

ON THE DEVELOPMENT OF AN EFFICIENT CHARCOAL
FOR THE PRECIPITATION OF GOLD AND SILVER
FROM THEIR CYANIDE SOLUTIONS

A THESIS

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FOREWORD

The results embodied in this thesis were obtained from work done at the Rare and Precious Metals Station of the United States Bureau of Mines and are incorporated in this report with the permission of the Director of the United States Bureau of Mines.

The writer is greatly indebted to Mr. John Gross, Metallurgist, U. S. Bureau of Mines, for the use of results of tests which he conducted jointly with the writer, and in addition, for many valuable suggestions given the author thraout the writing of the manuscript.

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ON THE DEVELOPMENT OF AN EFFICIENT CHARCOAL
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INTRODUCTION.

That charcoal has the property of precipitating certain metals from their solutions is no new discovery. John Percy (1)* mentions the work done in this connection as early as 1848 by Lasowski and he also gives some results of his own experiments made in 1859, when he precipitated silver from a silver nitrate solution. T. K. Rose (2) gives Percy the credit of being the first to obtain gold from a gold chloride solution since Percy succeeded in obtaining metallic gold on charcoal from gold chloride in 1869.

The first commercial use of the precipitating power of charcoal was in 1880 when W. M. Davis used charcoal to precipitate gold in connection with the chlorination process in a chlorination plant in Carolina. The use of charcoal in chlorination did not become very widespread tho it was successfully used at the Mount Morgan Mine, Queensland, Australia.

As the cyanide process began to replace the chlorination process it was only natural that charcoal should be given a trial as the precipitant of the precious metals from the cyanide solution, especially since the success of the cyanide process itself depended largely upon the finding of a suitable precipitant. Consequently, in July, 1894, Dr. W. D. Johnston of San Francisco, California, was granted U. S. Patent number 522,260 for the precipitation of gold and silver from their cyanide solutions by charcoal.

Except in special instances charcoal precipitation was not accepted. Shortly after Johnston obtained his patent it was, however, installed at the South German Mine, Malden, Victoria, Australia, and was successfully operated for several years. Donald Clark (3) has written a more or less detailed account of operations there. While these operations at Victoria showed that charcoal would do the work, it was not an efficient competitor of zinc because of its bulkiness and consequently practically all cyanide plants favored the zinc

* Numbers in parentheses refer to bibliography at end of article.

precipitation with the result that charcoal precipitation never became very important.

During the decade previous to 1911 very little, if any, interest was manifested in charcoal precipitation from cyanide solutions. It was about this time, tho, that certain graphitic schists and other carboniferous ores began to present treatment difficulties by premature precipitation. It was because of these difficulties that cyanide metallurgists began to study the effect of carbon in its various forms on cyanide solutions containing gold and silver. Much literature (4) has been published in this connection and the general conclusion drawn is that carbon is a deleterious constituent of ores to be cyanided.

Up to this time no one had studied the problem of charcoal precipitation from cyanide solution systematically to get at the underlying cause for the precipitation and to determine the mechanism of the precipitation. There were various theories propounded at various times but no definite results had been obtained in support of any one theory. Morris Green (5) in 1913 undertook to determine the nature of the precipitating action and finally arrived at the conclusion that the action was due to the occluded carbon monoxide gas contained in the pores of the charcoal. W. R. Feldtmann (6) then advanced another theory in which he stated the compound formed during charcoal precipitation was probably a carbonyl of the problematical formula $AcCyCOOy$. O. C. Halston (7) favored the idea that the action was an adsorption with a subsequent chemical change. Still others held to the older theory that the action was an electrical one but this theory was indeed extremely vague.

Considering the known facts attending all the above theories, A. W. Allen (8) conceived the idea that the charcoal caused the removal of the gold from a cyanide solution by the simple adsorption of the potassium-aurocyanide molecule by the charcoal. As proof of this theory he gives the straight line adsorption isotherm* using

* This isotherm has been obtained incorrectly since Allen plots the logs of amounts of metal adsorbed against the logs of amounts of gold in solution at beginning of test. Correct adsorption isotherms are obtained only by plotting the logs of amounts of metal adsorbed against the logs of amounts of metal left in solution at end of test, when adsorbed metal is in equilibrium with metal left in solution. That Allen obtained a straight line is an accident but it can be explained by the fact that Feldtmann's tests did not come to equilibrium in the time given.

data obtained by Feldtmann.

John Gross and J. Walter Scott (9) have recently confirmed Allen's conclusions in extensive experiments conducted at the Rare and Precious Metals Station of the U. S. Bureau of Mines. They show that the straight line adsorption isotherm is obtained and give other reasons* strengthening the simple theory of the adsorption of the potassium-aurocyanide molecule by the charcoal. Tests using silver as well as gold were also made and these results show that silver acts in the same manner as gold. It would seem that the simple adsorption theory offers the easiest explanation for the precipitation of gold and silver from cyanide solution by charcoal.

About 1917, during the World War, the cost of zinc precipitation at the Yuanni Mine, West Australia, became so excessive due to the high initial cost and the scarcity of zinc that K. Byron Moore and H. R. Edmonds developed and installed an improved charcoal precipitation scheme to take the place of the zinc precipitation. (10) It will be noted from reference (3) that the old Victorian method was very crude and particularly that they made use of only the coarse charcoal. The patent** granted to Moore and Edmonds embodied the ideas of stage filtration and fine grinding, the latter being a distinct contribution to charcoal precipitation practice. The charcoal "dust" was used in filter presses and upon becoming loaded to a figure of around 770 ounces gold per ton of charcoal, was burned. This Moore-Edmonds process merits consideration and represents the best-developed method of charcoal precipitation from cyanide solutions today.

In even this improved scheme there exist two conspicuous difficulties one or both of which must be overcome before charcoal precipitation can compete with zinc precipitation. The first of these is the large amount of charcoal necessary to precipitate a small amount of precious metal; the second is the difficulty of obtaining the precious metal in the form of bullion after its precipitation on charcoal.

It should probably be stated at this point that the writer

- * One characteristic of charcoal precipitation of gold and silver from cyanide solution is that the gold and silver are obtained on the charcoal in a form which is non-metallic and which is invisible even under the microscope.

** Australian Patent number 566.17

does not think charcoal precipitation will ever entirely compete with zinc precipitation but if either of the above difficulties can be overcome there will be a field opened for charcoal precipitation where zinc precipitation is being used at present simply for want of some slightly better or easier method; for examples, the precipitation of extremely low-grade waste solutions, the precipitation of foul solutions, and the precipitation of solutions at extremely isolated camps where zinc is scarce but where plenty of wood is available.

The remedies for the above two difficulties are respectively as follows:

1. Finding a "super"* charcoal which by virtue of its method of preparation or subsequent treatment would be capable of an extremely high precipitating efficiency as regards both rate and capacity;
2. Finding a method for the easy removal of the precious metal from the charcoal, leaving the charcoal unimpaired for its re-use as a precipitant.

This paper is intended to present results of tests conducted toward effecting remedy number one - the development of a "super"-charcoal. These results are presented under five headings:

1. VARIOUS FORMS OF CHARCOAL - OR CARBON;
2. CHARCOALS MADE FROM VARIOUS WOODS;
3. PRE-TREATED CHARCOALS;
4. CHEMICALLY TREATED CHARCOALS;
5. ACTIVATED AND OTHER INDUSTRIAL CHARCOALS.

* A term suggested by Mr. Balston, Assistant Chief Metallurgist of the U. S. Bureau of Mines.

TERMS AND ABBREVIATIONS DEFINED

- Activated** - so treated that the rate (and) (or) capacity is increased.
- Activity** - used synonymously with "rate", q.v.
- Capacity** - used synonymously with "load", q.v.
- Carbonisation** - making charcoal by gently heating raw material at a dull red heat until all volatile hydrocarbons have been driven off, then increasing the heat to about 1000° C. and holding this temperature for ten minutes. Operation conducted in a closed crucible.
- Charring** - used synonymously with "carbonization", q.v.
- D** - dried.
- Load** - the ultimate capacity of a charcoal for gold or silver. Expressed in ounces precious metal per ton charcoal.
- P** - pulverized.
- Pulverized** - ground in a porcelain mortar, usually to -200 mesh.
- Q** - quenched.
- Quenched** - charcoal reheated to approximately 1000 C. for two or three minutes and immediately plunged in water. Operation conducted on lump charcoal unless otherwise specified.
- Quenched direct** - charcoal plunged in water while still red hot from carbonization of raw material.
- Rate** - the speed with which gold and silver are removed from solution by charcoal.

REQUIREMENTS OF A SUPER CHARCOAL

Perhaps a clearer understanding of the work to be accomplished can be obtained by first considering the requirements of a super charcoal. Enumerated, these are

1. A high load capacity.
2. A good rate of precipitation.
3. A fair degree of density.
4. A structure capable of withstanding any necessary pretreatment.

1. A High Load Capacity - Beyond a doubt, the most important requirement for the ordinary adaptation of charcoal precipitation is that the charcoal should have a high load capacity; that is, it should be capable of removing a large amount of gold and silver from cyanide solution per unit weight of charcoal. Just why some charcoals should be more capable of removing precious metals from solution than others is not really understood; the theory attending this question will be more fully discussed under the section on Activated and Other Industrial Charcoals, page 41. At this point suffice it to say that it is probably due to a "cleaning out" of the pores of the charcoal.

Load figures as given in the literature vary considerably and of course depend on conditions of the solution to be precipitated as well as on the charcoal itself. The figure obtained during the work at the Yuanmi Mine (10a) was 770 ounces gold per ton of charcoal. Very little data is available on silver load figures but Mr. Gross and the writer, in experiments conducted at the Rare and Precious Metals Station of the U. S. Bureau of Mines, have found that for a given charcoal the silver load value is 55.1% that of the gold load value; in other words, silver is practically twice as difficult to remove from its cyanide solution as gold.

Considering the load figure obtained at the Yuanmi Mine as being the average figure one could obtain with ordinary charcoals, what is meant by a high load capacity requirement of a super charcoal? While the answer is merely one of opinion, it seems that a super charcoal should be capable of precipitating at least around 3000 ounces gold, or the corresponding silver figure of 1650 ounces, per ton charcoal from an ordinary mill solution. A load figure of from 5000 to 10,000 ounces gold would probably better represent a super charcoal, and while this figure seems extraordinarily large as compared with

the Australian figure of 770 ounces gold, still it may not be impossible to find a charcoal which will accomplish this at present impossible feat since a load of 17,000 ounces gold per ton charcoal has recently been obtained from a gold chloride solution at the Bureau of Mines.

2. A Good Rate of Precipitation - It should be remembered in considering load values that these are values obtained by long contact of solution with charcoal; consequently, in order to have a truly efficient charcoal, it should be capable of loading to a high figure in a comparatively short time, or in other words, it should have a fair rate of precipitation.

During any commercial charcoal precipitation scheme it is highly improbable that it will be economically possible to allow a charcoal to be in contact with a solution until it is fully loaded. A counter-current precipitation scheme of course approximates ideal conditions but even then it is very probable that the charcoal will never be completely loaded. It is impossible to give even approximate figures as to the rate of precipitation. Ideally, however, the rate would be instantaneous; practically, the rate would have to be fast enough that the charcoal could become loaded to a suitable figure in the time during which it could be conveniently left in contact with the solution in the mill.

3. A Fair Degree of Density - Upon first thought it might seem that a good charcoal should possess some particular density but this is hardly the case, although of course there are limits either way. For example, a charcoal should not be so hard and dense that it is difficult to pulverize nor should it be so light and fluffy that it is difficult to wet or occupy too much volume per unit weight, thus necessitating excessive filter area. Fortunately the density requirement is in most cases automatically taken care of since it is the exceptional charcoal that is either extremely light or extremely heavy.

4. A Structure Capable of Withstanding any Necessary Pretreatment - That the charcoal should lend itself readily to any pretreatment necessary is a requirement which needs no further comment.

In addition to the above requirements it is obvious that there should be a supply of raw material readily available, and that the process of charcoal manufacture should not be too complicated. These are requirements which are not peculiar to a super charcoal but which are common to any charcoal intended for precipitation purposes.

METHOD OF TESTING

The efficiency of a charcoal as a precipitant for gold and silver from cyanide solutions depends primarily upon its capacity, or load value, and secondarily upon its activity, or rate of precipitation. Consequently, tests were made on the various charcoals to obtain values on these two characteristics.

The data on the standard tests employed are as follows:

Loading Tests - - - - - 100 cc solution, containing
15 mgm gold (or 8 mgm silver),
no free cyanide or alkalinity.
200 mgm charcoal, -200 mesh.
48 hours contact.
Intermittent agitation.
Room temperature.

Rate of Precipitation Tests - 100 cc solution, containing
6 mgm silver (or 4 mgm gold),
no free cyanide or alkalinity.
400 mgm charcoal, -200 mesh, for silver tests
200 mgm charcoal, -200 mesh, for gold tests
30 minutes contact.
Intermittent agitation.
Room temperature.

It will be noticed that the differences in the two tests are that the loading tests contained more gold (or silver), less charcoal, and were allowed longer time of contact, than the rate of precipitation tests. The gold and silver content figures are given only approximately as they varied considerably in different series of tests; the charcoal, however, was always accurately weighed.

It will be noticed in some of the following series of tests that only a gold loading and a silver rate of precipitation tests was made. This is true of those tests made during the latter part of the work. After the work had been started, by plotting results of numerous tests it was found that a gold load figure was always an indication of the silver load figure; that is, that a charcoal having a low (or high) capacity for gold would also have a low (or high) capacity for silver. It was also found that the rate of precipitation of the silver was also a measure of the rate of precipitation of the gold. It did not follow, however, that a high capacity meant a high activity, or vice versa; in fact, there seemed to be no direct and constant relation between capacity and activity.

From the results of these conclusions it was evident that the capacity of a charcoal could be obtained by a gold loading test and the activity of the charcoal by a silver precipitation test. The gold load test was chosen since it gives higher load figures than the silver and is therefore more accurate relatively. The silver rate of precipitation test was chosen since silver is slower in precipitation than gold and therefore does not approach a "clean-up" of the solution so quickly. Naturally, a clean-up - or 100% precipitation - over a series of tests would give no relative figures.

In the case of either a loading test or a rate of precipitation test, after the charcoal had been in contact with the solution the prescribed length of time the solution was filtered and washed with distilled water four times, the washings being caught with the solution. It was allowable to catch the washings with the solution since results have shown that very little, if any, of the adsorbed metal is removed from the charcoal by washing with cold water. Both charcoal and solution were assayed.

The charcoal plus the filter paper was placed in a ten-gram fireclay crucible and ignited at a low heat in an electric muffle. The residue from the ignition was fluxed with a charge consisting of 15 grams soda-ash, 5 grams silica, 1 gram borax-glass, 30 grams litharge, excess flour, and was fused. The resulting lead button was cupelled and the assay finished in the regular manner.

The solution containing the gold (or silver) was precipitated with zinc dust and hydrochloric or sulphuric acid, and filtered. The filter plus the precipitated metal was placed in a ten-gram fireclay crucible, ignited, fluxed, fused, and finished in the same manner as the charcoal.

I. VARIOUS FORMS OF CHARCOAL - OR CARBON.

Charcoal can be made from several substances and in several ways and any attempt toward producing a super-charcoal should include some work with at least the most promising charcoals - or carbons - made from substances other than wood.

Sharwood and Clark (11) give a list of substances supposed to possess the power of precipitating precious metals from cyanide solutions and among them are some forms of carbon. Morris Green (5) also gives a list of various precipitants.

A list of the various forms of carbon, together with their methods of preparation, which were tested in connection with this work follows:

Coal - This sample was a piece of ordinary King coal, a sub-bituminous coal from Utah. In one test the coal was simply dry-crushed to -200 mesh and used in that condition. The same coal carbonized was also tested. The carbonizing process consisted of the standard method given on page 6, the coal being carbonized at about 4 mesh size. Tests were made on two differently treated samples of the carbonized material - the first sample was simply dry-crushed to -200 mesh, and the second was quenched direct, pulverized, and dried.

Coke - Two tests were made on samples of coke differently treated. The first consisted of using the material obtained by dry-crushing the coke to -200 mesh. The second consisted of using material which had been quenched, pulverized, and dried.

Graphite - Dixon's "Hecenderoga No. 2" Flake graphite was dry-crushed to -200 mesh. This material was also quenched and tested.

Flour Charcoal - Charcoal was made from flour by the standard carbonization method given on page 6. Tests were made on the resulting charcoal simply dry-crushed and on the resulting charcoal after quenching direct.

Lampblack - This sample consisted of the ordinary commercial grade of lampblack. Tests were made on the material as received, and on the quenched material.

Puffed Rice Charcoal - Puffed Rice made by the Quaker Oats Company was carbonized by the standard method. Tests were made on both

the dry-crushed charcoal and the quenched and pulverized material.

In partial explanation of the seemingly absurd choice of materials used for making these various charcoals it might be mentioned that puffed rice was selected as a material from which an exceedingly porous charcoal might possibly be made. This idea proved erroneous, however, as during carbonization the material lost its strikingly evident porosity.

Sugar Charcoal - This charcoal was prepared by the standard method of carbonization. The resulting charcoal was tested both dry-crushed and quenched. The charcoals made from flour and sugar resemble each other very much in that they are heavy, dense, and hard.

Sugar charcoal has often been used in connection with work on adsorption as it represents a very pure form of carbon. No data was available as to its power of adsorbing precious metals from cyanide solutions; hence its selection in this series.

The results obtained on the above forms of carbon are tabulated below. In all cases standard tests were used.

RATE OF PRECIPITATION TESTS
VARIOUS FORMS OF CHARCOAL

Test	Charcoal	Mgm Silver in			% Pptn.
		Char	Soln	Total	
956	Coal dry-pulv *	0.06	6.12	6.18	1.0
957	" carbonized dry-pulv	1.48	4.72	6.20	23.9
958	" " Q direct P D	1.31	5.93	6.24	25.0
692	Coke dry-pulv	0.12	4.06	4.18	2.9
693	" Q P D	0.18	3.87	4.05	4.4
1098	Graphite dry-pulv	0.16	6.05	6.21	2.6
1099	" QQ P D	0.18	6.20	6.38	2.8
952	Flour charcoal dry-pulv	1.42	4.58	6.00	23.7
953	" " Q direct P D	1.22	5.00	6.22	19.6
954	Lampblack as received *	0.36	6.10	6.46	5.6
955	" Q D *	0.51	5.36	5.89	8.6
697	Puffed rice charcoal dry-pulv	1.42	2.59	4.01	25.4
698	" " " Q P D	1.79	2.21	4.00	44.8
950	Sugar charcoal dry-pulv	1.44	4.54	5.98	24.1
951	" " Q direct P D	1.36	4.60	5.96	22.8

* Very hard to wet.

**LOADING TESTS
VARIOUS FORMS OF CHARCOAL**

Test	Charcoal	Mgm Gold in			Load oz/ton
		Char	Soln	Total	
932	Coal dry-pulv *	0.10	11.57	11.67	15
933	" carbonized dry-pulv	4.65	7.19	11.84	678
934	" " Q direct P D	4.59	7.21	11.80	669
704	Coke dry-pulv	0.15	14.70	14.85	22
705	" Q P D	0.18	14.68	14.86	26
1074	Graphite dry-pulv	0.10	11.24	11.34	15
1075	" Q P D	0.08	11.28	11.36	12
928	Flour charcoal dry-pulv	4.60	7.26	11.86	671
929	" " Q direct P D	4.63	7.15	11.78	675
930	Lampblack as received *	0.16	11.34	11.52	26
931	" Q D *	0.61	11.25	11.86	69
709	Puffed rice charcoal dry-pulv	8.31	6.48	14.79	1212
710	" " " Q P D	9.61	5.18	14.79	1402
926	Sugar charcoal dry-pulv	4.37	7.48	11.85	637
927	" " Q direct P D	4.29	7.60	11.89	626

* Very hard to wet.

The conclusions drawn from this series of tests are:

1. None of these charcoals have exceptional precipitating power.
2. Puffed rice makes the best charcoal, the reason probably being at least in part to its high porosity.
3. Carbonized coal, flour charcoal, and sugar charcoal are at best only average precipitants.
4. Direct quenching is of no benefit to any of the charcoals listed under conclusion 3.

II. CHARCOALS MADE FROM VARIOUS WOODS.

What wood is the best charcoal made from? This certainly is a question worthy of a little study, and while the subject is not a new one by any means, still it deserves a place in an article of such a nature as this.

Mr. S. W. Smith (12) mentioned that he thought perhaps the wood from which the charcoal was made affected the precipitating power of the resulting charcoal. And his point may be well taken. At least we do know that woods vary considerably in cellular structure; some are exceedingly porous and some are exceedingly dense.

It is known to the chemists employed in charcoal de-colorizing work that the very fine capillaries so necessary for gas retention must be replaced by larger if the charcoal is to be successfully used for decolorizing, because of the larger molecular aggregates which must be dealt with in the decolorizing work (13). Reasoning along this line it would seem that perhaps the charcoals with the large capillaries, or those made from porous woods, would be the most efficient precipitants for gold and silver from cyanide solutions since the molecule adsorbed in this instance is rather large. This at least is a line of reasoning which could be used in justification for trying various woods. The writer does not commit himself as to the validity of the above hypothesis; he simply states it as a possible theory.

In making the comparative tests on different woods all the various obtainable woods were used but the list is not nearly as complete as desired. It was hoped to be able to obtain an exceptionally hard variety, such as ironwood, but there was none available. The woods listed, however, do range from soft to comparatively hard and consequently some idea of the variation of precipitating power with density can be obtained.

Both gold and silver rate of precipitation and gold and silver loading tests were made on most of these charcoals. Each charcoal was made from its respective wood by the method described under "Carbonization" in the previous list of definitions. Each charcoal was then quenched, pulverized, and dried and the tests were made on this product. No tests were made on the plain charcoal; that is, the charcoal not quenched.

The results of these tests follow:

RATE OF PRECIPITATION TESTS
CHARCOALS MADE FROM VARIOUS WOODS.

Test	Charcoal	Mgm Metal in			% Pptn.
		Char	Soln	Total	
481	Gold Pine Q P D	1.60	0.02	1.62	98.6
552	" Redwood Q P D	2.15	0.02	2.17	99.1
484	" Yellow Pine Q P D	1.51	0.02	1.53	98.7
486	" Hickory Q P D	1.46	0.03	1.49	98.0
485	" Walnut Q P D	1.51	0.04	1.55	97.4
679*	Silver Willow Q P D	3.60	0.41	4.01	89.6
487	" Pine Q P D	2.85	1.52	4.37	65.2
566	" Redwood Q P D	3.03	0.40	3.43	88.3
490	" Yellow Pine Q P D	2.82	0.61	3.43	82.2
492	" Hickory Q P D	3.17	0.48	3.65	86.6
491	" Walnut Q P D	3.64	0.22	3.86	94.3

* Standard test (400 mgm. charcoal); all others 500 mgm. charcoal.

LOADING TESTS
CHARCOALS MADE FROM VARIOUS WOODS.

Test	Charcoal	Mgm Metal in			Load oz/ton
		Char	Soln	Total	
483*	Gold Willow Q P D	10.59	4.31	14.90	1544
493	" Pine Q P D	10.00	7.77	17.77	1167
580	" Redwood Q P D	11.02	10.68	21.70	1265
496	" Yellow Pine Q P D	10.57	6.98	17.55	1233
498	" Hickory Q P D	11.12	6.73	17.85	1297
497	" Walnut Q P D	11.75	6.03	17.78	1371
499	Silver Pine Q P D	3.47	4.18	7.65	405
594	" Redwood Q P D	3.50	4.22	7.72	408
502	" Yellow Pine Q P D	3.84	3.46	7.30	448
504	" Hickory Q P D	4.18	3.23	7.41	488
503	" Walnut Q P D	4.42	3.06	7.48	518

* Standard test (200 mgm. charcoal); all others 250 mgm. charcoal

The conclusions to be drawn from the above tables are not very numerous. These tests do indicate the following general facts however:

1. The precipitating efficiency of a charcoal is practically independent of the kind of wood from which it is made.
2. There seems to be no direct relation between precipitating efficiency and density of wood.

In view of the preceding conclusions, the large majority of the following tests were made on pine since pine was the most easily obtainable wood.

III. PRE-TREATED CHARCOALS.

CARBONIZING AT DIFFERENT TEMPERATURES - In view of the fact that active carbon is presumably made at low temperatures while inactive carbon is made at high temperatures, tests were made on pine carbonized at 500°C, 700°C, 900°C, to observe the effect of the temperature of carbonization on the precipitating efficiency.

In each case the charcoal was dry-pulverized to -200 mesh after it had been made at its respective temperature. Standard test conditions were used in each case.

The results of these tests follow:

DATE OF PRECIPITATION TESTS DIFFERENT TEMPERATURES OF CARBONIZATION

Test	Charcoal	Mgm Silver in			% Pptn.
		Char	Soln	Total	
937	Pine charred 500°C dry-pulv	1.28	4.72	6.00	21.3
939	" " 700°C "	3.41	2.67	6.08	56.1
941	" " 900°C "	3.56	2.56	6.12	58.2

LOADING TESTS DIFFERENT TEMPERATURES OF CARBONIZATION

Test	Charcoal	Mgm Gold in			Load gr/ton
		Char	Soln	Total	
913	Pine charred 500°C dry-pulv	2.62	9.19	11.81	382
915	" " 700°C "	5.16	6.70	11.86	752
917	" " 900°C "	5.00	6.88	11.88	729

These tests show very clearly that charcoal formed at 500°C is not nearly as good as that formed at the higher temperatures. While this is in seeming contradiction to the Hydrocarbon Theory

* See Hydrocarbon Theory under chapter on "Activated and Other Industrial Charcoals".

it possibly shows that the most important point in making charcoal is to raise the heat to a point which is sufficient to break down the hydrocarbons adsorbed on the active carbon base. The fact remains, however, that high temperature is conducive to the formation of an efficient charcoal.

CARBONIZING FOR DIFFERENT LENGTHS OF TIME - When carbonizing a wood it will be noticed that the first result of heating is a volatilization of the light hydrocarbon constituents of the wood. It is customary to heat the wood only gently during this stage and then after all the gases have been driven off to increase the temperature to the full heat. The charcoals used in the following tests were made in two ways and will be designated by the letters A and B. Samples of both A and B were reheated after cooling from the initial carbonization for periods of 5, 15, and 30 minutes, and were then quenched, pulverized, dried, and tested by the standard tests.

Charcoal A was prepared by driving the gases from the wood in a closed crucible at a very low temperature - a dull red. After there was no further evolution of gas the heat was increased to 900°C and this temperature was maintained for ten minutes. The charcoal was then allowed to cool.

Charcoal B was prepared by driving the gases from the wood in a closed crucible at the high temperature of 900°C. This same temperature was maintained for ten minutes after all the gases had been driven off. The charcoal was then allowed to cool.

The results of these tests follow:

RATE OF PRECIPITATION TESTS
CARBONIZING FOR DIFFERENT LENGTHS OF TIME

Test	Charcoal	Mgs Silver in			% Ppta.	
		Char	Soln	Total		
1102	Char A reheat 900°C 5 min.	Q P D	3.92	2.11	6.03	65.0
1103	" " " " 15 "	Q P D	4.58	1.63	6.21	73.8
1104	" " " " 30 "	Q P D	4.89	1.22	6.11	80.0
1105	Char B reheat 900°C 5 min.	Q P D	3.80	2.17	5.97	63.7
1106	" " " " 15 "	Q P D	4.61	1.55	6.16	74.8
1107	" " " " 30 "	Q P D	5.18	0.90	6.08	85.2

LOADING TESTS
CARBONIZING FOR DIFFERENT LENGTHS OF TIME

Test	Charcoal	Mgm Gold in			Load oz/ton
		Char	Soln	Total	
1078	Char A reheat 900° C 5 min. Q P D	6.64	4.68	11.32	968
1079	" " " " 15 " Q P D	9.83	1.53	11.36	1433
1080	" " " " 30 " Q P D	11.09	0.27	11.36	1617
1081	Char B reheat 900° C 5 min. Q P D	6.94	4.40	11.34	1012
1082	" " " " 15 " Q P D	10.05	1.32	11.37	1466
1083	" " " " 30 " Q P D	11.09	0.29	11.38	1617

There are two definite conclusions to be drawn from these tests. They are:

1. It is not necessary to drive off gases at low temperatures; the full heat of 900° C may be applied from the first.
2. The efficiency of the charcoal increases with the time exposed to heat up to a period of thirty minutes at least.

QUENCHING - The subject of quenching is one which is of much importance and its value has just of late been realized. Quenching a charcoal consists of heating the charcoal to a given temperature - usually around 900° C.- and then plunging it in water. The action whereby a charcoal obtains a greater precipitating power by this treatment is probably one of a cleaning-out of the pores.

The subject of quenching is so large that it has been thought advisable to divide it. Consequently only a few tests have been included in this particular section but several comparisons of quenched and unquenched charcoals will be found in the following pages. A specialized branch of the subject - that of quenching in various chemical reagents - has been included under the chapter on "Chemically Pre-Treated Charcoals". Therefore, it should be remembered that the space given to this subject at this particular time is not at all indicative of the value of quenching.

An interesting series of tests follows which shows the effect of quenching charcoals from different temperatures. In this series charcoals carbonized at 500°C and 900°C were quenched at 500°C and 900°C. Standard tests were made. The results follow:

RATE OF PRECIPITATION TESTS
QUENCHING FROM DIFFERENT TEMPERATURES

Test	Charcoal	Mgm Silver in			Pctn.
		Char	Soln	Total	
943	Pine charred 500°; Q 500°; P D	1.08	5.27	6.35	17.0
944	" " 900°; Q 500°; P D	3.50	2.67	6.17	56.7
945	" " 500°; Q 900°; P D	3.71	2.48	6.19	60.0
946	" " 900°; Q 900°; P D	3.89	2.07	5.90	65.3

LOADING TESTS
QUENCHING FROM DIFFERENT TEMPERATURES

Test	Charcoal	Mgm Gold in			Load oz/ton
		Char	Soln	Total	
919	Pine charred 500°; Q 500°; P D	2.83	8.85	11.68	413
920	" " 900°; Q 500°; P D	5.42	6.44	11.86	790
921	" " 500°; Q 900°; P D	5.13	6.63	11.76	748
922	" " 900°; Q 900°; P D	5.54	6.30	11.84	808

These results show that the charcoal carbonized and quenched at low temperature is very inferior to that carbonized and quenched at high temperature. A study of the above figures seems to show that it is immaterial whether the charcoal is exposed to the higher temperature during carbonization or during quenching; the high temperature is necessary during one of these treatments, however.

The subject of quenching will be elaborated on by means of various comparisons later in the paper.

VARYING MESH OF CHARCOAL - As mentioned in the introduction, the Moore-Edwards process makes use of the finely divided charcoal because it was found that the finer charcoal possessed the greater precipitating power.

A screen test was made on a sample of the pine charcoal, quenched, pulverized, and dried, as used on the ordinary test. The screen analysis is given below.

SCREEN ANALYSIS OF PINE CHARCOAL, Q P D.

<u>Mesh</u>	<u>Weight in Grams</u>	<u>% Weight</u>
-50 + 70	2.49	24.4
-70 + 300	2.14	20.9
- 300	<u>5.58</u>	<u>54.7</u>
Total	10.21	100.0

Each of the products was then tested for its precipitating power by using it in both rate of precipitation and loading tests. In the rate of precipitation tests 0.5 gram charcoal was added to 100 ccs of a two-pound cyanide solution containing approximately one milligram gold or two milligrams silver; in the loading tests 0.25 gram charcoal was added to 100 ccs of a two-pound cyanide solution containing one pound lime per ton and approximately fifteen milligrams gold and or twenty-one milligrams silver. Thirty minutes contact was given in the rate tests while twenty-four hours contact was given in the loading tests. The results of these tests are tabulated below:

RATE OF PREDIPITATION TESTS
VARYING MESH CHARCOAL

Test	Mesh Charcoal	Mgm Metal in			% Pptn.
		Char	Soln	Total	
230	Gold + 70	0.96	0.27	1.23	78.0
231	" -70 + 300	1.20	0.02	1.22	98.4
232	" - 300	1.25	trace	1.25	100.0
233	Silver + 70	1.00	1.04	2.04	49.0
234	" -70 + 300	1.28	0.89	2.17	59.0
235	" - 300	1.61	0.23	2.04	66.7

LOADING TESTS
VARYING MESH CHARCOAL

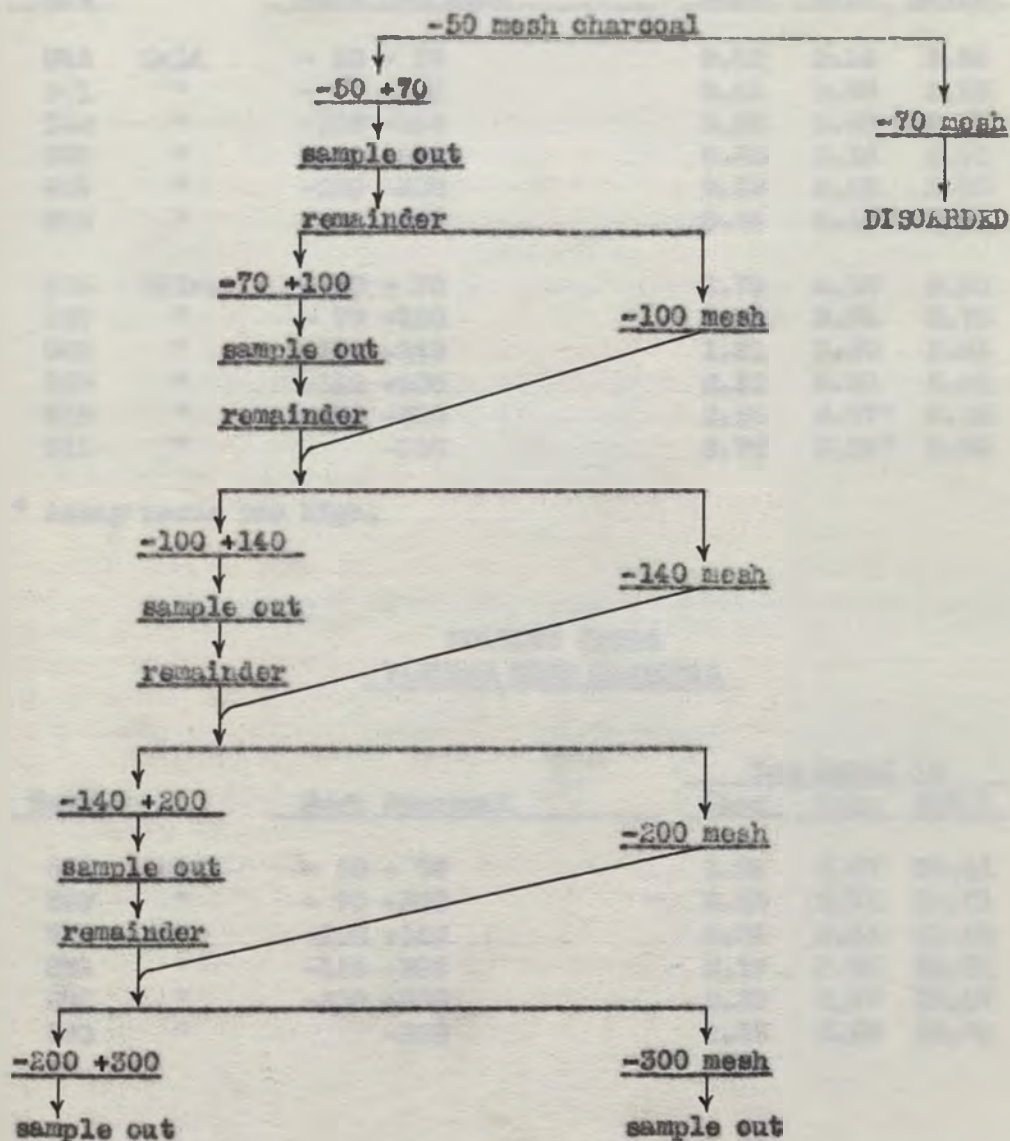
Test	Mesh Charcoal	Mgm Metal in			Load oz/ton
		Char	Soln	Total	
212	Gold + 70	7.38	8.08	15.46	861
213	" -70 + 300	7.91	7.61	15.52	923
214	" - 300	9.40	6.08	15.48	1097
215	Silver + 70	3.33	17.90	21.23	388
216	" -70 + 300	3.30	17.84	21.14	385
217	" - 300	4.38	16.68	21.06	511

It will be noticed that these tests show that the finer mesh sizes have both a faster rate and a larger capacity than the coarser mesh sizes.

Another test similar to the above was made later. It differed from the above in this respect however. In the above test the different meshes were obtained by the usual screen analysis method; that is, the sample was simply screened to the various sizes. In this ordinary screen analysis method it might be that the coarser mesh also represents a harder charcoal, or one which is really different in nature from the finer meshes. If this were true it is possible that it would not be a strict comparison of the efficiencies of the various sizes. The following test was made to eliminate this possible error.

In this experiment the ordinary quenched pine charcoal was used. After quenching it was wet-pulverized to -50 mesh and then dried. The different mesh charcoals were then prepared according to the following flowsheet, an examination of which will show that the sample of any mesh charcoal consists of exactly the same material as the sample of any other mesh charcoal.

PREPARATION OF DIFFERENT MESH CHARCOALS



Standard rate of precipitation and loading tests were then made on each of the samples taken from the various meshes. The results on these tests follow:

RATE OF PRECIPITATION TESTS
VARYING MESH CHARCOAL

Test	Mesh Charcoal	Mgm Metal in			% Pptn.
		Char	Soln	Total	
900	Gold - 50 + 70	0.42	2.24	2.66	15.8
901	" - 70 +100	0.42	2.33	2.75	15.3
902	" -100 +140	0.53	2.40	2.93	18.1
903	" -140 +200	0.53	2.18	2.71	19.6
904	" -200 +300	0.53	2.27	2.80	18.9
905	" -300	0.64	2.15	2.79	22.9
906	Silver - 50 + 70	1.75	4.10	5.85	29.9
907	" - 70 +100	1.81	3.94	5.75	31.1
908	" -100 +140	1.81	3.60	5.41	33.5
909	" -140 +200	2.32	3.32	5.64	41.1
910	" -200 +300	2.33	3.87*	6.20	37.6
911	" -300	2.79	3.54*	6.33	44.1

* Assay seems too high.

LOADING TESTS
VARYING MESH CHARCOAL

Test	Mesh Charcoal	Mgm Metal in			Load oz/ton
		Char	Soln	Total	
888	Gold - 50 + 70	1.94	8.47	10.41	283
889	" - 70 +100	2.00	8.71	10.71	292
890	" -100 +140	2.06	8.44	10.50	300
891	" -140 +200	2.19	8.62	10.81	319
892	" -200 +300	2.20	8.47	10.67	321
893	" -300	2.45	8.30	10.75	357

(Silver loading tests continued on following page).

LOADING TESTS
VARYING MESH CHARCOAL

<u>Test</u>		<u>Mesh Charcoal</u>	<u>Mgm Metal in</u>			<u>Load oz/ton</u>
			<u>Char</u>	<u>Soln</u>	<u>Total</u>	
894	Silver	- 50 + 70	3.77	3.74	7.51	550
895	"	- 70 +100	3.91	4.11	8.02	570
896	"	-100 +140	4.34	3.82	8.16	633
897	"	-140 +200	4.95	3.34	8.29	722
898	"	-200 +300	5.08	2.79	7.87	741
899	"	-300	5.62	2.46	8.08	820

The curves for this latter series of tests are shown in Figures I and II. In these curves the ordinates are the load figures, or the percentage precipitation as the case may be, while the abscissas are figures representing the ratios of surfaces exposed by grinding a unit volume of non-porous material to the different meshes. In the application of these ratios to these curves, the porosity of the charcoal has been ignored.

In explanation of the method by which these ratios were obtained, the following table is given. It should be remembered that the amount of surface exposed, neglecting porosity, varies as the square of the diameter of the particle.

OBTAINING SURFACE RATIOS PER UNIT VOLUME - IGNORING POROSITY.

<u>Mesh</u>	<u>Size Opening mm.</u>	<u>Ratios Mesh/Mesh</u>	<u>Surface Ratios Per Unit Volume</u>
- 50 + 70	0.300	6.0	1
- 70 +100	0.210	4.2	2
-100 +140	0.149	3.0	4
-140 +200	0.105	2.0	9
-200 +300	0.074	1.5	16
-300	0.050	1.0	36

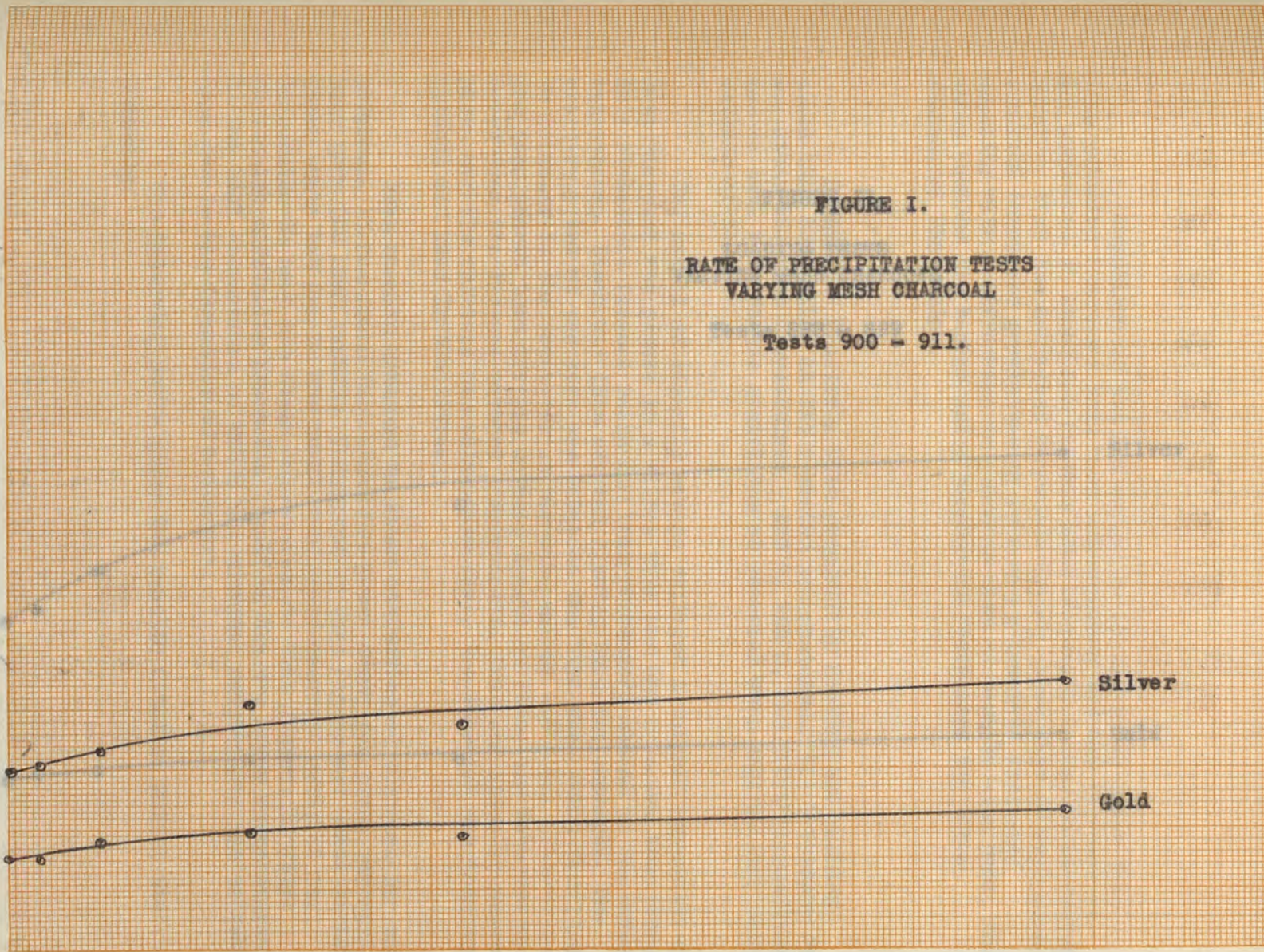
%
Precipitation

FIGURE 1.

RATE OF PRECIPITATION TESTS
VARYING MESH CHARCOAL

Tests 900 - 911.

100
90
80
70
60
50
40
30
20
10
0



Silver

Gold

surface ratio 1 2 4 9 16 36

Mesh charcoal -50 -70 -100 -140 -200 -300

A comparison of the two screen or sizing tests shows that fine grinding increases both rate and capacity but the increase is not enormous, at least not on this pine charcoal. It may be mentioned, however, that the Activated Charcoals in some cases show as much as a ten-fold increased precipitating rate and a two-fold increased capacity with a difference in grinding from -8 mesh to -200 mesh. For these results see tables under chapter on "Activated and Other Industrial Charcoals".

STEAMING - Charcoals were prepared by heating and passing steam thru them while at the elevated temperatures. This treatment was given at three temperatures - 620°C, 750°C, and 900°C respectively - and at each temperature quantities of charcoal were exposed for various lengths of time.

The method of steaming was as follows: A weighed amount of the lump charcoal was placed in a silica tube and the tube was then placed in a combustion furnace which had been previously heated to the desired temperature. Steam was then started flowing thru the charcoal. The starting point of the test was taken as the time when steam first began to condense in the condenser at the cold end of the tube. After steam had been passed thru for the desired length of time, the tube was removed from the furnace without disconnecting from the steam or condenser pipe, and the charcoal was allowed to cool. The charcoal was then dry-crushed and used in the tests.

From results obtained in steam activation of charcoal for war purposes, it was found that about one pound steam per pound charcoal per hour gave the best results. Consequently this figure was aimed at during these tests but due to the small weights of charcoal used, it was impossible to keep the steam consumption to this figure. No other particular difficulty presented itself at the two lower temperatures but at the high temperature of 900°C the charcoal consumption was extremely high due to the formation of water-gas.

The following table gives the results obtained during the steaming.

DATA ON STEAMING OPERATION

<u>Charcoal</u>	<u>Temp. of Steaming</u>	<u>Hours Steaming</u>	<u>Loss in Weight %</u>	<u>Lbs. Steam per Lb. Charcoal per Hour</u>
Pine	Low - 620°C	1	3.3	3.7
"	" "	2	5.0	5.0
"	" "	4	8.3	4.7
"	" "	6	16.7	3.8
Pine	Med - 750°C	1	13.3	1.7
"	" "	2	38.3	2.8
"	" "	4	58.3	5.6
"	" "	6	67.5	1.5
Walnut	High - 900°C	30 (min.)	60.0	3.3
Pine	" "	30 (min.)	36.7	4.7
"	" "	1	48.3	2.7
Hickory	" "	1	78.3	3.3

Rate of precipitation and loading tests were made on the various steamed charcoals in comparison to a standard sample of pine quenched, pulverized, and dried. The rate of precipitation tests were made using 100 ccs. of a two-pound cyanide solution containing approximately two milligrams gold or three and one half milligrams silver and 0.5 gram charcoal (except where noted) with intermittent agitation during thirty minutes. The loading tests were made using 100 ccs of a two-pound cyanide solution containing approximately twenty milligrams gold or eight milligrams silver and 0.250 gram charcoal (except where noted) with intermittent agitation during twenty-four hours.

The results of these tests follow:

RATE OF PRECIPITATION TESTS
STEAMED CHARCOAL

Test	Charcoal	Mgm Metal in			% Fptn.
		Char	Soln	Total	
539	Gold Pine Q P D	2.33	0.01	2.34	99.6
540	" Pine 620°C 1 hour	2.29	0.03	2.32	98.7
541	" " " 2 "	2.40	0.02	2.42	99.2
542	" " " 4 "	2.38	0.02	2.40	99.2
543	" " " 6 "	2.32	0.01	2.33	99.5
544	" Pine 750°C 1 hour	2.11	0.01	2.12	99.5
545	" " " 2 "	2.30	0.01	2.31	99.6
546*	" " " 4 "	1.15	0.01	1.16	99.2
547*	" " " 6 "	1.13	trace	1.13	100.0
548*	" Walnut 900°C 30 min.	1.18	trace	1.18	100.0
549	" Pine " 30 min.	2.20	0.01	2.21	99.5
550	" " " 1 hour	2.29	0.02	2.31	99.1
551**	" Hickory " 1 "	0.84	0.01	0.85	98.9
553	Silver Pine Q P D	2.91	0.62	3.53	82.4
554	" " 620°C 1 hour	2.89	0.70	3.59	80.5
555	" " " 2 "	3.19	0.47	3.66	87.2
556	" " " 4 "	3.25	0.41	3.66	88.8
557	" " " 6 "	3.13	0.45	3.58	87.5
558	" Pine 750°C 1 hour	3.21	0.22	3.43	93.6
559	" " " 2 "	3.45	0.14	3.59	96.1
560*	" " " 4 "	2.20	0.15	2.36	93.2
561*	" " " 6 "	1.63	0.11	1.74	93.7
562*	" Walnut 900°C 30 min.	1.51	0.28	1.79	84.4
563	" Pine " 30 min.	3.24	0.22	3.46	93.7
564	" " " 1 hour	3.11	0.15	3.26	95.4
565**	" Hickory " 1 "	1.28	0.54	1.82	70.4

* Used 50 cc. solution and 0.250 gram charcoal.

** " 40 " " " 0.200 " " "

LOADING TESTS
STEAMED CHARCOAL

Test	Charcoal	Mgm Metal in			Load oz/ton
		Char	Soln	Total	
567	Gold Pine Q P D	10.62	11.18	21.80	1239
568	" Pine 620° C 1 hour	9.76	12.00	21.76	1139
569	" " " 2 "	9.83	12.03	21.86	1147
570	" " " 4 "	9.88	12.25	22.13	1152
571	" " " 6 "	9.40	12.71	22.11	1097
572	" Pine 750° C 1 hour	8.87	11.10	19.97	1035
573	" " " 2 "	10.35	11.18	21.53	1207
574	" " " 4 "	9.32	12.35	21.67	1087
575	" " " 6 "	8.14	11.44	19.58	949
576*	" Walnut 900° C 30 min.	4.76	6.24	11.00	1111
577	" Pine " 30 min.	10.75	10.97	21.72	1252
578*	" " " 1 hour	5.82	5.25	11.07	1358
579**	" Hickory " 1 "	3.76	5.04	8.80	1097
581	Silver Pine Q P D	3.30	4.74	8.04	385
582	" Pine 620° C 1 hour	2.93	4.98	7.91	342
583	" " " 2 "	3.06	4.90	7.96	357
584	" " " 4 "	3.00	4.91	7.91	350
585	" " " 6 "	2.70	5.16	7.86	315
586	" Pine 750° C 1 hour	3.24	4.54	7.78	378
587	" " " 2 "	3.35	4.15	7.50	391
588	" " " 4 "	2.81	4.82	7.63	328
589	" " " 6 "	3.23	4.60	7.83	377
590*	" Walnut 900° C 30 min.	1.61	2.38	3.99	376
591	" Pine " 30 min.	3.55	4.33	7.68	390
592*	" " " 1 hour	1.83	1.96	3.79	427
593***	" Hickory " 1 "	0.47	0.56	1.03	416

* Used 50 ccs. solution and 0.125 gram charcoal.

** Used 40 ccs. solution and 0.100 gram charcoal.

*** Used 15 ccs. solution and 0.033 gram charcoal.

The results obtained from the tests on the steamed charcoals indicate the following points:

1. That steaming at high temperature accelerates the rate of precipitation.
2. That steaming at high temperature increases the load capacity of charcoal for gold and silver slightly.
3. That steaming for more than two hours decreases its efficiency.

The curves showing results obtained on steamed charcoals are given in Figures III and IV.

At a date later than that when the previous steaming tests were made a pine charcoal was steamed for only five minutes at 900° C under the same conditions as the previous tests and was found to attain a load of 1544 ounces gold per ton charcoal and in so doing practically "cleaned up" the solution. This would indicate that steaming at high temperature for a short time only would produce the best charcoal. Unfortunately time did not permit the further investigation of this particular point.

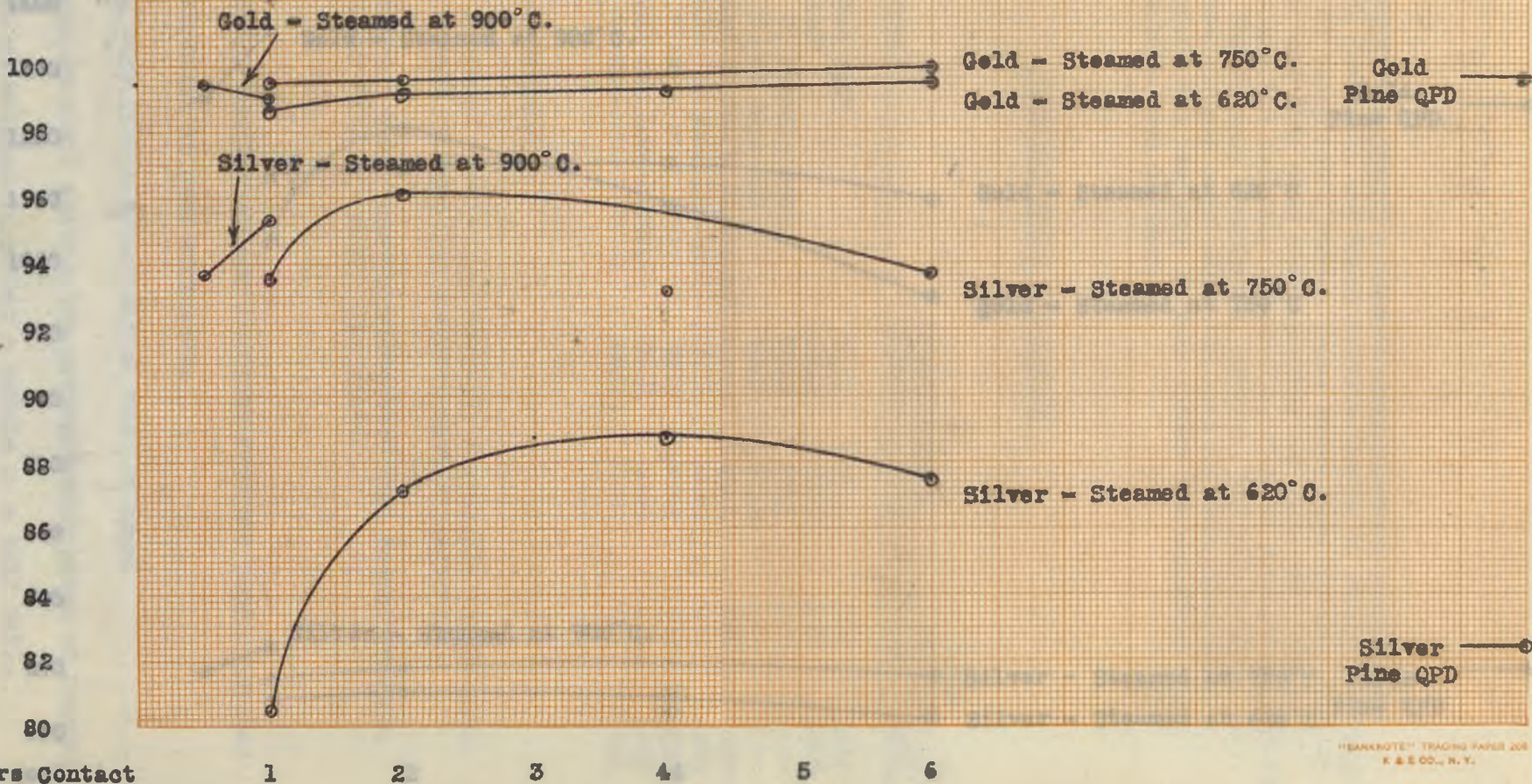
CARBONIZING IN LARGE PIECES - In case charcoal precipitation were to be installed in a mill one of the attendant problems would be to determine the size of pieces of wood at which charcoal could most efficiently be made. Usually this problem would resolve itself into a question of whether the charcoal could be made in large pieces. Consequently pine was carbonized in two-inch chunks - the largest size convenient to make in the laboratory - and the resulting charcoal was tested to see if it was as good as the charcoal made in the usual quarter-inch lumps.

After carbonization, the large chunk was divided into two portions - the outside half, and the inside half. Each portion was tested separately. For the results of these tests see page 36 under the comparison of "Inside of Charcoal vs Outside".

FIGURE III.

RATE OF PRECIPITATION TESTS
STEAMED CHARCOAL
Tests 539 - 564.

Precipitation



Hours Contact

FIGURE IV.

LOADING TESTS
STEAMED CHARCOAL

Tests 567 - 592.

Load
oz/ton

1400

1300

1200

1100

1000

900

800

700

600

500

400

300

Hours Contact

1

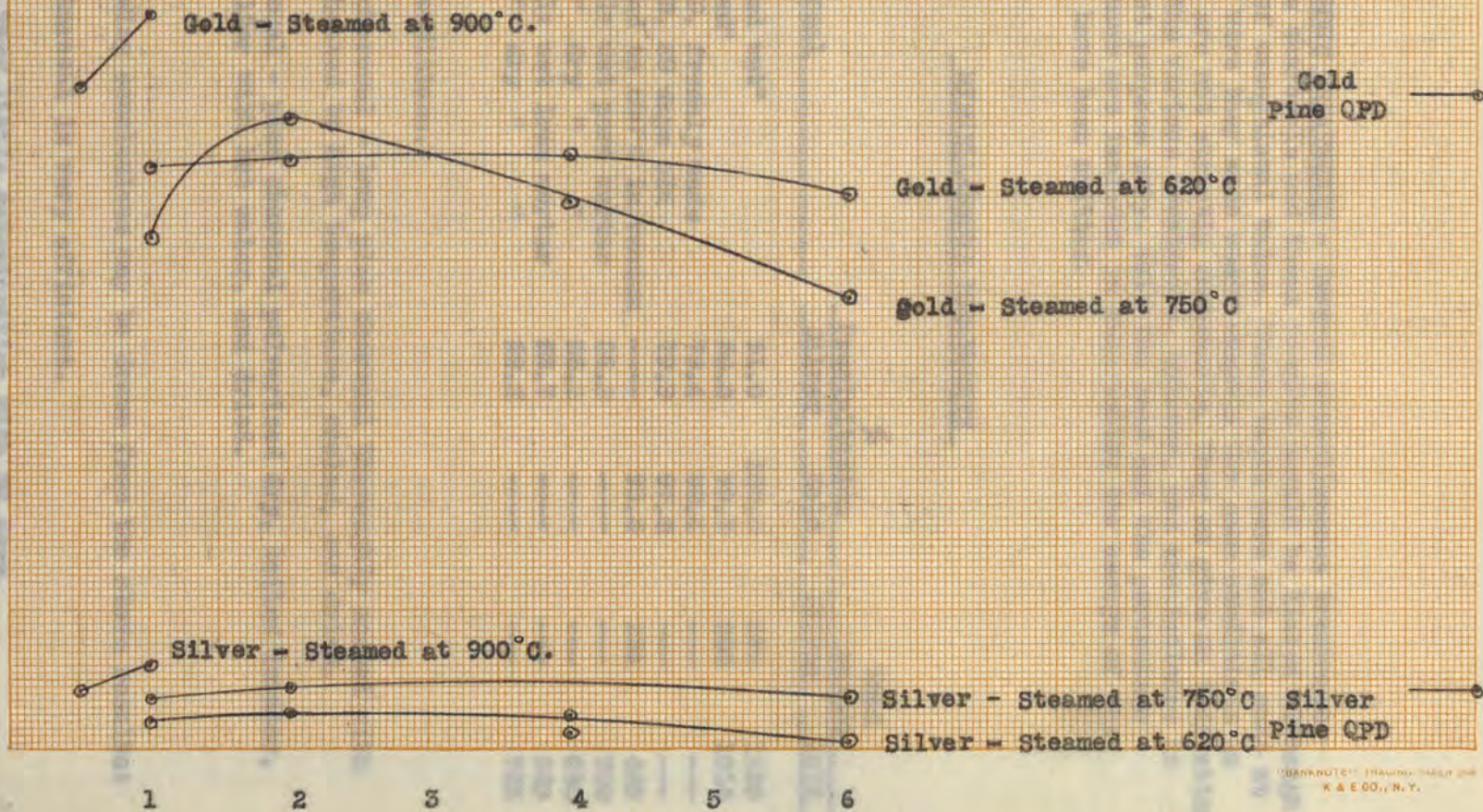
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3

4

5

6



MISCELLANEOUS TREATMENTS - Several miscellaneous treatments were given various charcoals and these results should be listed although none of them are of exceptional value. These tests were not all made at the same time nor were they made under exactly the same conditions so the results given are not strictly comparable. They do give an indication of the values of the various treatments, however, and are included in this paper for that purpose only. Only the load and the percentage precipitation figures are included in this table; the assays of the different samples have been omitted.

MISCELLANEOUS TREATMENTS

Test	Charcoal	% Precipitation		Load oz/ton	
		Silver	Gold	Silver	Gold
598	(a) "Heated wet"	91.0	100.0	592	1288
599	(b) "Boiled"	56.3	99.7	308	1015
244	Pine Q P D, freshly made	79.4	98.4	---	---
245	Pine Q P D, 20 days old	79.9	97.8	---	---
355	Pine heated to 600°C in vacuum	----	99.3	294	689
961*	Pine Q pulv wet pore mortar	56.2	----	---	700
962*	Pine QD " dry " "	55.2	----	---	690
963*	Pine Q pulv wet iron mortar	53.7	----	---	680
964*	Pine QD " dry " "	55.5	----	---	703

* Standard test conditions.

(a) "Heated wet" charcoal - lump pine charcoal thoroughly soaked with water, then heated to high temperature, cooled, and dried.

(b) "Boiled" charcoal - pine charcoal pulverized dry, boiled in water, washed on filter with hot water, and dried.

The following conclusions may be drawn from the above results:

1. "Heated wet" charcoal is very efficient.
2. Charcoal shows very little deterioration with 20 days.
3. Vacuum plus heat does not destroy the precipitating power of charcoal.
4. Charcoal may be pulverized in either a pebble or a ball mill.

COMPARISONS OF VARIOUS TREATMENTS.

In order to compare, or contrast, certain methods of treatment with other similar, or dissimilar, methods the following tables have been compiled. In these tables only the gold load figures and the silver percentage precipitation figures are given. All tests have been chosen so that the only variables are the ones being compared or contrasted.

DRY PULVERIZATION VS WET PULVERIZATION.

DRY PULVERIZATION VS WET PULVERIZATION

Tests	Charcoal	% Silver Precipitation		Gold Load oz/ton	
		Dry Pulv	Wet Pulv	Dry Pulv	Wet Pulv
739/40	Pine not Q	---	---	1053	952
736/41	Pine Q	---	---	1022	1002
747/49	Pine Chunk not Q - outside	40.1	36.6	968	951
748/50	" " " " inside	46.6	39.8	942	938
923/34	Pine steamed 900° C 5 min.	82.2	77.0	1544	1496
962/64	Pine Q - Pulv pore mortar	55.2	56.2	690	700
961/63	" " " iron "	55.5	53.7	703	680
965/66	Barrell's 50-min. not Q	56.6	58.4	1530	1533
967/68	" " " Q	86.3	92.5	1660	1702
970/71	70-min. Absorbite not Q	58.1	66.3	1495	1553
972/73	" " " Q	94.1	94.5	1549	1674
982/83	Pine char soaked 1% KOy not Q	22.9	32.5	599	640
980/81	" " " " " Q	63.5	66.0	854	881
1014/15	" " " " Na ₂ S not Q	21.6	40.8	548	569
1016/17	" " " " " Q	47.2	60.3	873	989
1026/27	" " " " NaOH not Q	40.0	50.1	589	627
1028/29	" " " " " Q	56.5	64.4	805	879
1032/33	" " " " ZnCl ₂ not Q	78.8	70.5	697	675
1034/35	" " " " " Q	96.8	93.8	1044	1000
1063/64	" " " sat. CaO not Q	29.0	29.9	665	666
1065/66	" " " " " Q	54.9	58.8	882	878

These figures show that there is very little to choose between wet and dry crushing.

QUENCHED VS NOT QUENCHED.

QUENCHED VS NOT QUENCHED

Tests	Charcoal	% Silver Precipitation		Gold Load oz/ton	
		Q	Not Q	Q	Not Q
760/65	Pine wet pulv	---	---	1002	952
769/71	Pine chunk Outside wet pulv	40.7	36.6	1005	951
770/72	" " Inside " "	43.5	39.8	951	938
965/67	Barrell's 50-min. dry pulv	86.3	56.6	1660	1530
966/68	" " " wet "	92.5	58.4	1702	1533
970/72	70-min. Absorbite dry pulv	94.1	58.1	1549	1495
971/73	" " " wet pulv	94.5	66.3	1674	1553
980/83	Pine char soaked 1% KOy wet P	66.0	32.5	881	640
981/82	" " " " " dry P	63.5	22.9	834	599
1016/15	" " " " Na ₂ S wetP	60.3	40.8	969	569
1017/14	" " " " " dry P	47.2	21.6	873	548
1028/27	" " " " NaOH wet P	64.4	50.1	879	627
1029/26	" " " " " dry P	56.5	40.0	805	588
1034/33	" " " " ZnCl ₂ wet P	93.8	70.5	1000	675
1035/32	" " " " " dry P	96.8	78.8	1044	697
1065/64	" " " sat. CaO wet P	58.8	29.9	878	666
1066/63	" " " " " dry P	54.9	29.0	882	665

These figures show beyond question the favorable results obtained by quenching.

NOT QUENCHED DRY PULV VS QUENCHED DIRECT WET PULV.

NOT QUENCHED DRY PULV VS QUENCHED DIRECT WET PULV

Tests	Charcoal	% Silver		Gold Load	
		Precipitation		oz/ton	
		Not Q Dry Pulv	Q Direct Wet Pulv	Not Q Dry Pulv	Q Direct Wet Pulv
913/14	Pine made at 500°C	21.5	24.1	382	449
915/16	" " " 700°C	56.1	44.1	752	717
917/18	" " " 900°C	58.2	51.8	729	715
923/25	Pine steamed 900°C 5 min.	82.2	88.2	1544	1711
926/27	Sugar charcoal	24.1	22.8	657	626
928/29	Flour charcoal	23.7	19.6	671	675
933/34	Coal carbonized	-----	-----	678	669

It would seem from these figures that quenching direct with a subsequent wet pulverizing had very little advantage over not quenching, dry pulverizing.

NOT QUENCHED DRY PULV VS QUENCHED WET PULV.

NOT QUENCHED DRY PULV VS QUENCHED WET PULV

(Table given on following page.)

NOT QUENCHED DRY PULV VS QUENCHED WET PULV.

Tests	Charcoal	% Silver Precipitation		Gold Load oz/ton	
		Hot Q	Q	Hot Q	Q
		Dry Pulv	Wet Pulv	Dry Pulv	Wet Pulv
764/60	Pine	-----	-----	1053	1002
773/69	Pine chunk - Outside	40.1	40.7	968	1005
774/70	" " - Inside	46.6	43.5	942	951
678/79	Willow charcoal	12.1	99.2	292	1544
685/66	Puffed rice charcoal	48.0	64.7	1212	1402
930/31	Lampblack	5.6	8.6	26	89
965/68	Burrell's 50-minute	56.6	92.5	1530	1702
970/73	70-minute Absorbite	58.1	94.5	1495	1674
982/60	Pine char soaked 1% KCy	22.9	66.0	599	881
1014/16	" " " " Na ₂ S	21.6	60.3	548	989
1026/28	" " " " NaOH	40.0	64.4	588	879
1032/34	" " " " ZnCl ₂	78.8	93.8	697	1000
1063/65	" " " saturated CaO	29.0	58.8	665	878

These tests help strengthen the conclusion that quenching improves the charcoal. However, there is another variable in this particular series - that of wet over dry crushing. In a preceding table, tho, it has been shown that there is little difference between wet and dry crushing; consequently it would look as tho the large differences in the above table were due primarily to the quenching.

Edmands (10,d) states that charcoal which has been quenched and wet pulverized is ten to twenty times better than a charcoal which has been aircooled and dry pulverized. These two variables are the ones compared in the above table. There is no indication of such an enormous difference between the two as Edmands gives; rather the author is more inclined to agree with Feldtman (14) who thinks Edmands has exaggerated the actual improvement.

INSIDE OF CHARCOAL VS OUTSIDE.

INSIDE OF CHARCOAL VS OUTSIDE

Tests	Charcoal	% Silver Precipitation		Gold Load oz/ton	
		Inside	Outside	Inside	Outside
769/70	Pine chunk Q palv wet D	43.5	40.7	951	1005
771/72	" " not Q " " D	39.8	36.6	938	951
773/74	" " " " " dry	46.6	40.1	942	968

As mentioned before (page 30), these tests were made to determine whether or not the size of the piece of wood during carbonization had any marked effect on the precipitating efficiency of the resulting charcoal; or in other words, does the precipitating efficiency limit the size at which charcoal can be made?

The conclusions as clearly shown in the above table are:

1. Charcoal made in two-inch pieces is practically as good as that made in smaller lumps.
2. The inside of a two-inch piece has a slightly increased precipitating rate over that of the outside.
3. The outside of a two-inch piece has a slightly increased capacity over that of the inside.

IV. CHEMICALLY TREATED CHARCOALS.

In the fore-going chapters all the tests have been concerned with charcoals which have been treated or altered physically or mechanically. Treating charcoals with various chemical reagents has been investigated and the results obtained are included in this chapter.

This subject naturally divides itself into two divisions since there are two ways in which a charcoal may be treated chemically. The first division includes those tests made on charcoals where both the charcoal and the wood (before carbonizing) have been soaked in the chemical reagent. The second division includes those tests made on charcoals which have been quenched in the chemical reagent.

Obviously, it was impossible to determine the effects of all the various chemical reagents available; consequently only a few of the common or more pertinent ones were tried.

CHARCOALS OR WOODS SOAKED IN REAGENT - The methods of exposing the charcoal or wood to the reagents were identical with each reagent.

In the case of the wood it was as follows: the pine cubes, before carbonization of course, were soaked for 16 hours in a one per cent solution of the particular reagent after which it was carbonized in the standard way. When this operation was finished it was allowed to cool and was then quenched, wet pulverized to -200 mesh, and dried.

In the case of the charcoal it was as follows: the pine charcoal was soaked for 16 hours in a one per cent solution of the particular reagent after which it was removed from the solution and allowed to dry. A portion of the dried charcoal was then dry pulverized while another portion was reheated, quenched, wet pulverized, and then dried. This quenched product gave a charcoal which was then comparable to the charcoal made from the treated wood.

In the following tables the length of time exposed to reagent (16 hours) and the strength of solution (1%) are omitted for brevity. They are understood, however, in each case unless other conditions have been specified. Standard test conditions were used throught the series.

RATE OF PRECIPITATION TESTS
CHARCOAL (OR WOOD) SOAKED IN REAGENT

Test	Charcoal			Mgm Silver in			% Pptn.
				Char	Soln.	Total	
1003	Pine wood	KCy	Q P D	3.04	2.90	5.94	51.2
1004	Pine char	"	Q P D	3.63	1.97	5.60	66.0
1006	" "	"	dry pulv	1.40	4.72	6.12	22.9
1037	Pine wood	K ₂ S	Q P D	6.20	0.07	6.27	98.9
1040	Pine char	"	Q P D	3.64	2.40	6.04	60.3
1038	" "	"	dry pulv	1.32	4.78	6.10	21.6
1043	Pine wood	HNO ₃	Q P D	4.95	1.00	5.95	83.2
1046	Pine char	"	Q P D	4.71	1.24	5.95	79.2
1044	" "	"	dry pulv	6.28	trace	6.28	100.0
1049	Pine wood	NaOH	Q P D	0.66	5.21	5.87	11.2
1052	Pine char	"	Q P D	3.90	2.16	6.06	64.4
1050	" "	"	dry pulv	2.40	3.60	6.00	40.0
1055	Pine wood	ZnCl ₂	Q P D	4.28	1.62	5.90	72.5
1058	Pine char	"	Q P D	5.80	0.38	6.18	93.8
1056	" "	"	dry pulv	4.79	1.29	6.08	78.8
1086	Pine wood	sat. CaO	Q P D	2.80	3.30	6.10	45.9
1089	Pine char	" "	Q P D	3.55	2.49	6.04	58.8
1087	" "	" "	dry pulv	1.76	4.30	6.06	29.0
1100	Pine char	5% H ₂ SO ₄	15 min. P D	2.21	3.84	6.05	36.5
1101	" "	8% HCl	15 min. P D	4.38	1.57	5.95	73.6

LOADING TESTS
CHARCOAL (OR WOOD) SOAKED IN REAGENT

Test	Charcoal			Mgm Gold in			Load oz/ton
				Char	Soln	Total	
979	Pine wood	KCy	Q P D	8.83	2.94	11.77	1288
980	Pine char	"	Q P D	6.04	5.70	11.74	881
982	" "	"	dry pulv	4.11	7.64	11.75	599
1015	Pine wood	H ₂ S	Q P D	4.81	5.62	10.43	701
1016	Pine char	"	Q P D	6.78	3.51	10.29	989
1014	" "	"	dry pulv	3.76	6.60	10.36	548
1019	Pine wood	HNO ₃	Q P D	7.42	2.89	10.31	1082
1022	Pine char	"	Q P D	7.83	2.54	10.37	1144
1020	" "	"	dry pulv	4.68	5.65	10.33	682
1025	Pine wood	NaOH	Q P D	2.87	7.44	10.31	419
1028	Pine char	"	Q P D	6.03	4.29	10.32	879
1026	" "	"	dry pulv	4.03	6.31	10.34	588
1031	Pine wood	ZnCl ₂	Q P D	6.66	3.56	10.22	971
1034	Pine char	"	Q P D	6.86	3.46	10.32	1000
1032	" "	"	dry pulv	4.78	5.60	10.38	697
1062	Pine wood	sat. CaO	Q P D	6.03	5.36	11.39	879
1065	Pine char	sat. CaO	Q P D	6.02	5.33	11.35	878
1063	" "	" "	dry pulv	4.56	6.83	11.39	665
1076	Pine char	5% H ₂ SO ₄	15 min. P D	4.51	6.89	11.40	658
1077	" "	5% HCl	15 min. P D	4.82	6.53	11.35	703

Besides the increased evidence that quenching is of benefit to a charcoal there are these few other conclusions to be drawn from the above tests:

1. Charcoal made from wood soaked in cyanide has the largest capacity of any of these chemically treated charcoals but it does not have the fastest rate.
2. A sodium hydroxide treatment of the wood before carbonization ruins the resulting charcoal both as to capacity and rate.
3. Nitric acid treated wood and charcoal give good capacity tests.
4. Sulphuric and hydrochloric acid treatments do not increase the precipitating power of the charcoal.
5. Soaking in a reagent does not seem to be the way to produce a super charcoal.

CHARCOALS QUENCHED IN REAGENT - It was thought perhaps a better cleaning out of the pores of the charcoal would be obtained if the charcoal was quenched in a solution of the reagent than if it was simply soaked in the solution. Therefore a few of these tests were tried.

In all cases but one the charcoals were heated to approximately 900°C and then quenched in a one per cent solution of the reagent; in the case of lime, a saturated solution instead of a one per cent solution was used. Standard test conditions were used thruout the series.

The results of these tests are given in the following tables:

RATE OF PRECIPITATION TESTS
CHARCOALS QUENCHED IN REAGENT

Test	Charcoal			Mm Silver in			% Pptn.	
				Char	Solu	Total		
766	Pine char	Q	hot water	P D	3.82	4.22	8.04	47.5
767	"	"	Q 1% KCy	P D	3.74	4.60	8.34	44.8
1042	"	"	Q 1% Na ₂ S	P D	3.46	2.45	5.91	58.5
1048	"	"	Q 1% HNO ₃	P D	6.29	trace	6.29	100.0
1054	"	"	Q 1% NaOH	P D	4.28	1.71	5.99	71.4
1060	"	"	Q 1% ZnCl ₂	P D	4.96	1.10	6.06	81.8
1091	"	"	Q sat. CaO	P D	3.39	2.76	6.15	55.1

LOADING TESTS
CHARCOALS QUENCHED IN REAGENT

Test	Charcoal			Mm Gold in			Load oz/ton	
				Char	Solu	Total		
742	Pine char	Q	hot water	P D	7.50	4.64	12.14	1094
743	"	"	Q 1% KCy	P D	7.67	4.56	12.23	1119
1018	"	"	Q 1% Na ₂ S	P D	6.20	4.18	10.38	904
1024	"	"	Q 1% HNO ₃	P D	6.59	3.74	10.33	961
1030	"	"	Q 1% NaOH	P D	7.51	2.32	10.33	1095
1036	"	"	Q 1% ZnCl ₂	P D	7.75	2.49	10.24	1130
1067	"	"	Q sat. CaO	P D	6.32	5.04	11.36	922

The only conclusion to be drawn from these tests is that quenching in various chemical solutions increases the precipitating efficiency of a charcoal no more than quenching in water. This would seem to indicate that during the quenching operation the action is merely one of steaming and that the chemical in the solution does not enter into the action at all.

V. ACTIVATED AND OTHER INDUSTRIAL CHARCOALS.

During the War several "activated" charcoals were produced for use in gas masks for the rapid and complete adsorption of poisonous gases. It was thought they might work as well for the precipitation of gold and silver from cyanide solutions as they did for gas adsorption. Before giving results of the tests made on these charcoals it is advisable to give a brief description of the theory of charcoal activation especially as worked out by the Chemical Warfare Service.

Dr. W. D. Bancroft (15) in a series of articles has given a very good summary of the status of charcoal as regards its various uses during the time prior to the War, and also discusses methods of preparation before that time. It was at the beginning of the War that more extensive experiments were made on the various materials which could be used for making charcoal suitable for gas adsorption.

F. M. Dorsey (16) who was a member of the Chemical Warfare Service makes the statement that "the denser the raw material the better the adsorptive power of charcoal for gas". He gives the following table of comparisons to emphasize his statement:

Willow (one of lightest woods)	- 1 unit	adsorptive power	
Ironwood (one of heaviest woods)	- 3 units	"	"
Cocconut hulls (extremely dense)	- 9 "	"	"

From this it is evident that the extremely dense charcoals are the best gas adsorbents; hence the great demand for nut shells and all kinds of fruit pits and seeds during the War.

This statement of Dorsey's is corroborated by work done by J. C. Phillip, Sydney Dunnill, and Olive Workman (17) who make the additional statement that light charcoals are more easily activated but do not have the ultimate capacity of the denser charcoals.

Lately there has been an attempt to produce these extremely dense charcoals by artificial means from a soft raw material such as sawdust. Dr. L. F. Hawley (18) has treated this subject rather fully and finds that it is possible to make a very dense charcoal resembling anthracite coal from sawdust by distillation under extremely high pressure and high temperature. This contribution came after the close of the War and consequently was not given an exhaustive trial.

There have been two theories (19) advanced in connection with charcoal activation, both of them dealing with activation by heating. The first of these is that the structure of the charcoal is changed by the heat alone; the second is that the hydrocarbons contained in the charcoal are oxidized by some means or other. The first theory has never been entirely disproved but it has been discarded in favor of the more popular Hydrocarbon Theory as worked out by the Chemical Warfare Service, and as described by H. K. Chaney (20).

The Hydrocarbon Theory of activation rests on two postulates:

1. That elementary carbon (other than diamond and graphite) exists in two modifications - active and inactive, or alpha and beta.
2. That all primary carbon consists of a stabilized complex of hydrocarbons adsorbed on a base of active, or alpha, carbon.

The active, or alpha, carbon has a very high adsorptive power while the inactive, or beta, carbon is characterized by its extremely low adsorptive power. Activation, then, consists of removing the beta carbon by some means and leaving the alpha carbon; or another way of making an activated charcoal is to produce the alpha modification without the beta modification.

The active form is deposited at relatively low temperatures - below 500°C to 600°C - by chemical or thermal decomposition of carbon bearing materials; the inactive form is deposited in like manner at temperatures above 600°C to 700°C.

The active form is rapidly attacked by oxidizing agents, so rapidly, in fact, that it is slightly oxidized by the air alone; the inactive form is relatively stable toward oxidizing agents.

The two possible ways, then, of producing activated charcoals would seem to be:

1. Carbonizing wood at a temperature below 500°C to minimize the formation of inactive carbon;
2. Differentially oxidizing, by means of air, steam, or carbon dioxide, the hydrocarbons adsorbed on the active base, leaving only the active carbon.

The first method has been proved to be impossible for the following reason:

As before mentioned, all primary carbon, regardless of the temperature at which it is made, consists of hydrocarbons adsorbed on a base of active carbon. A temperature of 500°C is not sufficient to drive off these hydrocarbons because of the peculiar conditions under which they are adsorbed. Consequently the temperature must necessarily be raised to about 1000°C at some time or other to get rid of the detrimental hydrocarbons. And the raising of the temperature would mean a formation of the inactive carbon. Therefore, by this method, the charcoal automatically becomes more or less inactive - in case of the low temperature, by hydrocarbons, and in case of the necessary high temperature, by inactive carbon.

The second way has been successfully accomplished and was the method used during the War. In this brief space it is impossible to discuss the development of this process for it was a development, step by step (16). The brief mention of the method as finally worked out will have to be sufficient. This method consisted of subjecting the charcoal previously made from coconut, and other nut, shells to a temperature of around 900°C and then treating it at the elevated temperature with superheated steam for seven hours. One cubic centimeter of a charcoal made by this method contains an adsorbing area of one thousand square meters.

A list of the Activated and other industrial charcoals tried as precipitants for gold and silver from cyanide solutions together with a brief description of each, follows:

1. Barneby-Chaney No. 1 - Soft, dull grains about 6 mesh but mostly fines. Grinds easily. Does not quench good. Hard to wet - about half floats.

2. Barneby-Chaney No. 2 - Hard, brightgrains about 12 mesh. Grinds hard. quenches fairly good. Contains soda-lime.

3. Barneby-Chaney 30-minute Absorbite (No. 145A) - Hard, bright grains about 6 mesh. Grinds hard. quenches good. Contains soda-lime. Evidently made from nut shells.

4. Barneby-Chaney 40-minute Absorbite (No. 155A) - Same as 30-minute Absorbite.

5. Barneby-Chaney 50-minute Absorbite (No. 156A) - Same as 30-minute Absorbite.

6. Barneby-Chaney 55-minute Absorbite (No. 157A) - Same as 30-minute Absorbite.

7. Barneby-Chaney 70-minute Absorbite - Same as 30-minute Absorbite.

8. Barrell's 40-minute Charcoal - Same as Barneby-Chaney 30-minute Absorbite.

9. Barrell's 50-minute Charcoal - Same as Barneby-Chaney 30-minute Absorbite.

10. Kelpchar - A very finely divided charcoal made from kelp. Does not quench good. Is not easily wet. Does not settle in solution well.

11. Spechar - A very finely divided charcoal. Very light and fluffy. Hard to quench. Hard to wet.

12. Super-Filtchar - Soft, dull grains about 8 mesh but mostly fines. Very light. Hard to quench. Hard to wet; tends to float.

Following are the addresses from which the above charcoals can be obtained:

Charcoals 1 to 7 - Barneby-Chaney Engineering Co.,
Columbus, Ohio.

Charcoals 8 and 9 - Barrell Technical Supply Co.,
Pittsburgh, Pa.

Charcoal 10 - Kelp-Potash Plant, Summerland, Calif.

Charcoal 11 - Industrial Chemical Co., New York City.

Charcoal 12 - Industrial Chemical Co., Tyrone, Pa.

The two standard tests - rate of precipitation tests and load tests - were made on each of these charcoals. Standard conditions of testing, as given on page 9, were adhered to except in the cases of the two charcoals marked with asterisks.

A little different procedure has been adopted in comparing these Activated charcoals than that used in the preceding examples. It will be noticed that the following tables of tests give a rate of precipitation and a loading test on each of three different forms of each particular charcoal; the first form is the charcoal just as received without any preparation except taking some particular size which did not necessitate crushing; the second form is the charcoal dry-crushed to -200 mesh; and the third form is the charcoal quenched, wet-crushed to -200 mesh, and dried.

The chapter on "Pre-Treated Charcoals" includes numerous tests which prove that both fine-grinding and quenching serve to increase the precipitating efficiency of a charcoal enormously and while the tests on the second and third forms of each of these Activated charcoals, as given in the preceding paragraph, could have been included in that chapter to strengthen the conclusion that fine-grinding and quenching are beneficial, it possibly is better to keep all the work done on these special Activated charcoals together in one chapter.

The following tables give the results of tests made on these Activated charcoals:

RATES OF PRECIPITATION TESTS
ACTIVATED AND OTHER INDUSTRIAL CHARCOALS

Test	Charcoal	Mgm Silver In			Ppbm
		Char	Soln	Total	
832	B. O. No. 1 as rec'd.	1.27	4.11	5.38	23.6
833	" " " dry pulv	2.61	2.81	5.42	48.2
834	" " " Q P D	2.78	2.88	5.66	49.1
835	B. O. No. 2 as rec'd.	0.42	5.15	5.57	7.5
836	" " " dry pulv	1.40	4.50	5.70	24.6
837	" " " Q P D	5.17	0.66	5.85	88.7
820	B. O. 30-min. Absorbite as rec'd.	0.53	4.10	4.45	7.5
821	" " " dry pulv	2.73	2.95	5.68	48.1
822	" " " Q P D	5.75	0.05	5.80	99.1
823	B. O. 40-min. Absorbite as rec'd.	0.38	3.81	4.19	9.1
824	" " " dry pulv	2.64	2.89	5.53	47.7
825	" " " Q P D	4.94	0.67	5.61	88.1
826	B. O. 50-min. Absorbite as rec'd.	0.46	3.88	4.52	10.7
827	" " " dry pulv	1.41	3.46	4.87	28.9
828	" " " Q P D	4.82	0.63	5.45	88.4
829	B. O. 55-min. Absorbite as rec'd.	0.26	5.26	5.52	4.7
830	" " " dry pulv	3.05	2.57	5.62	54.3
831	" " " Q P D	5.31	0.52	5.85	91.1
699	B. O. 70-min. Absorbite as rec'd.	0.42	3.60	4.02	10.4
700	" " " dry pulv	2.74	1.22	3.96	69.2
701	" " " Q P D	3.37	0.04	3.41	98.8
694	Burrell's 40-min. as rec'd.	0.12	3.80	3.92	3.1
695	" " " dry pulv	2.11	1.59	3.70	57.0
696	" " " Q P D	3.67	0.03	3.70	99.2
817	Burrell's 50-min. as rec'd.	0.50	5.07	5.57	9.0
818	" " " dry pulv	2.30	3.24	5.54	41.5
819	" " " Q P D	4.93	0.60	5.53	89.2
420	*Kelpohar as rec'd.	0.94	0.92	1.86	50.5
420A	" " " Q P D	1.68	0.21	1.89	88.8
488	*Suehar as rec'd.	1.91	1.71	3.62	52.8
489	" " " Q P D	3.43	0.74	4.17	82.3
838	Super-Filtchar as rec'd.	1.19	4.48	5.67	21.0
839	" " " dry pulv	3.57	2.27	5.84	61.1
840	" " " Q P D	4.85	1.04	5.87	82.3

* Used 500 mgm. charcoal instead of 400 mgm.

LOADING TESTS
ACTIVATED AND OTHER INDUSTRIAL CHARCOALS

Test	Charcoal	Mgm Gold in			Load oz/ton
		Char	Soln	Total	
808	B. C. No. 1 as rec'd.	7.19	7.75	14.94	1048
809	" " " dry pulv	6.58	8.04	14.62	960
810	" " " Q P D	8.56	5.68	14.42	1248
811	B. C. No. 2 as rec'd.	5.16	9.86	15.02	753
812	" " " dry pulv	7.94	6.83	14.77	1158
813	" " " Q P D	12.28	2.55	14.83	1791
796	B. C. 30-min. Absorbite as rec'd.	3.97	10.36	14.33	579
797	" " " " dry pulv	7.72	6.66	14.38	1126
798	" " " " Q P D	14.26	0.67	14.93	2080
799	B. C. 40-min. Absorbite as rec'd.	5.48	9.45	14.93	799
800	" " " " dry pulv	8.60	5.90	14.50	1254
801	" " " " Q P D	10.90	3.72	14.62	1590
802	B. C. 50-min. Absorbite as rec'd.	5.31	9.63	14.94	774
803	" " " " dry pulv	6.55	8.13	14.68	955
804	" " " " Q P D	11.81	3.00	14.81	1722
805	B. C. 55-min. Absorbite as rec'd.	5.47	9.45	14.92	798
806	" " " " dry pulv	9.30	5.45	14.75	1356
807	" " " " Q P D	12.36	1.93	14.29	1802
711	B. C. 70-min. Absorbite as rec'd.	5.76	9.00	14.76	840
712	" " " " dry pulv	9.24	5.60	14.84	1348
713	" " " " Q P D	10.69	4.04	14.73	1559
706	Burrell's 40-min. as rec'd.	4.71	9.22	13.93	687
707	" " " dry pulv	9.03	5.70	14.73	1317
708	" " " Q P D	11.76	3.05	14.81	1715
793	Burrell's 50-min. as rec'd.	6.88	7.73	14.58	999
794	" " " dry pulv	8.97	5.27	14.24	1308
795	" " " Q P D	11.99	2.74	14.73	1748
415	*Kelpchar as rec'd.	1.79	11.78	13.57	209
415A	* " " Q D	5.85	7.63	13.48	682
494	*Suehar as rec'd.	5.52	11.56	17.08	644
495	* " " Q D	9.03	7.66	16.69	1053
814	Super-Filtchar as rec'd.	8.41	6.44	14.85	1226
815	" " " dry pulv	9.30	5.00	14.30	1356
816	" " " Q P D	11.29	3.54	14.83	1646

* Used 250 mgm. charcoal instead of 200 mgm.

It will be seen that all of these Activated charcoals act more or less alike, the charcoals as received all being rather poor precipitants. These tests also emphasize the statement that the rate of precipitation is not necessarily proportional to the load value; for example, Kelpchar, as received, with a silver rate of precipitation of 50.5% shows a gold load value of only 209 ounces per ton, while Barneby-Chaney No. 1, as received, shows a silver rate of precipitation of only 23.6% but a gold load value of 1048 ounces per ton.

The effect of pulverization is strongly brought out by these tests. All the charcoals show increased rates of precipitation and load values upon being crushed to -200 mesh*. The rate of precipitation increased as much as twenty-fold with the case of the Barrell's 40-minute while the load value was in several cases doubled.

Quenching these Activated charcoals with a subsequent wet-pulverization to -200 mesh renders some of them the closest to the desired super-charcoal of any of the charcoals experimented with. It should be remembered, however, that even these do not approach the load values a super-charcoal should have. Because the tests made on the quenched charcoals are not strictly comparable to the tests made on the dry-crushed charcoals since the quenched charcoals were wet-crushed and therefore differ from the dry-crushed tests in two ways, it is difficult to say just how much of the increased precipitating power is due to the quenching and how much to the wet-crushing. Previous tests, however, together with the tests on Kelpchar and Suchar, indicate that the quenching is the active treatment.

By virtue of their previous activation treatments, these Activated ** charcoals can adsorb gases rapidly and abundantly. Assuming the quenching process to be a further cleaning-out of the pores of the charcoal, after quenching, these charcoals should all consist essentially of alpha carbon according to the Hydrocarbon Theory. Consequently they should all exhibit similar precipitating powers after quenching. And, while not identical by any means, their respective load values do fall within the range of from 1500 to 2000 ounces per ton while all but two come within the range of from 1550 to 1800. It would therefore seem that

* Except Barneby-Chaney No. 1. This can probably be explained by the fact that this charcoal is exceedingly porous and is permeable to the solution even in the coarse condition.

** Kelpchar, Suchar, and Super-Filtchar are not included in this hypothesis since they are Industrial and not Activated Charcoals.

alpha

even the extremely active carbon has a limit to its capacity. If this is true and if 2000 ounces gold per ton charcoal represents this limit of capacity it would seem hopeless toward ever producing a super-charcoal with the requirements as given in the first of this article.

Briefly, the conclusions drawn from the tests on Activated and other Industrial charcoals are:

1. All Activated charcoals, as received, are relatively poor precipitants.
2. Pulverization increases their precipitating efficiencies.
3. Quenching, with a subsequent wet-pulverization, gives even greater precipitating efficiencies.
4. Barney-Chaney 30-minute Absorbite, Q P D, is the charcoal which gives the fastest precipitation rate and also the largest load value of any of the charcoals tested.
5. All Activated charcoals, Q P D, which were tested were found to be better than pine charcoal, Q P D.

GENERAL CONCLUSIONS.

The main purpose of this research has not exactly been fully accomplished since this purpose was to develop a super-charcoal and it has not been done. However, in the search for this super-charcoal some valuable data has been gathered. Therefore the writer feels that the work has been of real value and that the results contained in this report are a contribution, even tho it be a small one, to the general problem of charcoal precipitation of gold and silver from cyanide solutions.

The following general conclusions have been drawn from a study of all the preceding tests:

1. Charcoal for the precipitation of gold and silver from cyanide solutions can be made from any kind of wood without greatly affecting the precipitating efficiency.
2. Charcoal is most efficient when made at a high temperature.
3. The wood used for making charcoal can be carbonized in any size lumps (up to two-inch chunks at least).
4. Charcoal made by carbonizing wood for a period of thirty minutes is more efficient than charcoal made by carbonizing wood for a shorter period of time.
5. Quenching improves the precipitating efficiency of a charcoal.
6. Quenching the charcoal from a high temperature gives a more efficient charcoal than quenching from a low temperature.
7. Quenching charcoal in a solution of a chemical increases its efficiency no more than quenching it in water.
8. Steaming, for a short period of time at a high temperature especially, activates the charcoal.
9. A charcoal may be either dry or wet pulverized with hardly any change in its precipitating power resulting.
10. A charcoal may be pulverized in either an iron or a porcelain mortar (i. e., a ball or a pebble mill).

11. The precipitating efficiency of a charcoal increases with finer grinding.
12. Twenty-day old charcoal has practically as good a precipitating power as fresh charcoal.
13. Soaking the wood prior to carbonization, or soaking the charcoal itself, in any of the ordinary chemical reagent solutions does not greatly benefit the charcoal.
14. The Activated charcoals developed for gas mask use during the War show the greatest precipitating powers of any of the charcoals tested.
15. The high cost of any of these Activated charcoals would very probably preclude its use in a commercial application of charcoal precipitation of gold and silver from cyanide solutions.

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