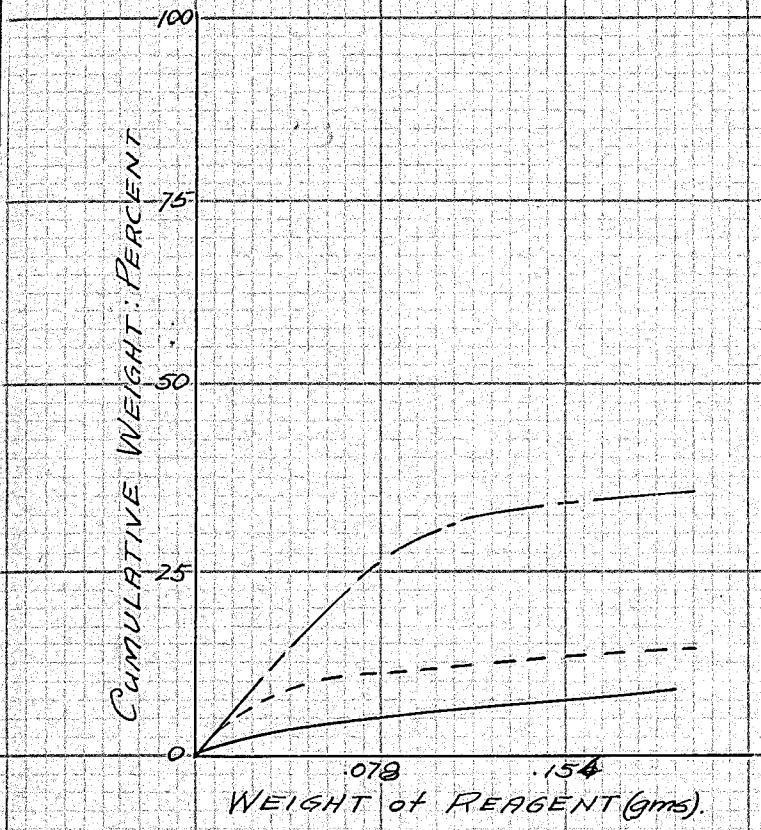
REAGENT
#5 PINE OIL G.N.S.

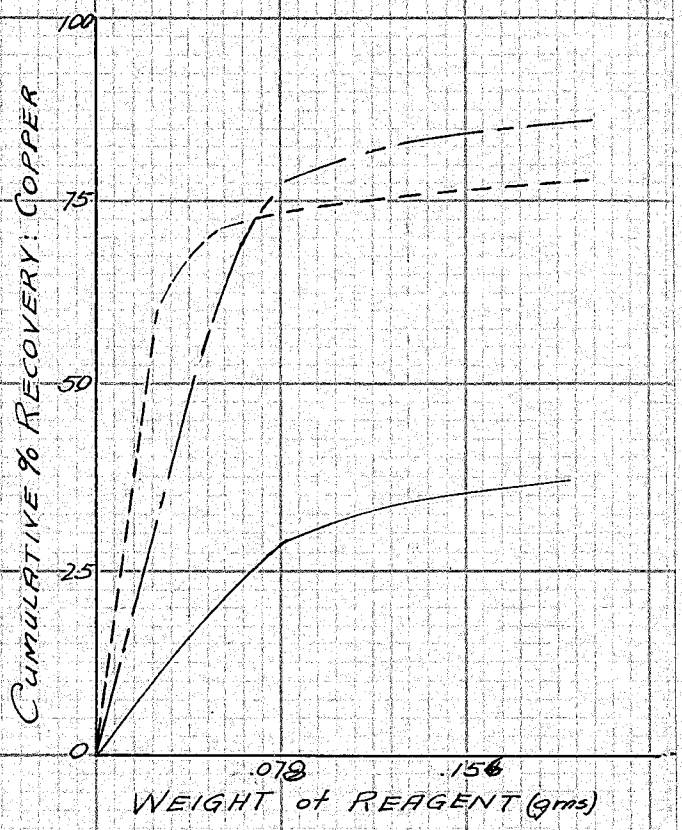
TEST Nº27 NATURAL ——————

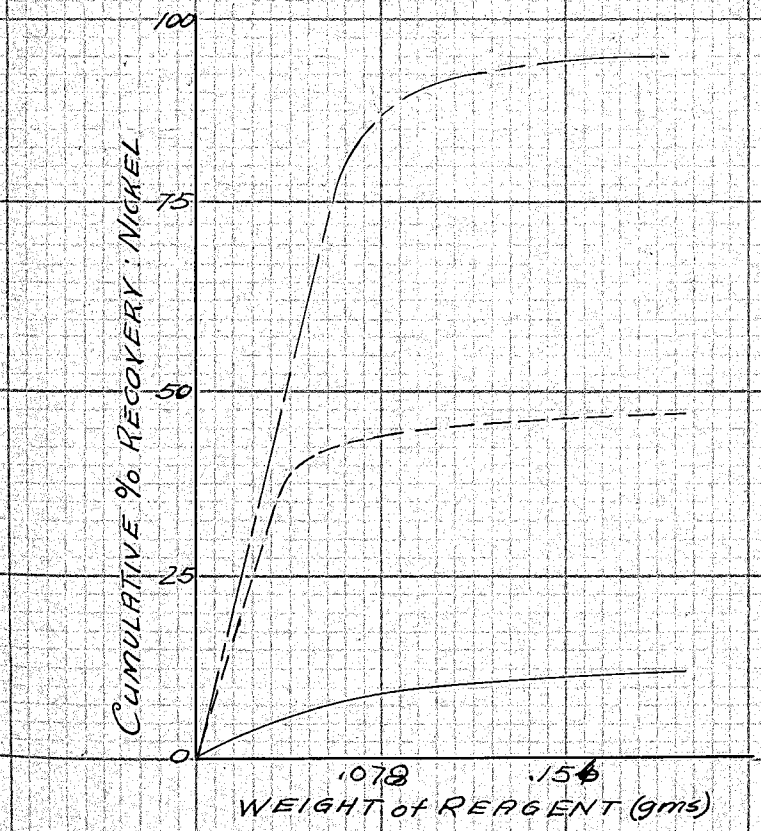
TEST Nº28 ACID. — — — —

TEST Nº29 ALKALINE. - - - - - -

GRAPH Nº4







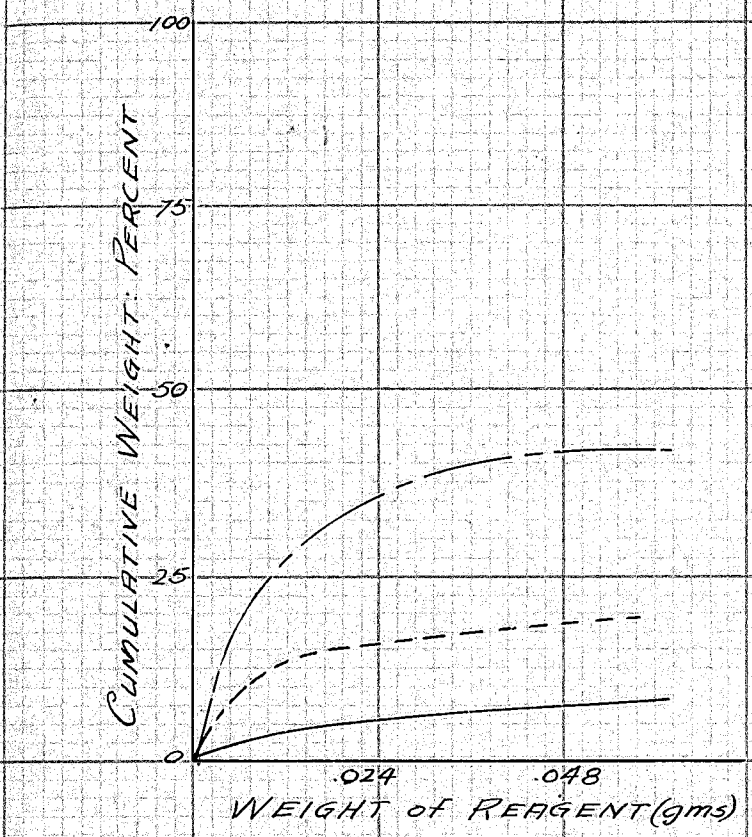
REAGENT
'A'

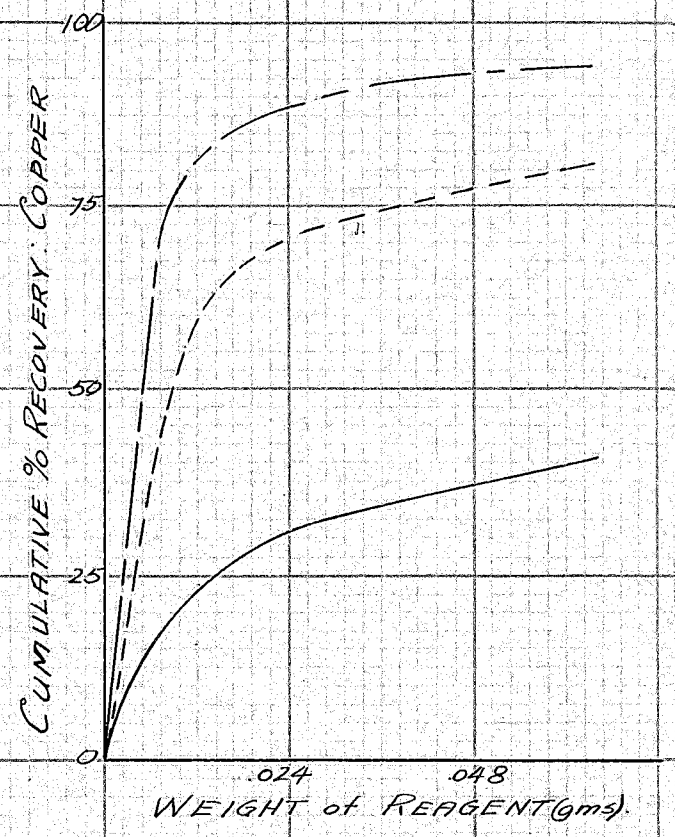
TEST Nº 30 NATURAL

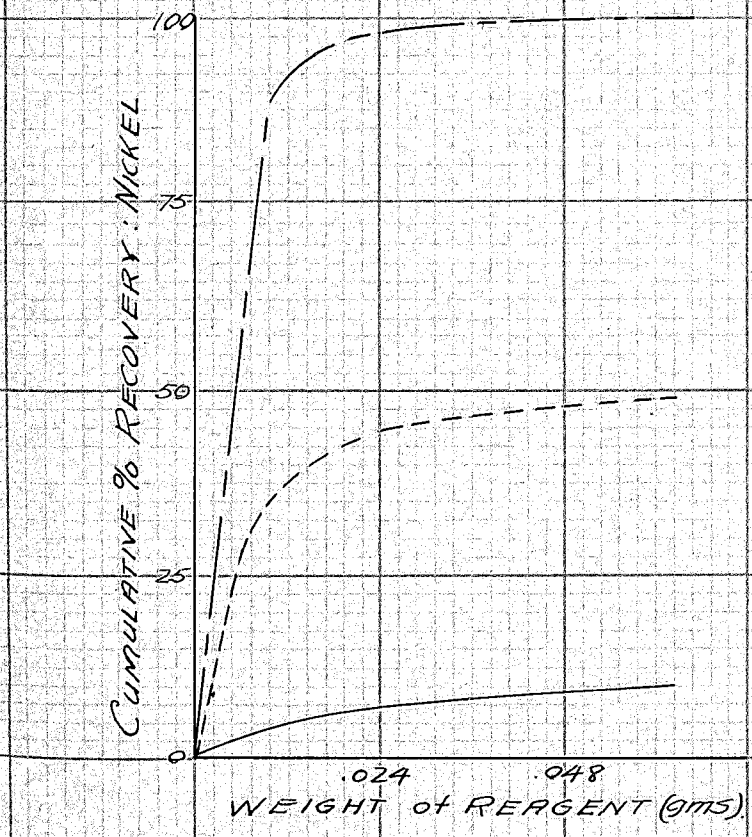
TEST Nº 31 ALKALINE

TEST Nº 32 ACID.

GRAPH Nº5







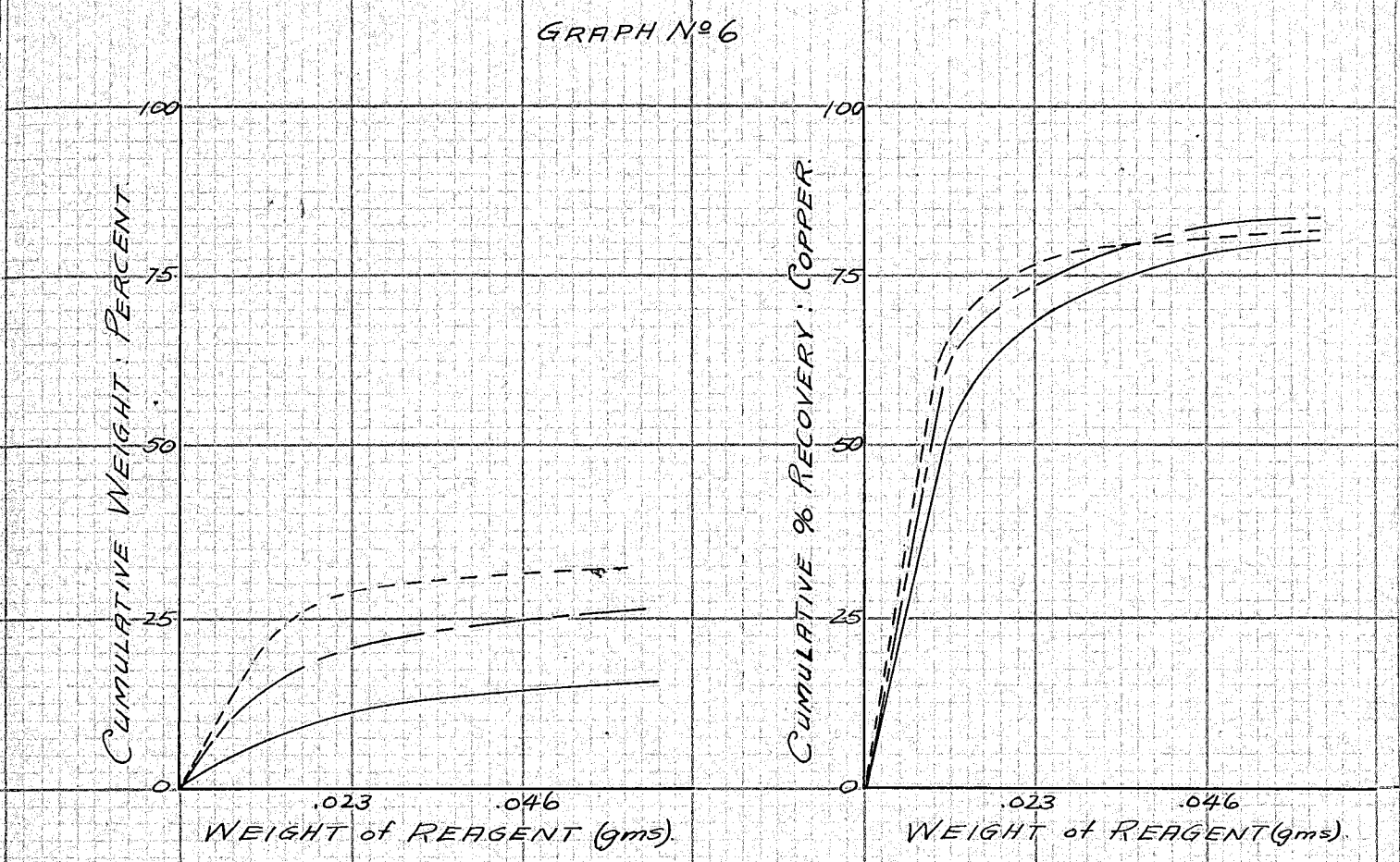
REAGENT 'F'

TEST Nº 33 NATURAL.

TEST Nº 34 ALKALINE

TEST Nº 35 ACID.

GRAPH Nº 6



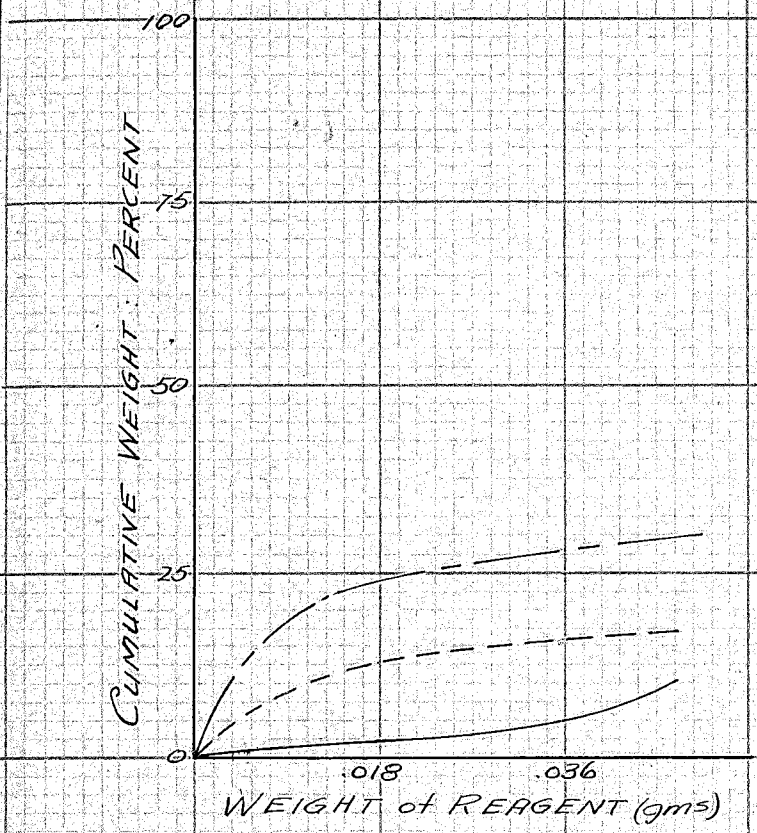
REAGENT 'G'

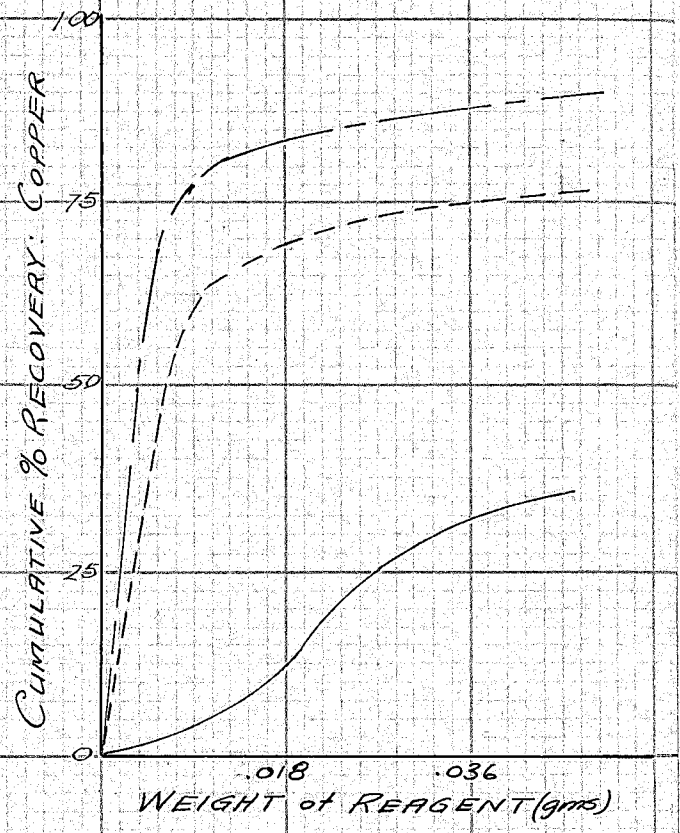
TEST Nº 36 NATURAL. ————

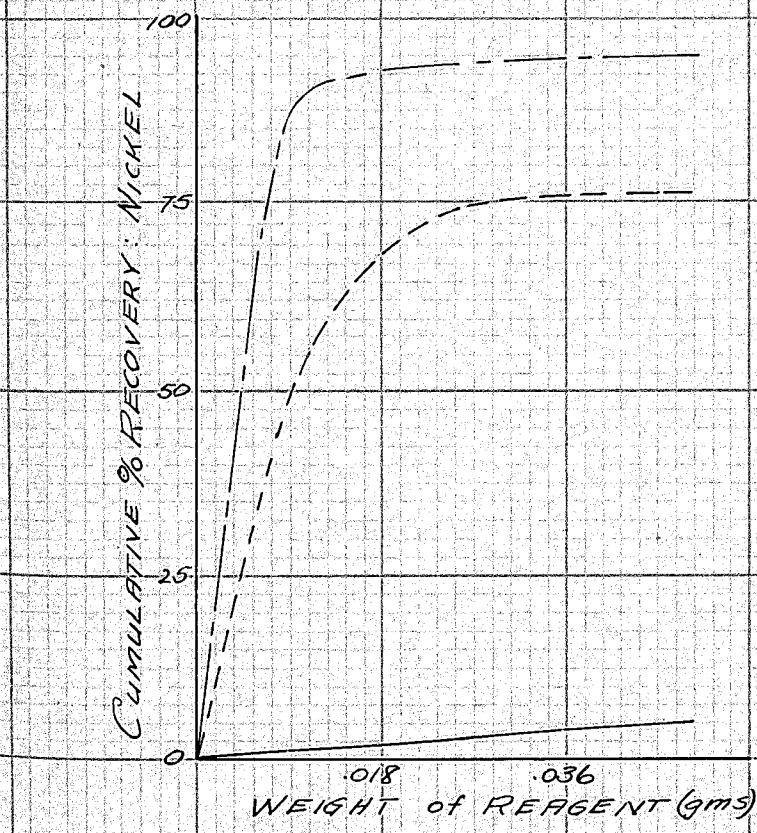
TEST Nº 37 ALKALINE. — — — —

TEST Nº 38 ACID. —— - ——

GRAPH Nº 7.







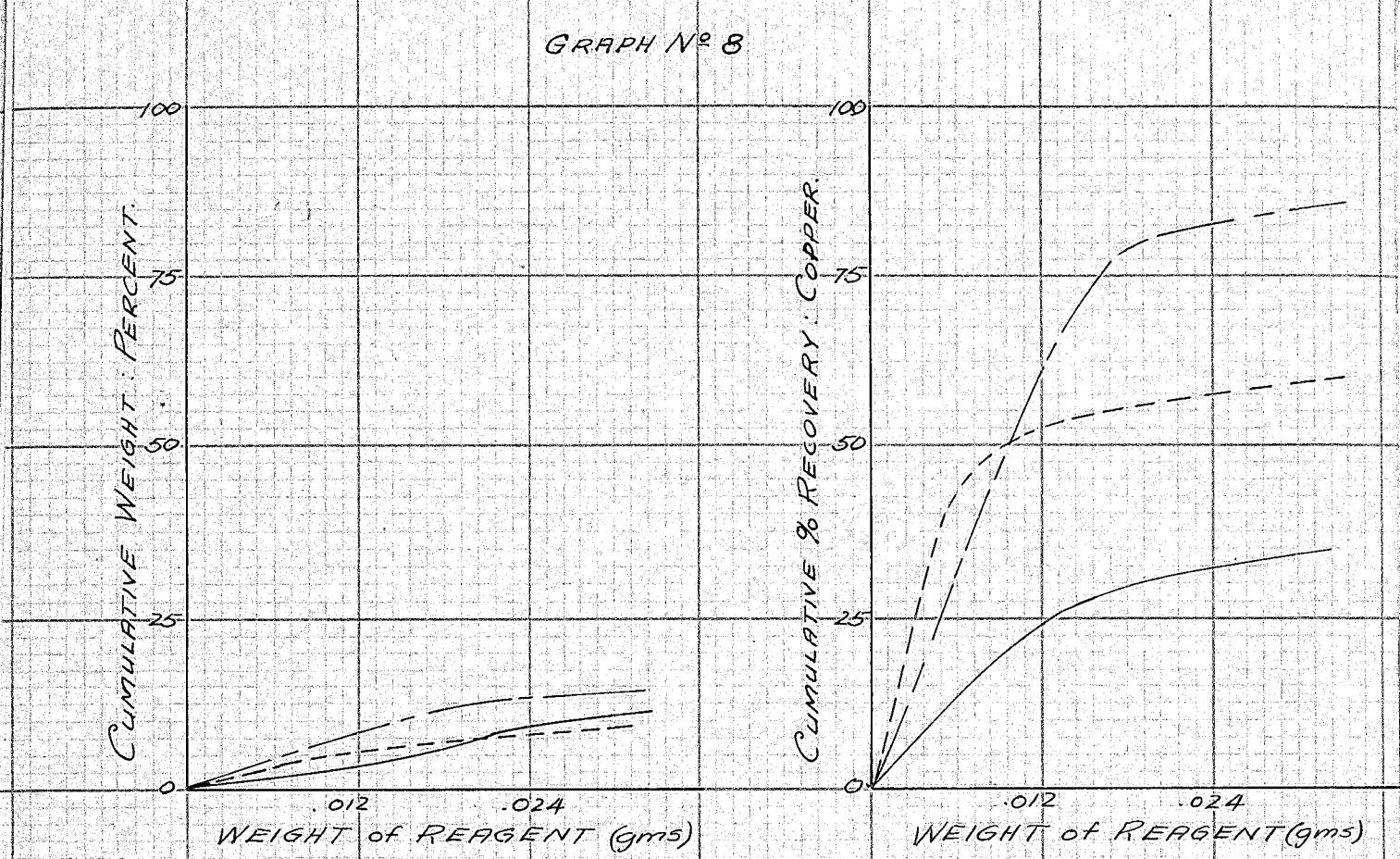
REAGENT 'I'

TEST Nº 39 NATURAL _____

TEST Nº 40 ALKALINE - - - - - -

TEST Nº 41 ACID. _ _ _ _ _

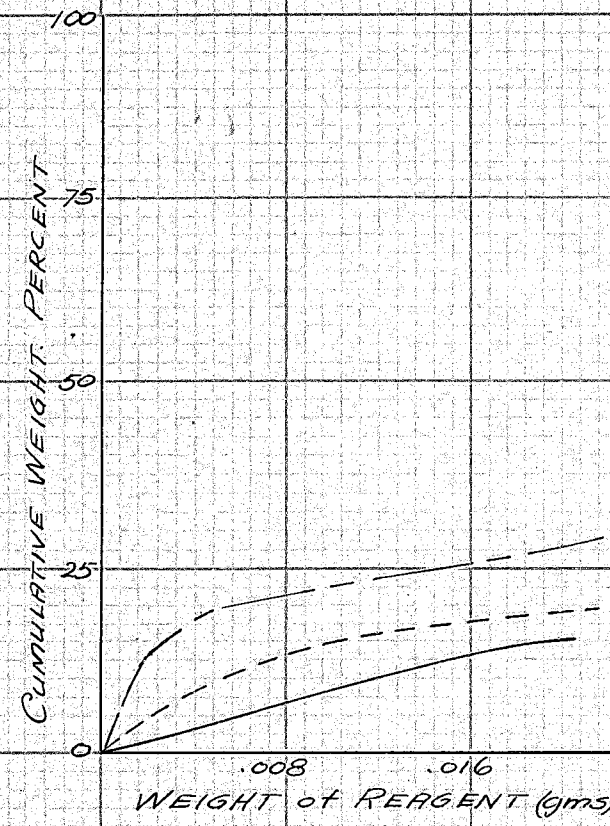
GRAPH Nº 8

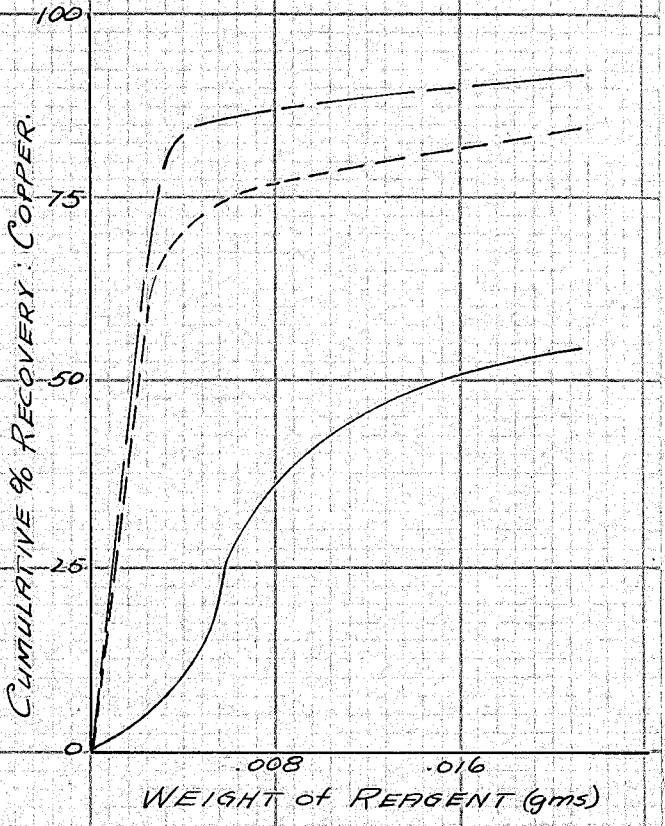

100
75
50
25
0
CUMULATIVE WEIGHT : PERCENT.
.012
.024
WEIGHT of REAGENT (gms)

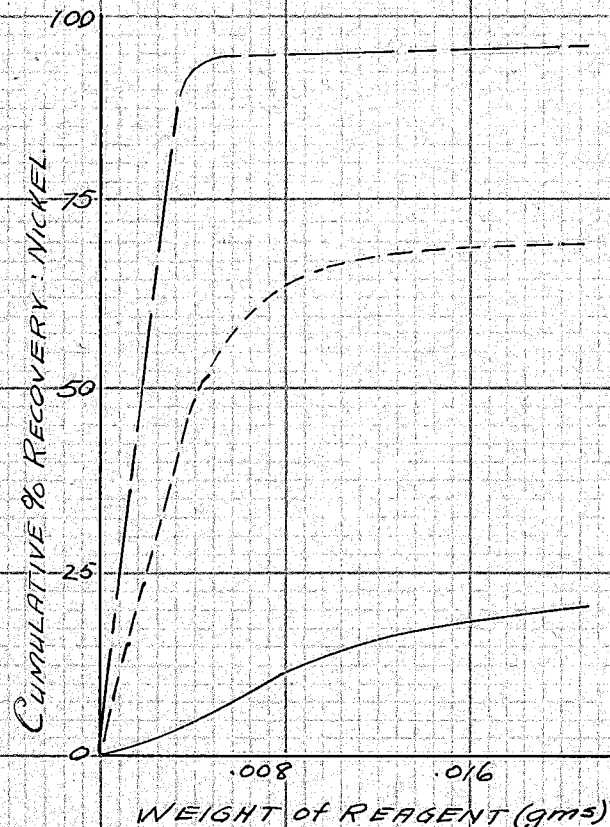
100
75
50
25
0
CUMULATIVE % RECOVERY : COPPER.
.012
.024
WEIGHT of REAGENT (gms)

100
75
50
25
0
CUMULATIVE % RECOVERY : NICKEL.
.012
.024
WEIGHT of REAGENT (gms)
REAGENT 'J'
TEST Nº 42 NATURAL
TEST Nº 43 ALKALINE.
TEST Nº 44 ACID.

GRAPH Nº 9







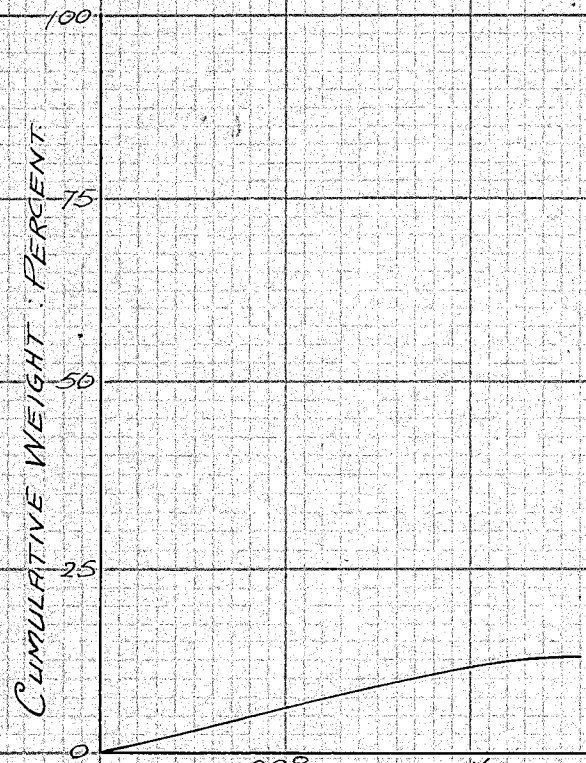
REAGENT 'P'

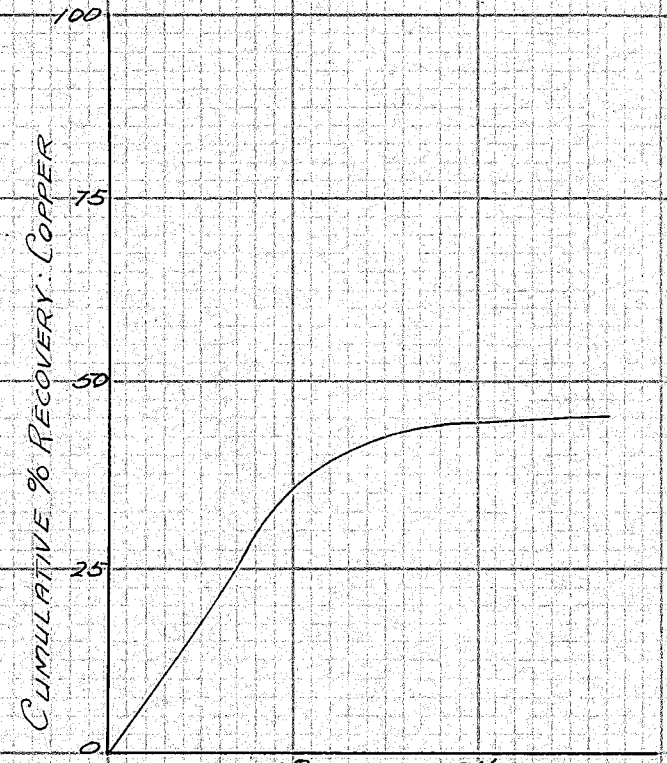
TEST Nº 48 NATURAL ————

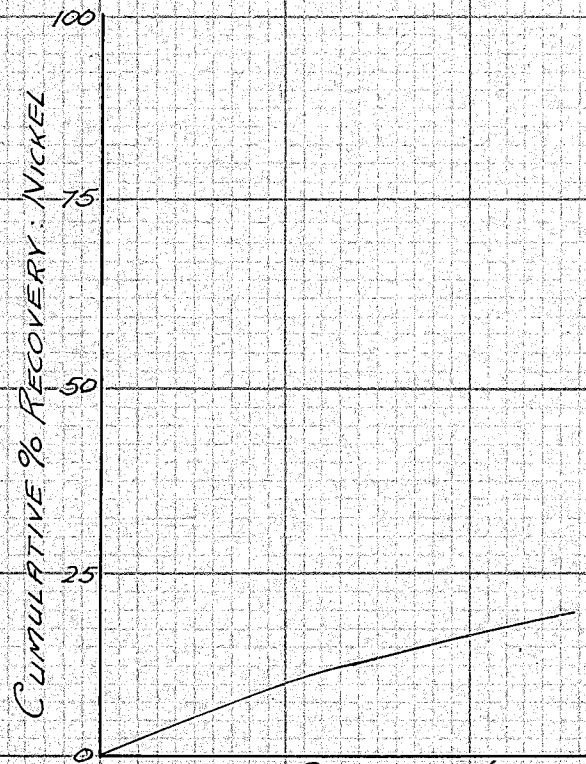
TEST Nº 49 ALKALINE - - - - - -

TEST Nº 50 ACID — — — —

GRAPH Nº 10



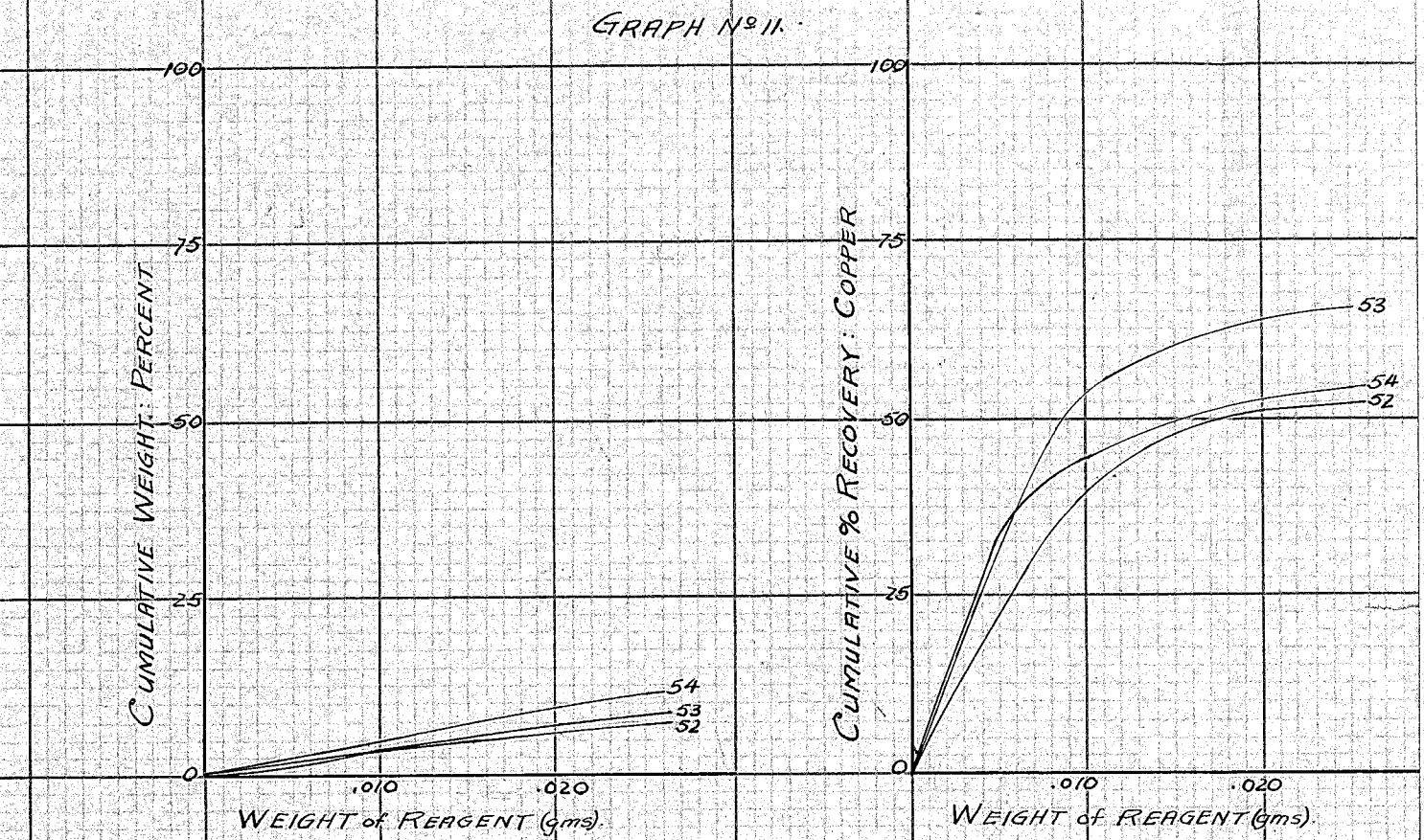


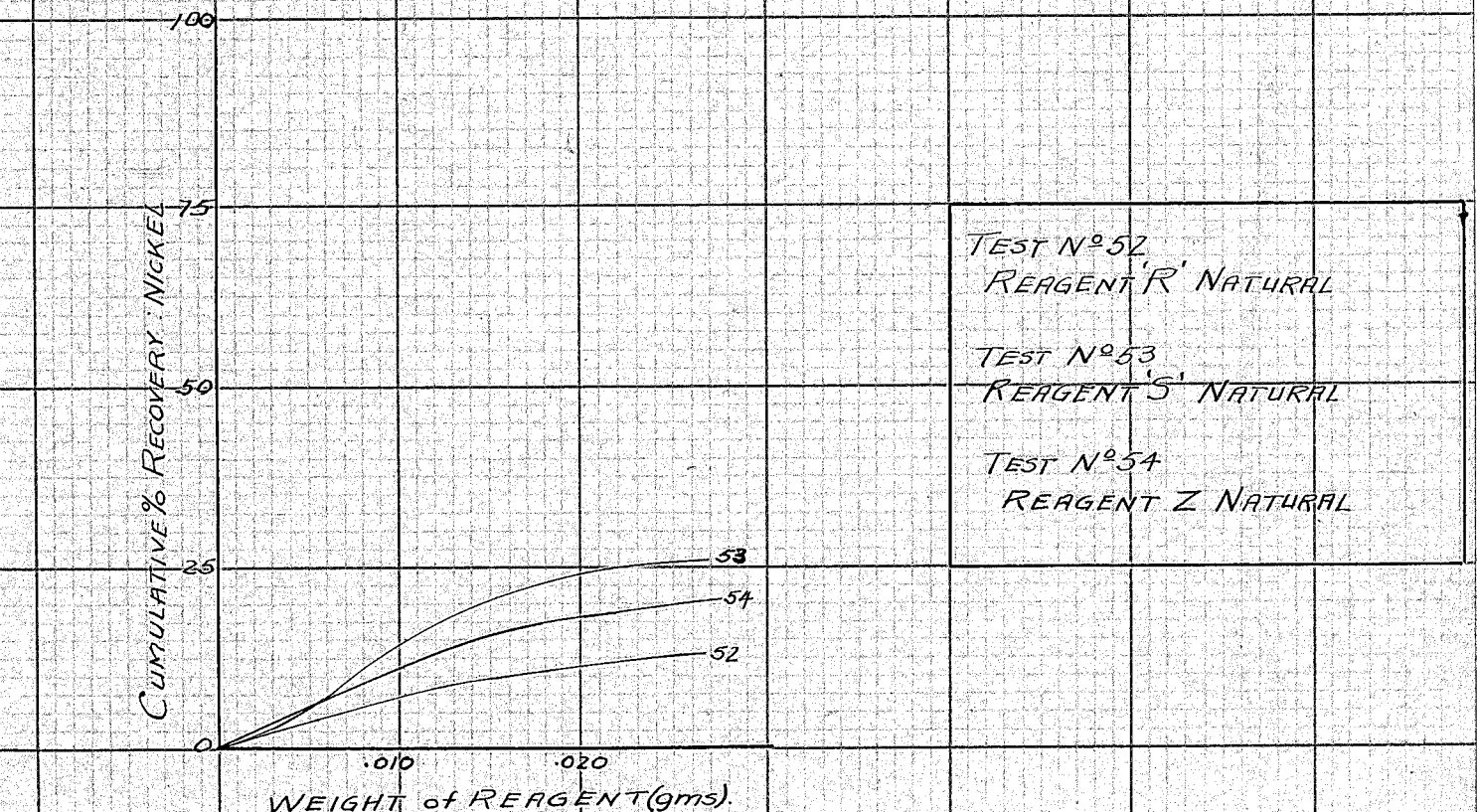


REAGENT
'Q'

TEST Nº 51. NATURAL

GRAPH Nº 11.





TEST Nº 52
REAGENT 'R' NATURAL

TEST Nº 53
REAGENT 'S' NATURAL

TEST Nº 54
REAGENT Z NATURAL

SHEET N°1

STANDARD CONDITIONS OF TEST

To Ball Mill

1000 gms ore

1000 c.c. H_2O

Grind - 15 Min @ 44 RPM.

To Flotation Cell

Reagent - 6 drops per Conc^{n}

Mixed - 1 Min.

Agitated & Skimmed - 10 min

TEST	REAGENT	PRODUCT	WEIGHT OF PRODUCT	PERCENT OF TOTAL WEIGHT	CUMULATIVE % OF WEIGHT	WEIGHT OF REAGENT	CONDITION OF FROTH	PH CONTROL			COPPER			NICKEL		
								H_2SO_4 1:2	Na OH	P.H.	ASSAY	% RECOVERY	CUMULATIVE RECOVERY	ASSAY	% RECOVERY	CUMULATIVE RECOVERY
			GMS.	%		GMS		CC	GMS		%	%		%	%	
22	TERPINEOL	C.1	24.3	2.93	2.43	.17	4C			6.5	3.87	27.1	27.1	5.16	10.5	10.53
		C.2	25.0	2.50	4.93	.34	4C			7.66	2.08	15.0	42.1	2.60	5.5	16.01
		C.3	51.7	5.17	10.10	.51	4bc			7.8	1.17	17.4	59.5	3.17	13.6	29.6
		C.4	34.4	3.44	13.54	.68	4bc			7.12	.55	5.4	64.9	2.16	6.2	35.8
		C.5	30.8	3.08	16.62	.85	4b			7.69	.95	8.4	73.4	2.24	5.8	41.6
		Tails	835.1	83.51							.11	26.5		.83	33.4	
23	TERPINEOL	C.1	31.8	3.04	3.04	.17	6C			7.7	3.34	30.0	30.0	2.38	6.6	6.6
		C.2	87.3	8.34	11.38	.34	6C			7.0	1.25	30.9	60.9	3.59	26.7	33.3
		C.3	36.4	3.48	14.82	.51	6C			7.5	.57	5.7	66.6	2.31	7.5	40.8
		C.4	25.0	2.49	17.31	.68	6bc			7.5	.46	3.3	69.9	1.84	4.0	44.8
		C.5	40.8	3.90	21.21	.85	6bc			7.6	.38	4.3	74.2	2.00	7.1	51.8
		Tails	826.5	79.00						7.7	.11	25.7		.67	48.1	
24	TERPINEOL	C.1	32.0	3.16	3.16	.028	6b			7.08	3.41	33.8	33.8	2.20	5.4	5.4
		C.2	26.2	2.59	5.75	.036	7bc			7.0	1.86	13.2	47.0	2.04	4.0	9.4
		C.3	20.1	1.99	7.74	.084	7bc			7.0	1.43	7.8	54.8	1.45	2.2	11.6
		C.4	11.2	1.11	8.85	.112	7bc			7.3	1.28	3.8	58.6	1.37	1.2	12.8
		C.5	10.1	1.00	9.85	.140	7b			7.75	1.58	4.3	62.9	1.12	.8	13.6
		Tails	912.0	90.10							.15	37.1		1.24	86.4	
25	TERPINEOL	C.1	23.3	2.25	2.25	.028	5bc	50.		5.64	7.85	17.6	17.6	2.90	6.57	6.57
		C.2	38.1	3.68	5.93	.056	7bc			5.30	2.60	26.4	44.0	3.34	12.10	18.67
		C.3	29.1	2.81	8.74	.084	7b			5.2	1.06	8.3	52.3	1.95	5.43	24.10
		C.4	17.3	1.67	10.41	.112	7C			4.65	.59	2.7	55.0	1.38	2.28	26.38
		C.5	15.3	1.48	11.89	.140	4C			4.65	.35	1.3	56.3	1.01	1.43	27.81
		Tails	912.8	88.05							.18	43.7		.83	72.20	
26	TERPINEOL	C.1	19.1	1.88	1.88	.028	5b		.67	7.96	1.16	5.8	5.8	1.88	3.3	3.3
		C.2	35.4	3.48	5.36	.056	7b			7.94	1.97	18.5	24.3	1.72	5.6	8.9
		C.3	21.7	2.14	7.50	.084	7bc			7.69	1.79	10.3	34.6	1.52	3.0	11.9
		C.4	9.8	.96	8.46	.112	7bc			7.45	.95	2.4	37.0	1.41	1.3	13.2
		C.5	8.3	.82	9.28	.140	7bc			7.43	.71	1.6	38.6	1.32	1.0	14.2
		Tails	932.8	91.70							.25	61.5		1.01	86.0	
27	5 PINE OIL	C.1	35.4	3.5	3.5	.028	6b			7.26	1.73	19.1	19.1	1.81	5.3	5.3
		C.2	12.3	1.2	4.7	.056	7ab			7.37	3.18	12.2	31.3	1.83	1.8	7.1
		C.3	19.0	1.9	6.6	.084	7b			7.46	1.61	9.8	41.1	1.56	2.6	9.6
		C.4	9.4	.9	7.5	.112	7b			7.40	.87	2.5	43.6	1.41	1.1	10.7
		C.5	16.8	1.6	9.1	.140	7b			7.44	.84	6	44.2	1.36	1.9	12.6
		Tails	924.7	91.1							.19	55.5		1.14	87.2	
28	5 PINE OIL	C.1	36.8	3.5	3.5	.028	6b	50		5.59	3.51	39.7	39.7	3.22	9.6	9.6
		C.2	47.4	4.5	8.0	.056	6b			4.41	1.39	20.1	59.8	3.02	11.4	21.0
		C.3														
		C.4	10.9	1.0	9.0	.112	6b			4.34	.36	1.2	61.0	1.21	1.0	22.0
		C.5	20.0	1.9	10.9	.140	6bc			4.34	.28	1.8	62.8	.83	1.0	23.0
		Tails	940.8	89.2							.13	37.2		1.02	76.6	
29	5 PINE OIL	C.1	37.2	3.6	3.6	.028	6ab		1.11	4.92	3.16	34.5	34.5	3.44	10.1	10.1
		C.2	31.5	3.1	6.7	.056	7b			9.51	1.56	14.4	48.9	3.88	9.6	19.7
		C.3	54.3	5.3	12.0	.084	7b			9.10	.62	10.0	58.9	2.64	11.3	31.0
		C.4	13.9	1.3	13.3	.112	7b			8.5	.39	1.5	60.4	1.18	1.3	32.3
		C.5	10.8	1.1	14.4	.140	7b			8.41	.46	1.5	61.9	1.15	.9	33.2
		Tails	861.7	85.4							.15	38.0		.97	66.7	
30	A.	C.1	28.3	2.8	2.8	.039	5bc			7.56	1.87	14.8	14.8	1.95	4.62	4.6
		C.2	25.4	2.5	5.3	.078	5ab			7.20	2.07	14.8	29.6	1.97	4.2	8.8
		C.3	11.8	1.2	6.5	.117	4b			7.30	.99	3.3	32.9	1.34	1.3	10.1
		C.4	7.9	.8	7.3	.156	3ab			7.27	.90	2.0	34.9	1.31	.8	10.9
		C.5	9.7	9	8.2	.195	2ab			7.44	.87	2.2	37.1	1.29	1.0	11.9
		Tails	936.5	91.9							.24	62.8		1.15	87.4	
31	A.	C.1	92.0	9.2	9.2	.039	5ab		.89	10.59	2.40	70.5	70.5	4.77	40.0	40.0
		C.2	11.9	1.2	10.4	.078	5ab			9.40	.71	7.5	73.0	1.65	1.8	41.8
		C.3	18.9	1.9	12.3	.117	5a				.43	2.5	75.5	1.25	2.2	44.0
		C.4	14.4	1.4	13.7	.156	4ab			8.75	.38	1.6	77.1	.96	1.3	45.3
		C.5	7.2	.7	14.4	.195	4ab			8.68	.46	1.0	78.1	.99	.6	45.9
		Tails	859.1	85.9							.08	21.9		.73	54.1	
32	A.	C.1	120.2	11.3	11.3	.039	1a	50		1.76	1.67	49.4	49.4	3.65	50.5	50.5
		C.2	176.9	16.6	27.9	.078	4b			1.99	.68	29.5	78.9	1.88	38.2	88.7
		C.3	34.5	3.7	31.6	.117	2b			2.20	.32	3.2	82.1	.93	4.3	93.0
		C.4	27.3	2.5	34.1	.156	1b			2.20	.37	2.5	84.6	.56	1.7	94.7
		C.6	10.6	1.0	35.1	.196	4b	25		2.09	.32	.7	85.3	.47	.6	95.3
		Tails	688.5	64.7							.09	14.8		.06	4.8	

SHEET No 2

TEST	REAGENT	PRODUCT	WEIGHT OF PRODUCT GMS	PERCENT OF TOTAL WEIGHT %	CUMULATIVE % OF WEIGHT %	WEIGHT OF REAGENT gms	CONDITION OF FROTH	PH CONTROL H2SO4 1:2 cc	PH CONTROL NaOH gms	PH CONTROL P.H.	COPPER ASSAY %	COPPER RECOVERY %	COPPER CUMULATIVE RECOVERY	NICKEL ASSAY %	NICKEL RECOVERY %	NICKEL CUMULATIVE RECOVERY
33	F.	C.1	26.0	2.5	2.5	.012	7C			7.09	328	23.2	23.2	1.92	4.0	4.0
		C.2	21.6	2.1	4.6	.024	7C			7.22	1.41	8.3	31.5	1.77	3.0	7.0
		C.3	12.8	1.2	5.8	.036	7C			7.40	.93	3.3	34.8	1.51	1.5	8.5
		C.4	8.7	.9	6.7	.048	6C			7.53	.99	2.5	37.3	1.30	.9	9.4
		C.5	6.5	.6	7.3	.060	6C			7.5	1.82	3.3	40.6	.89	.5	9.9
		Tails	950.0	93.0							.24	59.6		1.19	90.1	
34	F.	C.1	134.5	13.0	13.0	.012	7b		III	11.0	1.77	61.8	61.8	2.68	37.6	37.6
		C.2	23.0	2.2	15.2	.024	6b			9.84	1.51	9.1	70.9	2.67	6.3	43.9
		C.3	14.2	1.4	16.6	.036	6b			9.20	.78	2.8	73.7	1.27	1.9	45.8
		C.4	14.0	1.4	18.0	.048	6b			8.75	.83	3.1	76.8	.93	1.3	47.1
		C.5	8.0	.8	18.8	.060	5b			8.79	.68	1.3	78.1	.87	.7	47.8
		Tails	839.8	81.2							.10	21.8		.60	52.4	
35	F.	C.1	280.6	27.2	27.2	.012	7ab	50		1.6	1.03	82.3	82.3	3.68	93.0	93.0
		C.2	79.5	7.7	34.9	.024	7bc			2.2	.24	5.4	87.7	.67	4.8	97.8
		C.3	48.9	4.7	39.6	.036	7bc			2.7	.26	3.7	91.4	.28	1.3	99.1
		C.4	15.2	1.5	41.1	.048	7C			3.65	.29	1.1	92.5	.12	.2	99.3
		C.5	5.5	.5	41.6	.060	6C			4.15	.41	.6	93.1	.12	.1	99.4
		Tails	600.3	58.2							.04	6.9		.016	.8	
36	G.	C.1	65.9	6.5	6.5	.0115	7dv			7.30	2.60	53.7	53.7	2.67	14.7	14.7
		C.2	43.3	4.2	10.7	.023	7dv			7.35	1.10	15.1	68.1	2.61	9.5	24.2
		C.3	21.4	2.1	12.8	.0345	7CV			7.53	.59	4.7	72.8	1.85	3.3	27.5
		C.4	11.0	1.1	13.9	.046	7DCV			7.62	.78	2.8	75.6	1.32	1.3	28.8
		C.5	11.9	1.1	15.0	.0575	6QV			7.69	64	2.5	78.1	1.38	1.3	30.1
		Tails	879.8	85.1							.08	21.9		.95	69.8	
37	G.	C.1	211.1	21.1	21.1	.0115	4bv		2.22	12.27	1.01	66.2	66.2	3.75	82.6	82.6
		C.2	69.3	6.9	28.0	.023	7CV			12.37	.49	11.1	77.3	.85	6.2	88.8
		C.3	12.5	1.3	29.3	.0345	3bv			10.53	.45	1.9	79.2	.16	.2	89.0
		C.4	12.3	1.2	30.5	.046	3bv			9.86	.22	.9	80.1	.08	.1	89.1
		C.5	8.0	.8	31.3	.0575	2qbv			9.54	.50	1.2	81.3	.09	.1	89.2
		Tails	694.6	69.4							.09	19.3		.15	10.9	
38	G.	C.1	105.6	9.9	9.9	.0115	6CV	50		3.69	1.21	55.2	55.2	5.37	56.5	56.5
		C.1a	46.3	4.3	14.2					4.46	.45	9.1	64.3	2.47	11.3	67.8
		C.2	66.6	6.2	20.4	.023	6CV			4.50	.40	11.7	76.0	1.40	9.3	78.1
		C.3	20.6	1.9	22.3	.0345	6qb			4.70	.30	2.6	78.6	.67	1.4	78.5
		C.4	22.4	2.1	24.4	.046	7qb			4.72	.40	3.9	82.5	.62	1.4	79.9
		C.5	4.3	1.3	25.7	.0575	6bc			4.70	.67	3.5	86.0	.24	.3	80.2
		Tails	741.3	72.3							.04	13.9		.25	19.7	
39	I.	C.1	11.4	1.1	1.1	.009	2bx			6.85	.45	2.38	2.38	1.05	1.27	1.27
		C.2	7.3	.7	1.8	.018	2bx			7.8	2.51	8.6	10.98	1.08	.85	2.12
		C.3	12.4	1.2	3.0	.027	3bx			7.92	2.52	14.7	25.68	1.32	1.70	3.82
		C.4	8.2	.8	3.8	.036	2bx			8.18	1.49	5.7	31.38	1.10	.95	4.77
		C.5	4.1	.40	7.8	.045	2bx			7.86	2.27	4.3	35.68	1.12	.53	5.30
		Tails	969.2	96.0							.14	64.8		.92	94.6	
40	I.	C.1	86.6	8.4	8.4	.009	5qbx		2.22	12.3	1.92	63.3	63.3	4.65	48.7	48.7
		C.2	38.3	3.7	12.1	.018	7bv			11.2	.43	6.1	69.4	4.23	19.6	68.3
		C.3	24.7	2.4	14.5	.027	6bx			10.5	.32	3.1	72.5	2.50	7.5	75.8
		C.4	9.8	1.0	15.5	.036	6CV			9.91	.49	1.9	74.4	.77	.9	76.7
		C.5	7.7	.7	16.2	.045	6bcv			9.52	.59	1.9	76.3	.46	.4	77.1
		Tails	859.3	83.7							.07	23.7		.22	22.8	
41	I.	1141	114.1	11.0	11.0	.009	6CV	50		2.32	1.43	61.1	61.1	6.03	64.6	64.6
		C.1a	83.0	8.9	19.9					2.64	.52	18.0	79.1	2.21	20.7	90.3
		C.2	34.7	3.3	23.2	.018	6CV			3.0	.34	4.5	83.6	1.01	3.5	93.8
		C.3	16.0	1.5	24.7	.027	6CV			3.65	.26	1.5	85.1	.54	.9	94.7
		C.4	32.7	3.1	27.8	.036	7CV			4.32	.22	2.6	87.7	.22	.7	95.4
		C.5	13.3	1.3	29.1	.045	6CV			4.35	.38	1.5	89.2	.18	.2	95.6
		Tails	737.1	70.8							.04	10.9		.06	4.3	
42	J.	C.1	14.3	1.4	1.4	.006	3qx			7.42	2.35	12.8	12.8	1.99	2.9	2.9
		C.2	18.0	1.8	3.2	.012	3qx			1.5	1.92	13.2	26.0	1.62	3.1	6.0
		C.3	10.0	1.0	4.2	.018	3qx			7.5	1.42	5.3	31.3	1.61	1.7	7.7
		C.4	5.5	.5	4.7	.024	3qx			7.33	.33	.8	32.1	1.18	.6	8.3
		C.5	10.7	1.0	5.7	.030	4qx			7.32	.57	2.3	34.3	.97	1.1	9.4
		Tails	970.1	94.3							.18	65.7		.89	90.6	
43	J.	C.1	30.2	3.0	3.0	.006	3qx		2.22	10.67	4.18	45.7	45.7	3.22	11.6	11.6
		C.2	26.3	2.6	5.6	.012	4qx			10.17	.78	7.6	53.3	3.97	12.4	24.0
		C.3	9.0	.9	6.5	.018	4qx			9.7	.79	2.5	55.8	2.64	2.8	26.8
		C.4	11.0	1.1	7.6	.024	4qx			9.4	.43	1.8	57.6	.90	1.2	28.0
		C.5	14.3	1.4	9.0	.030	4qx			9.35	.46	2.5	60.1	.65	1.1	29.1
		Tails	914.4	91.4							.12	39.9		.65	70.9	
44	J.	C.1	31.3	2.9	2.9	.006	7bx	50		5.98	3.15	32.4	32.4	7.03	22.8	22.8
		C.2	49.8	4.7	7.6	.012	6bx			9.18	1.79	29.1	61.5	4.08	21.1	43.9
		C.3	43.4	4.1	11.7	.018	6bx			9.67	1.31	18.6	80.1	1.67	7.5	51.4
		C.4	13.8	1.3	13.0	.024	6bx			9.67	.54	2.3	82.4	.64	.9	52.3
		C.5	14.5	1.4	14.4	.036	6bx			9.83	.62	2.9	85.3	.35	.5	52.8
		Tails	910.1	85.5							.05	14.6		.50	47.2	

SHEET Nº 3

TEST	REAGENT	PRODUCT	WEIGHT OF PRODUCT gms	PERCENT OF TOTAL WEIGHT %	CUMULATIVE % OF WEIGHT %	WEIGHT OF REAGENT gms	CONDITION OF FROTH	pH CONTROL H2SO4 1:2 c.c	pH CONTROL NaOH gms	pH	COPPER ASSAY %	COPPER RECOVERY %	COPPER CUMULATIVE RECOVERY	NICKEL ASSAY %	NICKEL RECOVERY %	NICKEL CUMULATIVE RECOVERY
48	P.	C.1	143	2.9	2.9	.004	3a			7.25	.76	6.4	8.7	1.24	3.8	3.8
		C.2	414	4.2	7.1	.008	4ax			7.26	1.82	29.1	37.5	1.83	8.1	11.9
		C.3	242	2.9	10.0	.012	4ax			7.26	.68	7.7	45.2	.93	2.9	14.8
		C.4	340	3.4	13.4	.016	5abx			7.35	.46	6.1	51.3	.97	3.5	18.3
		C.5	240	2.4	15.8	.020	5abx			7.80	.31	2.7	54.0	.81	2.0	20.3
		Tails	8567	84.3							.14	46.0		.88	79.7	
49	P.	C.1	844	8.4	8.4	.004	5ax		2.22	9.85	2.17	71.0	71.0	5.45	49.0	49.0
		C.2	533	5.3	13.7	.008	6b			9.63	.31	6.6	77.6	2.74	15.5	64.5
		C.3	275	2.7	16.4	.012	6b			9.43	.25	2.7	80.3	1.32	3.8	68.3
		C.4	117	1.2	17.6	.016	6b			9.17	.31	1.6	81.9	.47	.5	68.8
		C.5	211	2.1	19.7	.020	6b			9.03	.30	2.3	84.2	.32	.7	69.5
		Tails	8189	80.7						8.96	.05	15.9		.35	30.4	
50	P.	C.1	198.1	19.1	19.1	.004	7dv	50		3.16	1.13	85.3	85.3	4.69	93.8	93.8
		C.2	258	2.5	21.6	.008	6dx			3.18	.24	2.3	87.6	.55	1.4	95.2
		C.3	230	2.2	23.8	.012	6dv			3.22	.13	1.1	88.7	.18	.4	95.6
		C.4	228	2.2	26.0	.016	6dx			3.37	.16	1.5	90.2	.12	.3	95.9
		C.5	218	2.1	28.1	.020	6dx			3.37	.20	1.5	91.7	.12	.3	96.2
		Tails	7465	71.8						3.35	.03	8.36		.05	3.73	
51	Q.	C.1	29.9	3.0	3.0	.004	4ax			6.31	1.61	17.1	17.1	1.33	4.9	4.9
		C.2	35.9	3.5	6.5	.008	5ax			7.01	1.57	20.0	37.1	1.23	5.3	10.2
		C.3	31.4	3.1	9.6	.012	5ax			7.08	.51	5.7	42.8	.94	3.5	13.7
		C.4	18.3	1.8	11.4	.016	5ax			7.27	.29	1.8	44.6	.91	2.1	15.8
		C.5	20.8	2.1	13.5	.020	5ax			7.36	.28	2.1	46.7	.89	2.3	18.1
		Tails	875.1	86.6						7.40	.17	53.2		.77	81.9	
52	R.	C.1	21.8	2.1	2.1	.005	30bx			8.65	2.39	22.1	22.1	2.02	4.9	4.9
		C.2	15.6	1.5	3.6	.010	40x			8.60	2.70	17.9	40.0	1.91	3.3	8.2
		C.3	11.9	1.1	4.7	.015	50v			8.54	1.51	7.2	47.2	1.72	2.1	10.3
		C.4	12.3	1.2	5.9	.020	7av			8.40	.65	3.4	50.6	1.17	1.5	11.8
		C.5	12.5	1.2	7.1	.025	7bv			8.36	.15	.8	51.4	.86	1.2	13.0
		Tails	949.7	92.6							.12	48.6		.83	86.8	
53	S.	C.1	14.4	1.4	1.4	.005	2bx			8.67	5.35	32.0	32.0	3.20	5.1	5.1
		C.2	20.4	2.0	3.4	.010	2bx			8.67	2.69	22.8	54.8	4.49	10.2	15.3
		C.3	21.4	2.1	5.5	.015	30bx			8.38	.58	5.0	54.8	2.50	6.0	21.3
		C.4	15.4	1.5	7.0	.020	40x			8.25	.63	4.1	63.9	1.99	3.4	24.7
		C.5	10.2	1.0	8.0	.025	30x			7.87	.35	1.7	65.6	1.03	1.2	25.9
		Tails	920.8	92.1							.09	34.4		.72	74.1	
54	Z.	C.1	25.0	2.5	2.5	.005	30x			7.85	3.36	33.0	33.0	2.58	7.4	7.4
		C.2	19.4	1.9	4.4	.010	30x			7.85	1.48	11.4	44.4	2.10	4.6	12.0
		C.3	30.8	3.1	7.5	.015	20x			7.95	.39	4.7	49.1	1.22	4.3	16.3
		C.4	21.6	2.1	9.6	.020	30x			7.97	.39	2.8	51.9	.91	2.3	18.6
		C.5	18.5	1.8	11.4	.025	40x			7.97	.27	2.0	53.9	.79	1.6	20.2
		Tails	898.3	88.6						8.05	.13	46.1		.79	79.9	

CONDITION of FROTH

Depth of Froth

"1 – Few bubbles near lip.
"2 – $\frac{1}{4}$" layer
"3 – $\frac{1}{4}$"-$\frac{1}{2}$" Layer
"4 – $\frac{1}{2}$"-$\frac{3}{4}$" Layer
"5 – $\frac{3}{4}$"-1$\frac{1}{2}$" Layer
"6 – 1$\frac{1}{2}$"-2$\frac{1}{2}$" Layer
"7 – 2$\frac{1}{2}$" and overflowing

Size of Bubbles

a – $\frac{3}{8}$" or over
b – $\frac{3}{8}$"-$\frac{1}{8}$"
c – $\frac{1}{8}$"-$\frac{1}{16}$"
d – Very fine.

Strength & lasting power of bubbles

T – tough – Lasts till pan is put in oven
U – Lasts till all froth reaches pan.
X – Brittle – bursts while overflowing.