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FIFTIETH MEETING AMERICAN CHEMICAL SOCIETY

The Spring Meeting of the American Chemical Society convened in New Orleans, March 31st to April 3rd; the total registration was 256. The formal opening session and the public symposium by the Division of Industrial and Engineering Chemists were held at Tulane University on Thursday, April 1st. The meetings of the Divisions and the General Public Meeting on Thursday evening, took place in the Grunewald Hotel, the official headquarters.

Registration was practically completed on Wednesday. Each member, or guest, was presented with a badge and a watch fob, the design of the seal being a combination of the Louisiana State seal and the A. C. S. insignia. No official meetings took place on Wednesday and the guests made the most of the opportunity for sightseeing, in which they were aided by the Reception and Entertainment Committee.

It was the stated intention of the Local Committees, headed by Mr. W. L. Howell, Chairman of the Local Section, to show the visitors as many of the unique and characteristic features of New Orleans as was possible in the limited time allowed. In this he was ably assisted by his nine committees, including the Ladies' Committee led by Mrs. E. J. Northrup.

On Wednesday afternoon the visiting ladies were treated to a motor trip which whirled them from the Grunewald Hotel through the interesting but fast disappearing French quarter out through lovely tropical parks to the shores of Lake Pontchartrain and back among the newer and more pretentious residence sections of the city to the foot of Canal Street where they joined the rest of the convention in the boat ride on the Mississippi. The steamer "*Sydney*" had been chartered for the occasion by the Local Section; it was decorated with Spanish moss on the outside, and the cabin, lavishly adorned with flowers and vines, presented a truly southern appearance; here the complimentary smoker was held later in the evening. Turtle soup, cold meats, salads, ice cream and cakes, "smokes" of various kinds, beer and punch were served in abundance to 275 members and guests. Music by Anderson's darky band and Walter Coquille's Entertainers, comic songs and real darky dancing helped to promote in an informal way the making of new acquaintances, as well as to relieve the visitors from the strain occasioned by the long railroad journey to New Orleans. The committee in charge deserve the hearty thanks of the Society for providing such a delightful means of beginning the meeting.

The Council met at the Hotel Grunewald on Wednesday evening. The minutes of the meeting appear in full in the May issue of the *Journal of the Society*.

The Society was formally welcomed to New Orleans by Mayor Martin Behrman, and by Dr. Robert Sharp, President of Tulane University. In reply to their cordial greetings and expressions of appreciation of the value of the services of chemists to the whole South as well as to New Orleans, President Charles Holmes Herty spoke for the Society: his address is printed in full below. The formal opening address on "The Industrial Resources and Opportunities of the South," by Dr. A. D. Little, is also presented below. The Symposium on "The Contributions of the Chemist to American Industries," including the address by Dr. Bernhard C. Hesse on "The Chemist's Contribution to the Industrial Development of the United States—A Record of Achievement," appeared in full in the preceding issue of THIS JOURNAL. The entire program of papers is printed elsewhere in this issue.

On Thursday, the Tulane Refectory served a complimentary luncheon to the convention; afterwards an hour was spent in an inspection of the buildings and extensive grounds of the University.

Through the efforts of Prof. Phillip Asher, Chairman of the Publicity Committee, the New Orleans papers had given ample notice of the convention and all public meetings were well attended.

The Abstractors' Dinner was served at the Chess, Checkers and Whist Club on Thursday evening. Editor E. J. Crane emphasized the unusual and preeminent importance of our Abstract Journal during the present unsettled period, which will continue, of course, until some time after the close of the European war. Up to the present time the chief aim has been to make Abstracts cover the entire field of chemical and related literatures, completely and promptly, but now that this is practically accomplished, arrangements are being made to materially improve the quality of the Abstracts furnished. Abstractors and users of Abstracts were invited to coöperate towards this end.

The Banquet was held on Friday evening at the Restaurant de la Louisiane, the entire cuisine being Creole. One hundred and nineteen guests enjoyed the unusual and delicious feast. The ladies were presented with huge fragrant bouquets of sweetpeas and ferns and each received a handsome silver souvenir spoon, the design on the handle representing a river scene at the docks of New Orleans. Professor B. P. Caldwell, of Tulane University, acted as Toastmaster and short speeches were made by Prof. Herty, President of the Society; Mr. Howell, Chairman of the Local Section; Dr. Carl Alsberg, Head of the U. S. Bureau of Chemistry; and Dr. Chas. L. Parsons, Secretary of the Society.

The Committee on Excursions had arranged for the inspection of the New Orleans Water Purification Plant and an excursion to the Salt Mine at Weeks Island, 130 miles from New Orleans. Reports of these excursions are given elsewhere in this issue.

In addition to being welcomed at all sessions of the meeting and all social functions, the visiting ladies were entertained by a personally conducted tour through the Vieux Carré and a visit to the Newcomb pottery. All were charmed with the tropical aspects of the city and voiced warm praise of the cordial hospitality of the people of New Orleans.

The Louisiana Section and Tulane University de-

Delegates of the Fiftieth Meeting of the American Chemical Society at Tulane University, New Orleans

serve the highest praise for the skillfull and efficient manner in which they handled the details of the convention as well as for the many unique and enjoyable features which they added to the purely scientific and business program of the Fiftieth Meeting of our Society.

PRESIDENT'S ADDRESS

By Charles Holmes Herty

It is my pleasant duty, in behalf of the members of the American Chemical Society, to express our grateful appreciation of the cordial words of welcome so generously spoken by the people of New Orleans through Mayor Behrman, and by the members of Tulane University through President Sharp.

So hearty and so evidently sincere is this greeting that no other assurance could be required than the gracious words of the speakers. Yet another proof does exist. Ten years ago this Society met in New Orleans and the memories of that delightful week are still keenly alive in the hearts of all who were present at that meeting. It was not a matter of surprise, therefore, that the invitation to meet here again was gladly accepted.

But as I think of the tremendous changes which have taken place in the South during the intervening decade I cannot help but feel that the acceptance of the invitation was prompted also by a desire to get into sympathetic touch with that new spirit whose throbbing can be felt throughout our beloved southland today.

That spirit is not yet entirely freed from the shackles of ultra-conservatism and long-accustomedness, but the thought of the nearness of the day of its full emancipation tempts me beyond resistance to quit the rôle of responding guest and to join with you of New Orleans in welcoming to our midst this group of men whose presence has always proved an incalculable blessing.

Ours is a land lavishly blessed with natural resources—theirs the hands which take these products under closest scrutiny and by patient and laborious research shape them into greater blessings for humanity.

Of what value were the wonderful deep-seated sulfur deposits of this state until the dogged persistence of a Frasch brought this golden material to the surface by an ingenious application of the breadmaker's art, and thereby changed completely the sulfur market of the world. Are we to rest content with supplying this raw material while the methods of changing it into more valuable forms are so well known and are open for use by all?

Again, we fall so easily into the poetic habit of speaking of our "snow-white" fields of cotton, although we well know that when this cotton has been woven into cloth it shows a marked yellow coloration. But the chemist comes to the aid of nature and sets free from its tranquilizing union with sodium that element, chlorine, which gives the perfect bleach, so that a cotton cloth may be made that is pleasing to the eye. Here in your vast deposits of rock salt is stored sufficient chlorine to bleach the cotton crops for years to come. Shall it continue in this idle sleep?

Our esthetic tastes are also exacting; mere whiteness does not satisfy; variety of color is demanded, and at the outset nature was drawn upon for dyes, successful binding to the cotton cloth being effected by the chemist through the aid of various mordants. Then followed the wonderful development of the coal-tar dye industry, a fascinating chapter in German chemical industry, culminating in the discovery of that group of dyes which need no mordant for attaching themselves firmly to the cotton fiber. In the development of this industry nature has been far surpassed in regard to both shades and durability. So insistent is this demand for colors that many of our laboring class are today threatened with enforced idleness if the artificial dyestuff supply is completely shut off by the complications of the foreign war. Much more will be said upon this subject during this meetby those far better qualified to speak concerning it.

The chemist brings cotton and nitric acid together and behold a wonderful series of substances, varying from guncotton, that powerful explosive now playing so terrible a rôle in the fate of mankind, through camera and moving picture films to celluloid, to the beautiful artificial silk, and in lighter vein, if you will, to the wigs of straight black hair which have supplanted the anti-kink nostrums so eagerly bought by the more modern of our darker population.

The statutes of Mississippi once imposed a heavy fine for allowing cottonseed to endanger health by its rotting, or for fouling the streams into which it was thrown, but the chemist solved the problem of profitable cottonseed oil manufacture and a new source of wealth was opened to the South. Even today he is changing that oil by a new process into a better lard than ever graced a greasy grunter.

Much use is made of the chemist in this oil industry, but it cannot be considered to be upon a thoroughly rational basis until it pays for its raw product, cottonseed, according to the analytical results as to oil and protein present. Past economic conditions have not justified this, but the present is beginning to show it and the future will surely establish it.

Thanks to the splendid work of Charles M. Hall, the bauxite of my native state, Georgia, finds its way to Niagara Falls for change into the beautiful metal aluminum by the electric current generated there by falling water; yet all around its native home the power of the mountain streams has for centuries been neglected.

Even today shall we rest content with utilizing this power simply for purposes of transportation and illumination while we remain a producer of raw material? This same water power converted into the form of the electric current can set free your chlorine, can make available the nitrogen of the free air for nitric acid, and can isolate your aluminum. Our thoughts for the future development of chemical industries in the South must turn to the better utilization of our now almost neglected water powers.

These are simply types which I have mentioned to you this morning; a host of other illustrations could be given, but I must not go further in this line for the first paper on our program today, by Mr. A. D. Little, will tell the full story. We are especially glad to welcome Mr. Little into our midst, for he has been strongly drawn to the possibilities of our section and his is the clear eye which sees and the steady hand which can point the way to a truly greater future; for there is waste all around us and the development of our resources has scarcely begun.

I cannot close, however, without registering a plea which is not local or sectional in its character—a plea for closer coöperation between business men and the chemists of our technical laboratories and our educational institutions. Chemistry is no "black art;" the days of magic are past; the methods of research are well known. Patience, time, accumulating experience and good training are sure to bring rich results. The accomplishments of chemists in the past are ample proof of this statement. Why should the pioneer be always subjected to scoffing and to ridicule? Cannot the man of finance distinguish between a chemist and a fakir? The earmarks are plain. Our program today contains affirmative testimony on this point from some of the greatest business men of this country. They have been able to make the distinction, and they have no vested right in that ability. Dr. Hesse will tonight summarize this situation in an address which will clear many matters and give inspiration for new hope.

I confidently believe that such a hope is fully justified. The stimulation of this war period and the awakening of our whole people to the need of closer coöperation warrant the belief that, while the South will always remain a great agricultural section, through the blessings of its fertile soil and splendid climate, there will also be developed here industries undreamed of at present. These will convert our raw material into more and more highly finished products, not for the purpose of mere sordid accumulation of wealth, but to relieve in the masses of our people that pinch of hardship and privation which followed the close of our civil war and which for many years has made the struggle for existence paramount to all else. Is there reason for aught but optimism? Is not the air vibrant with the conviction that a new day is dawning for the South?

What part are we of the South to play in that development? The great discoveries we now make use of are not the products of southern brains. Frasch of Germany developed our sulfur, Hall of Ohio our aluminum, Gayley of Pennsylvania increased the output of our blast furnaces by his dry-air blast, de Chardonnet of France gave us artificial silk, Mercer of England our mercerized cotton, Sabatier of France the reaction by which our cottonseed oil is hardened, Germany the great bulk of our dyestuffs.

What can our young men do? For those whose tastes lead them to chemistry as a profession, I would urge a more thorough training in the methods of research, which can be obtained in our universities. I know that this necessitates a postponement for several years of entrance into active business life, and requires an extra expenditure of funds which many of our brightest young men do not possess. Here lies the responsibility of our wealthier people—to aid by giving full educational advantages to young men of this type and further to see that their own sons realize and appreciate the great part they may play in this development if properly equipped. Love of country, section, and state, which mean sympathy and acquaintance with those among whom we are to work, constitute a most valuable advantage in the struggle for success when it forms the broad foundation on which is laid a thorough educational training.

Can our young men afford to sit idly by and not do their share in this great development now at hand? My faith in their courage and ability, when once aroused, is unwavering.

Chapel Hill, North Carolina

THE INDUSTRIAL RESOURCES AND OPPORTUNITIES OF THE SOUTH[1]

By Arthur D. Little

Only those who have stood upon the seashore and there endeavored conscientiously to place the Atlantic Ocean inside a quart bottle by the aid of a teaspoon will appreciate the temerity and difficulties involved in an attempt to present within the compass of a brief address the industrial potentialities of the South. Probably no one but a relative stranger to the South would make the attempt at all. Nevertheless we are all prone to overlook the obvious in our immediate surroundings, and the visitor who looks upon them from a different standpoint with sympathetic interest and keen appreciation may sometimes point out new aspects in them and values before unrecognized. The man who views a mountain range from a distance may even trace its outlines and sense its trend better than those who dwell upon its slopes. So it happens that one whose knowledge of the South is in no way comparable to your own may hope, through your indulgence, to enlist your interest and possibly to turn your thought in new directions.

The awful spectacle of a world in arms which we are forced to contemplate today must recall with a peculiar vividness to many men and women North and South the horrors and desolation of another struggle which was concluded, happily as we all now believe, just fifty years ago. When we consider that the wealth of the whole United States in 1850 was estimated at a little more than $7,000,000,000, and the cost of the war to the South has been conservatively figured at $4,000,000,000, we may gain some faint notion of the material burden under which the South slowly arose to work out her destiny.

The situation she then faced was one to daunt the stoutest hearts. It involved a reorganization of the whole economic and social structure in a land mourning the loss of the flower of its youth and manhood, with broken credit, capital destroyed, industry prostrate, and streams of immigration diverted. To the burdens of the Reconstruction Period were added the paralyzing fallacies of the Greenback issue and the nation-wide disasters and stagnation of the panic of 1873 and the five lean years which followed. Not until 1880 did the South begin to come into its own.

EXTENT OF SOUTHERN INDUSTRIES

In 1880 the agricultural capital of the South was $2,762,000,000 and the total value of its agricultural output $756,000,000. The cotton crop was 5,761,000 bales of which the South used 179,000 bales and the North 1,610,000. Only about $330,000,000 were invested in manufactures; the mineral output was $18,000,000; the railway mileage was approximately 25,000, and the population 18,600,000. With these figures in our minds let us attempt the construction of a concept of the industrial South today.

The population of the South in 1912 has risen to 33,475,000, and the railway mileage to 90,930. The population of the whole United States in 1880 was about 50,000,000 and the total railway mileage 93,000. In general it may be said that the South today is in a far stronger position industrially than was the entire country in 1880. It cuts more lumber, mines nearly twice as much coal, produces nearly four times the petroleum, and nearly six times the spelter. It has more looms and spindles and a much larger investment in manufacturing plants. Its agricultural capital is greater and the products of its farms are worth 50 per cent more. It makes nearly as much pig iron and twice as much coke as the whole country produced only thirty-five years ago.

AGRICULTURE IN THE SOUTH

Agriculture is still and always will be the greatest business of the South and the backbone of its prosperity although even now the value of manufactured products exceeds, by nearly $900,000,000, the revenue from its farms.

As all the world knows, the South affords a peculiarly favorable habitat to the cotton plant and the 36,000,000 acres under cotton produce annually from 14,000,000 to 16,000,000 bales of the fiber, or about 65 per cent of the world's crop. In this connection it may be said in passing that chemists by developing methods for utilizing values in the cottonseed have added from $12 to $14 per bale, or perhaps $200,000,000 yearly, to the value of this single crop, so that the seed alone is now worth nearly as much as the entire crop of 1860. Cotton and seed together constitute about 30 per cent of the total value of southern farm products, excluding live stock. The ultimate products of the cotton plant together constitute 30 per cent of the merchandise exports of the whole United States. The value of staple, linters and seed in 1913 was $911,000,000. Corresponding values for 1914 were $704,000,000, so that the European war may fairly be said to have cost the South, on this one item, over $200,000,000.

Many years ago a certain café in New York attained a cheap but wide-spread notoriety by embedding in the mosaic of its floor a few hundred silver dollars. There are 600,000,000 acres in the South and nearly every one of them carries on its surface more dollars than the floor of that café. Upon 110,000,000 of these acres the South now raises crops valued at more than $3,000,000,000. From 1880 to 1910 agricultural capi-

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[1] Opening Address, New Orleans Meeting, American Chemical Society, March 31 to April 3, 1915.

tal increased from about $2,800,000,000 to nearly $11,000,000,000, or 296 per cent.

In spite of the proud preëminence of cotton in southern agriculture a considerable diversity of crops has already been established. Texas alone has raised 200,000,000 bushels of corn in a single year and the value of the 1913 corn crop in the South was $766,000,000. In that year the value of the hay raised was $111,000,000, wheat $95,000,000, and tobacco $72,000,000, with another $125,000,000 in oats, Irish and sweet potatoes, sugar cane and citrus fruits. Twenty million head of cattle, 25,000,000 swine and 9,000,000 sheep add their values to the wealth of southern farms.

MANUFACTURING IN THE SOUTH

Strangers to the South do not commonly think of this portion of our country as a manufacturing community. They may therefore well be surprised to learn that already the manufactures of the South greatly exceed in value the products of its farms and reach the stupendous total of more than $4,000,000,000. In the 29 years from 1880 to 1909 the capital invested in the South in manufactures increased 900 per cent and the value of manufactured products 407 per cent. The census survey of the entire country enumerates 262 different lines of manufacture. Of these 236 are already carried on in the South. Sixty-five per cent of the new spindles installed in the United States since 1890 are in place in southern cotton mills which now operate over 12,000,000 spindles and consume nearly 3,000,000 bales of cotton, whereas the northern mills in 1913 used only 2,500,000. Two southern states already manufacture more cotton than they raise. The value of cotton goods produced is nearly $250,000,000. One seldom hears of southern flour and grist mills, yet their product reaches the striking total of $209,000,000.

The factory products of one southern state, Missouri, reached a value of $1,688,000,000 in 1912, which included nearly $50,000,000 in boots and shoes and corncob pipes to the number of 28,000,000: the value of Missouri manufactures today is probably nearly or quite equal to the total value of southern agricultural products in 1880. West Virginia claims the largest pottery and largest glass factory in this country and the largest ax factory in the world.

In nine years, beginning with 1900, eleven southern manufacturing industries, including some of the greatest importance, increased their annual output by amounts ranging from 259 per cent to 2,380 per cent. The total increase in 92 leading industries was from $1,288,000,000 to $2,696,000,000, or 106 per cent. During the same period capital invested in factories rose in Texas from $64,000,000 to $217,000,000.

SOUTHERN FORESTS AND LUMBER INDUSTRIES

The total forest area of the South is estimated at 259,000,000 acres. That of Germany is about 35,000,000. In 1913 the whole United States cut 38,000,000,000 feet of lumber, of which the South cut over 22 billion, including 15 billion feet of yellow pine. One Louisiana sawmill cuts 1,000,000 feet of this wood a day. Eight years ago the site selected for this mill was in a stretch of virgin forest. Today it stands upon the outskirts of the thriving and unusually attractive little city of Bogalusa with over 10,000 inhabitants and stores, residences and public buildings which would be the pride of many an older community of much greater size.

The outstanding predominance of yellow pine should not cause us to overlook the fact that of more than fifty woods manufactured into lumber in the United States the South cuts over forty. In case of ten of the more important of these fifty woods the cut of individual southern states ranks first.

The annual value of southern lumber is about $350,000,000, but the reported cut excludes so many primary wood products of larger importance that at least another $100,000,000 must be added to represent their value and $25,000,000 more for naval stores.

COAL, COKE AND IRON

Coal lies at the basis of civilization and its stored-up energy is the present measure of man's command over nature. Excluding lignite, the coal areas of the southern states amount to about 88,000 square miles or over 50 times the coal areas of Germany, seven times those of Great Britain and twice those of all Europe including Russia. The South's present proved reserves of coal are estimated at 530,000,000,000 tons or 25 per cent more than the more thorough exploitation of all European countries has disclosed—and these southern reserves comprise 75 per cent of all the coking coal in the United States. West Virginia alone has a far greater coal area than Great Britain and Germany combined and she has mined less than $^1/_6$ of one per cent of the 150,000,000,000 tons beneath her surface. Nevertheless her 1912 output of 67,000,000 tons was 50 per cent more than all the bituminous coal mined in the United States in 1880. Alabama already stands next to Pennsylvania in coke production.

With coal, limestone and iron ore closely adjacent within her borders Alabama has already demonstrated her ability to manufacture pig iron more cheaply than any other locality on earth and "he who has the iron will get the gold." Her present output of 2,000,000 tons is merely an earnest of her potentialities. The immediately available southern iron ores are estimated at 2,600,000,000 tons with even greater reserves of ores of lower grade. Together these constitute not less than 50 per cent of the total iron ore reserves of the country.

PETROLEUM AND NATURAL GAS

It is doubtful if any American product is better known throughout the East than those tins of kerosene which bear the label of the Standard Oil Company. Our automobiles consume an amount of gasoline equivalent in volume to the water supply of a town of 40,000 inhabitants. The range of endeavor of Newfoundland fishermen is determined by its price and the flight of aeroplanes over the battlefields of Europe is measured by its supply. In 1890 the South produced less than 500,000 barrels of petroleum. In 1912 its output was 84,800,000 barrels. Passing by the great deposits of Louisiana and Texas, it may be pointed out that the oil production of Oklahoma alone in 1911 was 54,000,000 barrels.

Among these bounties of Nature with which the South has been so plenteously endowed few have greater potential values and none have been wasted more recklessly than natural gas. More than 60 per cent of the gas output of the country, or 290,000,000,000 feet, must now be credited to the South. From the standpoint of industrial utilization this is more than 1,000,000,000 feet per working day.

WATER POWER IN THE SOUTH

The relative cheapness of water power as compared to steam has determined in the North the location and development of many great manufacturing centers like Holyoke, Lowell and Lawrence in Massachusetts, and Rumford Falls and Lewiston in Maine. The application of this power to electrochemical industries has made Niagara Falls the most interesting place on earth to chemists. Cheap water power not only implies but ensures the ultimate development of public utilities and the establishment of manufacturing plants within the radius which it may serve.

Seven years ago the United States Geological Survey estimated the minimum available power in eleven of the streams which have their headwaters in the Southern Appalachian Mountains at 2,800,000 H. P. The estimate for all the streams of the South has been put at about 5,000,000 H. P. Only about one-fifth of this power has been developed and of this amount nearly 800,000 H. P. is in the five states of Alabama, Georgia, North Carolina, South Carolina and Virginia. Georgia alone has available 500,000 H. P.

SECONDARY MINERAL RESOURCES

The lavishness with which Nature has bestowed her gifts upon the South is nowhere more apparent than in the extraordinary variety and range of what may be termed the secondary mineral resources of this fortunate section of our country. An output of $5,800 worth of diamonds per week of the best South African quality in Pike County, Arkansas, is interesting and promises to become spectacular, but it shrinks to insignificance before many other southern mineral products. The whole country knows of the annual shipment of 8,000,000 boxes of Florida oranges and grape fruit, but relatively few of us give thought to the 3,000,000 tons of the infinitely more important phosphate rock which Florida produces. This is about four-fifths of the country's output, practically all of which now comes from the South.

Portland cement requires for its manufacture an assured supply of limestone and clay or shale adjacent to cheap fuel. Nowhere are these conditions met more fully or more generally than in the South. As a result its development of the manufacture of Portland cement has become one of the industrial miracles of the world. In 1890 the production for the whole United States was less than 400,000 barrels. In 1911 the output of cement in the southern states alone was nearly 11,000,000 barrels.

The South has inexhaustible supplies of clays which exhibit every desirable range of quality. There are clays in any amount desired for the making of common brick and tiles, cheap pottery and drain pipe, terra cotta and paving brick, and prodigal amounts of the finer white plastic clays and kaolins for china and the purposes of paper making. The production of Fuller's earth is almost exclusively a southern industry.

The South is equally fortunate in its endless stores of sand and gravel, road material and building stones. The latter range from the superb Georgia marbles and the granite of Stone Mountain near Atlanta, through every variety and quality, to meet all structural demands.

Immense deposits of gypsum occur in several southern states and ochres, mica, graphite, barytes, and corundum are among the well known mineral products of the South.

The history of industrial chemistry is a record replete with romance, and one of its best known stories is that which chronicles the development of the aluminum industry. In 1855 the metal cost $90 a pound; the Castner process brought the price to $4 in 1889. Then Hall in America and Héroult in Europe simultaneously developed the process which permits its cheap production by electrolyzing alumina in a fused bath of cryolite. Bauxite is an impure alumina and has become the chief source of the metal. Arkansas leads in the production of bauxite, but Georgia, Alabama and Tennessee contribute largely to the growing demands.

Another romance of chemical achievement is that which tells the story of the sulfur mines in Calcasieu Parish, Louisiana. There sulfur in inexhaustible amounts lies 1,000 feet below the surface and under 500 feet of quicksands. An Austrian Company, a French Company and many American Companies had tried in many ingenious ways to work this deposit, but each had failed. Frasch solved the problem by forcing superheated water down a boring, and pumping out the melted sulfur through an inner tube. Today Louisiana holds easily within her hands the sulfur markets of the world and supplies one-half the world's consumption.

Sulfur, as the direct source of sulfuric acid, constitutes the foundation of all chemical industries. The keystone of the structure is common salt. This the South bountifully supplies at Avery's Island, also in Louisiana, and in the salt wells of Oklahoma and West Virginia.

The largest sulfuric acid plant in the world is at Ducktown, Tennessee, but the striking feature of the installation which holds this record is that the acid is made from smelter fume, which commonly in other plants goes only to create a nuisance. The copper production, which is the primary output of the plant, is over 18,000,000 lbs. per year. The largest copper refining plant in the world is at Patapsco, Maryland, with an annual production of 200,000,000 lbs.

In 1911, 42 per cent of the lead output of the country came from the South and 41 per cent of the zinc production. The value of Missouri zinc alone was

$14,000,000. The largest pyrites producing plant in the whole country is in Louis County, Virginia.

There are produced in the United States 57 useful minerals. Of these every one is mined in the South except platinum and borax.

THE FAILURES OF THE SOUTH

We have reviewed in the most casual and disjointed manner the immediate achievements and demonstrated resources of the South in those things which make for industrial preëminence. All these figures are well known to you. They have been set forth time and again in the publications of the federal government and those of your own states, and reiterated with compelling emphasis and illuminating comment by that apostle of southern achievement and prosperity, the *Manufacturer's Record*. The aggregate of these stupendous figures represents an achievement and a heritage of which any people may well be proud, but the community whose eyes are filled with a vision of the future should take measure not of its successes but of its failures. What are the failures to be charged against the South?

First of all there is the stupendous failure of its agriculture. In 1909 only about 18 per cent of the total area of the South was tilled, whereas 75 per cent is available for tilled crops. What is more to the point, the 110,000,000 acres, which were tilled, were most of them tilled badly. Upon 35,000,000 acres the South raises as a maximum 16,000,000 bales of cotton—less than $^1/_2$ bale per acre. In some localities the yield shrinks even to 132 lbs. per acre. As compared with this, Georgia has raised upon 2500 acres 2700 bales, while as much as 2.38 bales has been raised upon a single acre in Texas. Little more than deeper ploughing and intelligent fertilization is required to double the present cotton crop or to produce the 1914 crop upon half the present acreage, leaving 18,000,000 acres available for corn and other crops. In one southern state 232 bushels of corn have been raised on a single acre; in another 13 acres of lettuce have sold for $12,000, and in a third 5,000 acres of cabbages have yielded $800,000 and 2,000 acres $600,000 worth of cucumbers. In the same state 145 million cabbage plants were started upon 346 acres and exported to other states to complete their growth. A single acre of Florida celery has paid $1,500 in freight to the railroad. North Carolina, which shipped 1,600 carloads of strawberries from Wilmington, in one season, reports 15,000,000 acres within the state upon which no agricultural improvements have been made. Alabama still buys largely of western grain, provisions and even hay, while Arkansas bought $80,000,000 worth of foodstuffs last year.

Next perhaps in importance is the failure of southern lumbering which is one of the most wasteful operations conducted on the whole broad face of the earth. In cutting 15,000,000,000 feet of merchantable yellow pine the South wastes not less than 30,000,000,000 feet, which, if intelligently utilized as raw material, should yield ten times the profit derived from lumbering.

For every ton of coal mined in the South, or for that matter in the country, one-half a ton was wasted or left underground in such condition that it can probably never be recovered.

The most atrocious and unnecessary wastes which have attended the development of any resources of our country have been those which have accompanied the exploitation of natural gas. As to these the South is no more culpable than other portions of our country upon which this extraordinary boon of nature was conferred. Nevertheless it may interest you as southern men who would conserve the resources of your birthright to know that the waste of gas in the Oklahoma fields alone has been as high as 150,000,000,000 cubic feet a year, and is now annually not less than 25,000,000,000 cubic feet. The time is fast approaching when natural gas will have its value determined by the number and value of the synthetic products which chemists are able to derive from its several components. For the present it may suffice to point out that every 100,000,000 cubic feet of natural gas represents on the basis of a ten-hour day 588,000 horse power, if consumed in a fair gas engine on fluctuating load averaging 50 per cent of rated capacity. West Virginia is now the largest producer of natural gas in the country and the especial disability under which the South now labors is exemplified by the fact that a very large part if not the major portion of the gas originating in West Virginia is piped outside the state and used for the generation of heat and light and power elsewhere.

It has already been pointed out that the South contains over 50 per cent of the total iron resources of the country. Nevertheless it produces only 12.5 per cent of the pig iron made and consumes not over 150 lbs. per capita while the whole country consumes 650 lbs. per capita. Here again we have before us the fundamental difficulty which confronts the South. A ton of iron ore shipped as ore returns only $2 and provides less than one day's work for one man. If shipped as stoves it returns $40 and has provided a day's work for ten men. The South has been selling raw materials. It should sell brain values and labor values.

Owing to its later advent as a large producer and its relatively more general introduction of by-products from coke ovens, the South has been less wasteful than the North of the ammonia values in its coal. It will probably never be possible to recover more than a moderate proportion of these values, but the extent of the problem in the whole country may be indicated by the fact that the total volatile ammonia in the coal mined annually in the United States would be worth, at $60 per ton for ammonia sulfate, over $300,000,000. We save less than $4,000,000. In Germany four-fifths of all coke is made in by-product ovens: in the United States only about one-sixth is so made.

In the Florida pebble field the tonnage of phosphate rock wasted is two or three times the total tonnage saved. The waste occurs mainly through the washing away of fine particles by the water used in mining and for cleaning the larger aggregates. In the Tennessee field there is relatively much less waste.

The wastes in zinc mining and smelting constitute another heavy drain upon your resources. Less than

50 per cent of the zinc in the mines ever reaches the form of spelter.

Many other comparable examples of the prodigal use of utter waste of valuable raw material might easily be cited though perhaps to no advantage at this time. There are signs that the era of thoughtless or willful extravagance is passing. Means of production, methods of practice and systems of organization which have been worked out painfully and at great cost elsewhere are being gradually adopted in the South but a more general appreciation of their advantages may well be urged.

An excellent example of intelligent conservation is afforded by the great pulp mill at Canton, North Carolina. Formerly the spent chips from the chestnut extract plants were burned. Now they are boiled in caustic soda and converted into high-grade pulp and paper.

All visitors to the South who have been so fortunate as to partake of the hospitality of southern homes cherish always thereafter a warm appreciation of the grace and courtesy of southern life. The charm of New Orleans is proverbial and the metropolitan aspect and quality of many southern cities like Jacksonville and Atlanta strikes the observer at once. One may nevertheless be permitted to suggest that the South would gain immeasurably by giving to a larger proportion of its smaller towns and country places that atmosphere of trig neatness and comfortable prosperity which characterizes so many of the older villages of Massachusetts and Vermont and reflects the pleasantness of life in them. The South is also greatly handicapped by the general quality of its roads. Only about 60,000 miles out of 850,000 have ever been improved.

VALUE OF INDUSTRIAL TRAINING FOR NEGROES

One of the greatest of the relatively undeveloped potential industrial assets of the South is undoubtedly the negro. The negro population in the southern states is about 10,000,000, and by the efficiency of the units of that population the prosperity of the South is profoundly affected. Many negro farmers are now raising from 30 to 60 bushels of corn per acre where formerly they raised from 5 to 15 bushels. Where they produced from 150 to 200 lbs. of lint cotton per acre many now secure 250 to 600 lbs. Nevertheless, a demonstration agent of the Department of Agriculture has recently found negroes farming almost entirely by hand. Three persons carried on the planting of the grain: the first would dig a hole for the seed, the second would plant it and the third would cover it. He introduced the use of the plow in this twentieth century.

Scarcely any work carried on in the South today is more truly constructive or fraught with greater ultimate possibilities than that which goes forward at Tuskegee and in those other institutions of which it is the type. Since its foundation approximately 9,000 young negro men and women have received two years of industrial training. They entered with an average earning capacity of about $100 per year. Their earnings after training have averaged $700, which by the way is above the average for doctors and lawyers in Massachusetts. The average length of time that these 9,000 students have been out is 14 years and in that time their estimated earnings have been $88,200,000. Deduct from this the $12,600,000 which they might have earned without their special training and the already accrued value of that training which it cost Tuskegee $1,467,000 to impart is $75,600,000. Is there any more profitable business in which the South can engage?

We have given a brief consideration to the imperial resources of the potential South and have sketched in a few high lights, in an attempt to picture something of the South's amazing progress and achievement. Let us turn our attention to the trend and goal of her development.

SOUTHERN RURAL LIFE NEEDS ENRICHENING

The first of her problems would seem to be the organization of rural life to make it richer, more satisfying, more profitable and pleasanter. It is bound up with the problem of the reorganization of southern agriculture. The South has really not begun to farm. To prove this thesis one has only to turn to the results secured by agricultural demonstrators, demonstration farms, boys' clubs, the girls' tomato clubs, the McRae experiment in North Carolina and the output of truck farms under scientific control in many southern states. There is not a single southern crop which cannot easily be increased 500 per cent. For 2 per cent of the value of a single potential crop 20,000,000 acres of swamp land in Louisiana could be drained and the South's output of cotton doubled. There are no more fertile lands on earth than the Louisiana lowlands, and Louisiana, which might have been in ages past another Egypt, should become another and a greater Holland, and in Holland lands potentially less productive sell for $500 to $1500 per acre. Tennessee has a swamp area of 1,000,000 acres. Along the Atlantic Coast are 25,000,000 acres of sandy loam ideally adapted to intensive farming. Texas has an area of 170,000,000 acres, greater by 55,000 square miles than either France or Germany, but less than 30,000,000 acres are yet improved. It now carries over 10,000,000 head of live stock while Texas bees are worth $5,000,000 and produce each year honey and comb to the value of $5,000,000. It pays to keep a bee in Texas.

One yields in passing to the temptation to refer to the camphor trees of Florida and Texas and the date palms profitably grown on the islands near the Texas coast. But details and figures merely obscure the broad and basic proposition which is that the agricultural possibilities of the South are almost beyond conception and that in their development can profitably be employed all that enterprise, capital and science can supply for many years. Diversified, intensive agriculture by individual endeavor, corporation farming and community effort under scientific direction and control will find full scope and reap harvests unthought of now.

CONSERVATION—THE SOUTH'S FOREMOST INDUSTRIAL PROBLEM

Foremost among the industrial problems of the South would seem to be the suppression of wastes, the vastly greater development of labor values in its products and the keeping at home of money now needlessly spent elsewhere. The South has been too generally content with shipping crude materials and primary products and too ready to accept from other sections the things which it might better produce at home.

For gigantic wastes which may immediately be utilized to the enormous profit of the South, no industry is comparable to the lumbering of yellow pine. Our studies have shown that in Louisiana at least, under exceptionally able management, the products of the average yellow pine tree may be classified as follows: Needles and twigs, 2.25 per cent; limbs under 3 in., 2.54 per cent; cord wood, 6.142 per cent; pulp wood, 4.154 per cent; red and rotten, 8.05 per cent; sawdust and shavings, 17.62 per cent; lightwood, 0.61 per cent; stump 6.48 per cent; lath, 1.39 per cent; shingles, 0.06 per cent; and finally lumber and box shooks, 31.97 per cent.

Two-thirds of the tree is at present wasted either as litter in the field or as mill waste; and $3 a thousand is a good profit on lumber.

While northern paper mills are paying on the average $18.37 for the wood to make a ton of paper the South is throwing away tens of thousands of cords of pulp wood every day, only a cord and a half of which is needed to make a ton of Kraft paper worth $70. The ultimate development of a vast paper industry in the South is assured, but as a recent editorial in the New Orleans *Item* pointed out "Great industries do not spring from great opportunities. They result from the initiative of some individual. The captain of industry may create an industrial empire in a desert and bring his materials hundreds of miles from spots far more favored by nature than is their destination. We in Louisiana lack industrial empire because we lack captains of industry."

The recently culminating discoveries in a century long research have proved that 20 gallons of 95 per cent ethyl alcohol, that is, not wood alcohol, but the alcohol commonly produced from grain, may be obtained from a cord of yellow pine sawdust or hogged waste. From a bushel of corn worth say 80 cents only $2^1/_4$ gallons are obtained. Such difficulties as have attended the initial large scale operation of this process are certain to be overcome, and have in fact for the most part already been surmounted. Cheap industrial alcohol made in enormous volume from yellow pine waste and available for motor fuel, lighting, heating and a thousand miscellaneous applications in the arts is a certainty of the future.

In Georgia a great plant for the production of naval stores is shut down, primarily, it is claimed, because the annual loss of solvent represented 23 per cent of the entire plant investment. New processes promise a solvent loss of less than 2 per cent.

Several types of gas producer are now operating profitably on wood waste. New methods of controlled distillation have been developed and applied to wood and it has been proved both by the Forest Service and our own laboratory that turpentine and rosin may be profitably extracted from stumps and lightwood by processes which permit the manufacture of paper from the extracted chips. The production of lumber in the South will ultimately become a mere incident in the business of lumbering. No longer then will logging tramways be pulled up the moment the saw logs on the tract have been removed. They will stay until the tract is cleared of cord wood, pulp wood, light wood, stumps and saw logs. The cleared land will be devoted to grazing or to farming under the stimulus of demonstration farms or corporation management, and the lumber mill will become the center of a whole group of highly profitable industrial activities.

PRESENT MANUFACTURING LIMITED

Less than 30 per cent of the lumber produced in any southern state receives any further industrial handling in the state of origin. Cottonseed oil is shipped to Chicago, Berlin, and New Hampshire, to be hydrogenated and converted into lard and butter substitutes. Bauxite is sold for $5 a ton to be subjected elsewhere to the purifying treatment which raises its value to $60. The South will one day benefit enormously by a cheap process of producing alumina direct from clay. It will give new values to southern clay beds and to southern water powers and transfer the aluminum industry to this section. It does not appear, however, that any effort is being made in the southern states to develop such a process.

There are at Webster, N. C., millions of tons of low-grade nickel ore awaiting only a commercial method of extraction. Thus halloysite in large quantities occurs on Taylor's Mountain, near Gore, Ga. It contains 30 to 35 per cent of alumina, said to be soluble in dilute sulfuric acid to form a clean white alum cake almost wholly free from iron and silica. If these claims can be established there is the basis for a large industry. A single northern paper company consumes 12,000,000 lbs. of alum a year.

No locality in the United States and perhaps none in the world presents such advantages for the establishment of the great basic chemical industries as Louisiana. Here in close juxtaposition are found cheap salt, even cheaper sulfur, gas, oil, rosin, turpentine and wood waste while near-by are the coal and minerals of Arkansas and Alabama.

SMALL NUMBER OF CHEMISTS IN THE SOUTH

It is noteworthy in view of the extraordinary opportunities for chemical development presented by the South that in the southern states are to be found only about 10 per cent of the chemists of the country as represented by the membership of the American Chemical Society. The Society has 7180 members, of whom only 746 are in the entire South whereas New York has 1186 members, Pennsylvania 659, Massachusetts 511. What one chemist can do for the South has been shown by Frasch in Louisiana, by Wesson wherever cottonseed oil is made, and by our distinguished president, Dr. Herty, in the conservation of turpentine and increase of yields.

CONCLUSION

Fragmentary and utterly inadequate as this attempted presentation of southern resources has proved to be it will have served its purpose if it has brought freshly home to some of you who live in this supremely favored section of our country the responsibility for individual initiative imposed upon you. Opportunity implies responsibility. Gentlemen, you are heirs to an imperial inheritance and its responsibilities are yours.

93 Broad St., Boston

ORIGINAL PAPERS

ELECTROPLATING WITH COBALT[1]

By Herbert T. Kalmus, C. H. Harper and W. L. Savell

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In 1842, Professor Boetger pointed out that dense and lustrous deposits of nickel could be obtained, which, on account of their resistance to oxidation, great hardness and elegant appearance, were capable of many applications. The outcome of this has been that during the last 20 years commercial plating with nickel has developed to an industry of very great magnitude. On the other hand, no plates of cobalt or of its alloys have ever been in extended commercial use. No doubt part of the reason is because of the difficulty of obtaining a supply of cobalt metal at an attractive price. On the other hand, for commercial plating, where labor, overhead charges, the preparation of the surface to be plated, the difficulty of maintaining the bath, the amount of buffing, the current efficiency, and particularly the speed with which the work may be run through the baths, are so considerable a fraction of the cost of the finished work, the price of the metal to make up the anodes and the salts is by no means alone the determining factor in the choice of that metal. Moreover, the speed of plating largely determines the hardness and other physical properties of the plate, which in turn determine the weight of metal required for satisfactory commercial tests.

A great many technical points in connection with the plating of cobalt have not been investigated; the corresponding investigations for nickel have been comparatively thorough. Before platers can adopt cobalt for many purposes, on a considerable scale, a number of questions must be definitely answered by experiments, such as:

1—Can cobalt be plated on iron, steel, brass, tin, German silver, lead, etc., to yield as uniform, as adhesive, and as satisfactory a finished surface as nickel?

2—Is cobalt plate harder than nickel plate?

3—Is cobalt plate less corrosive than nickel plate under ordinary atmospheric action?

4—What bath is most suitable for the deposition of cobalt where a heavy protective coating, which may be buffed to a superior finish, is required to be deposited in a minimum of time?

5—Can a satisfactory cobalt bath be maintained at such an increased concentration as compared with the nickel bath, that plating from it may proceed with greater speed?

6—Is the cobalt bath more or less troublesome than the nickel bath as regards crystallization, etc.?

7—Should alkali, acid, or neutral baths be used for cobalt plating?

8—Is the nature of the deposit improved by hardeners such as boric acid, citric acid, magnesium salts, etc.?

9—How does the maximum current density at which cobalt may be deposited commercially compare with the maximum current densities used in the commercial deposition of nickel?

10—What electromotive force had best be used for cobalt plating, using the bath found most suitable for a given class of work?

11—How do cobalt anodes compare with nickel anodes as regards solubility, under the conditions of the plating bath?

12—What are the relative current efficiencies of cobalt and nickel plating under the best conditions?

13—How do the electrical conductivities of satisfactory cobalt and nickel plating solutions compare?

14—Can cobalt be deposited to considerable thicknesses from any solution in accordance with commercial practice?

15—What is the relative cost of cobalt and nickel plating?

Although numerous statements have been published in the past with regard to cobalt plating, the conclusions to be drawn from a survey of the existing literature and patents would lead one to be very skeptical as to the advantages of cobalt plating over nickel plating. It is noticeable, however, that the conditions for the production of good cobalt plates, as given by different authors, vary tremendously among themselves. Not only are the conclusions often diametrically opposite, as shown below, but likewise the data from which these conclusions are drawn.

Consider alone the question of the relative maximum current densities with which cobalt and nickel may be successfully plated. There is little or nothing in the literature relating to the solutions of cobalt which we have found in this laboratory to be most suitable for fast plating. If it can be shown to be practically feasible to plate cobalt from a bath at several times the speed possible for nickel, other things being equal or in favor of the cobalt, this greater speed of turning out the work, with attendant economics, might offset a very considerable difference in the initial cost of the anodes and salts of the two metals. It must certainly appeal to anyone that if cobalt-ammonium sulfate, because of its very much higher solubility than nickel-ammonium sulfate, or for other reasons, may be used as a plating bath at very much higher current densities, that with such a bath the plater might turn out cobalt plates more economically than nickel plates. Moreover, plating at greater speed means a harder and denser plate with consequent less weight of metal required.

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[1] Authors' abstract of report under the above title to the Canadian Department of Mines, published by permission of the Director of Mines, Ottawa, Canada. This publication is one of a series on the general investigations of the metal cobalt and its alloys, particularly with reference to finding increased commercial usage for them, now being conducted at the School of Mining, Queen's University, Kingston, Ontario, for the Mines Branch, Canadian Department of Mines. See also This Journal, **6** (1914), 107 and 115; **7** (1915), 6.

This paper is concerned with the presentation of a large amount of experimental data on cobalt plating. It attempts to record data, to summarize, and to draw conclusions with reference to practical cobalt plating and its application in the industries. Theoretical considerations concerning the explanation of the results are reserved for a separate publication.

A large number of plating experiments were undertaken at this laboratory in the study of the questions outlined above. Numerous types of cobalt baths were used and various concentrations of each solution. The object of this paper is to set forth the data of these experiments and the conclusions to be drawn therefrom.

LITERATURE ON ELECTRODEPOSITION OF COBALT

Langbein, in his well-known work, "Electro-Deposition of Metals,"[1] devotes nearly 175 pages to the deposition of nickel, and a scant 2 pages to the deposition of cobalt. With regard to cobalt, Langbein remarks:[1] "For plating with cobalt, the baths given under 'Nickeling' may be used by substituting for the nickel salt a corresponding quantity of cobalt salt. By observing the rules given for nickeling, the operation proceeds with ease. Anodes of metallic cobalt are to be used in place of nickel anodes.

"Nickel being cheaper and its color somewhat whiter, electroplating with cobalt is but little practiced. On account of the greater solubility of cobalt in dilute sulfuric acid, it is, however, under all circumstances, to be preferred for facing valuable copper plates for printing.

"According to the more or less careful adjustment of such plates in the press, the facing in some places is more or less attacked, and it may be desired to remove the coating and make a fresh deposit. For this purpose Gaiffe has proposed the use of cobalt in place of nickel, because the former dissolves slowly but completely in dilute sulfuric acid. He recommends a solution of one part of chloride of cobalt in ten of water. The solution is to be neutralized with aqua ammonia, and the plates are to be electroplated with the use of a moderate current."

From our experiments we find in general that the substitution of cobalt for nickel in Langbein's baths, as recommended by him, does not do justice to the metal cobalt. These baths have been primarily worked out for nickel, whereas cobalt, being in many instances of far greater solubility, requires a much more concentrated bath than that recommended for the fastest and best plating. Some of our best cobalt solutions are not included at all in Langbein's list.

MacMillan,[2] Watt,[3] and others report that cobalt deposits are harder than the corresponding nickel deposits. Brochet[4] says: "Cobalting has been proposed in place of nickeling when a deposit of greatest hardness is desired."

On the other hand Langbein,[5] Wahl[6] and others say that cobalt plates are softer than the corresponding nickel ones.

S. P. Thompson[7] finds that articles plated with cobalt are less corroded in the atmosphere of London than either silver or nickel plate, while Stolba[1] reports that cobalt salts treated like nickel salts yield metallic deposits of a steel-gray color, less lustrous than nickel and more liable to tarnish.

While some authorities report that it is practically impossible to obtain a deposit of cobalt more than a few hundredths of a millimeter in thickness, Bouant[2] says: "Electrolytic deposits of cobalt are easily obtained even of a very great thickness, so that electrodeposition of cobalt is as easy as that of copper."

A review of much of the literature on the electrodeposition of cobalt was presented at the meeting of the American Electrochemical Society, at Atlantic City, in April, 1913, by O. P. Watts. A consideration of Watts' paper emphasizes the diversity of opinion with regard to cobalt plating above mentioned.

Watts mentions about fifty solutions of cobalt which have been used with greater or lesser success. Some of these are similar to ones used by us in our experiments, but several of our best solutions are not included in the list. Many of these baths are recommended only for very weak currents, others are more or less indefinite, and there is much contradiction among them. For example, the first solution in Watts' list is—"Becquerel's solution, 37.5 grams of cobalt chloride neutralized by ammonia or potassium hydroxide, gives a brilliant, white, hard and brittle deposit; a very weak current must be used." Later, quoting from Watts, Isaac Adams says in a patent application: "I have found that a solution made and used in the manner described in the books will not produce such a continuous and uniform deposit of cobalt as is necessary for the successful and practical electroplating of metals with cobalt. * * * I have found further that the simple salts of cobalt, such as are recommended by Becquerel and others, are not such salts as could be used in practical electroplating with cobalt. * * * * * "

Even in a matter so immediate and important to the practical plater as the acidity or basicity of his plating bath, there is no general agreement among the authorities even for nickel solutions, much less for cobalt. Dr. Langbein[3] writes: "All nickel baths work best when they possess a neutral or slightly acid reaction * * an alkaline reaction of nickel baths is absolutely detrimental; such baths deposit a metal dull and with yellowish color and do not yield thick deposits." Bennett, Kenny and Dugliss, in a paper read before the American Electrochemical Society at New York City, April, 1914, state as two of their seven general conclusions the following: "A good deposit of nickel may be obtained from the double sulfate if the solution at the surface of the cathode is kept alkaline. * * * Since alkalinity is necessary for good efficiency, it is very probable that in acid solutions nickel is deposited only when impoverishment of the hydrogen ions has caused the solution to become alkaline and given the conditions under which nickel may deposit."

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[1] Dr. Geo. Langbein, "Electro-Deposition of Metals," 6th Edition Revised, Henry Carey Baird and Co., Philadelphia, p. 318.

[2] MacMillan, "Electro-Metallurgy," **1901**, p. 227.

[3] Watt-Phillips, "Electro-Plating and Electro-Refining of Metals," **1902**, p. 360.

[4] "Manuel Pratique de Galvanoplastie," **1908**, p. 313.

[5] "Electro-plating of Metals," 6th Edition, p. 319.

[6] Watt-Phillips, "Electro-Plating and Electro-Refining of Metals," **1902**, p. 360.

[7] *Journal of Institute of Electrical Engineers*, **1892**, p. 561.

[1] *Electrical Review*, Nov. 18, **1887**, p. 503.

[2] Bouant, "La Galvanoplastie," **1894**, p. 294.

[3] Langbein, "Electro-Deposition of Metals," 6th Edition Revised, p. 251.

These are but a few of many contradictory statements to be found in the literature.

SUBDIVISION AND ARRANGEMENT OF EXPERIMENTS

A very large number of plating experiments were conducted by us at this laboratory for the purposes outlined above, in connection with which some sixteen different types of solution or baths were employed and studied, as noted below:

SERIES	SOLUTIONS
I	Cobalt-ammonium sulfate.
II	Cobalt-ammonium sulfate, with an excess of ammonium sulfate.
III	Cobalt-ammonium sulfate, ammonium sulfate and citric acid.
IV	Cobalt-ammonium sulfate and ammonium chloride.
V	Cobalt chloride with ammonium chloride.
VI	Cobalt-ammonium sulfate and boric acid.
VII	Cobalt-ammonium sulfate, cobalt carbonate and boric acid.
VIII	Cobalt sulfate, potassium citrate and ammonium chloride.
IX	Cobalt phosphate and sodium pyrophosphate.
X	Cobalt-ammonium sulfate and magnesium sulfate.
XI	Cobalt sulfate, neutral ammonium tartrate, and tannic acid.
XII	Cobalt sulfate, potassium tartrate and tartaric acid.
XIII	Cobalt sulfate, sodium chloride and boric acid.
XIV	Cobalt sulfate, ammonium sulfate, magnesium sulfate and boric acid.
XV	Cobalt-ethyl sulfate, sodium sulfate and ammonium chloride.
XVI	Cobalt sulfate, ammonium sulfate, ammonium chloride and boric acid.

Each set of plating experiments with a definite group of principal components in the bath has been given a series number. Variations in concentration or changes in the relative proportions of the components or additions to a bath, have been designated by the use of letters, A, B, C, etc. Also, where a nickel bath has been used, analogous to a given cobalt bath, the data for the experiments on it are noted under the corresponding cobalt series.

There were two distinct series of plating experiments, one set conducted at this laboratory and one in the plating department of the Russell Motor Car Co., Toronto.

METHOD AND ARRANGEMENT FOR LABORATORY PLATING EXPERIMENTS

ARRANGEMENT OF ELECTRICAL CIRCUIT—Power was taken from three storage batteries connected in series, yielding approximately 6 volts. The various baths were connected independently across the 6 volt terminals of this storage-battery set, with appropriate resistance in series with each. In this way the potential across the electrodes of each was cut down to the desired value. A 5 volt range Weston voltmeter, reading to 0.01 volt, was connected directly across the electrodes of each bath. A Weston milliammeter, 600 milliampere scale, was connected in series with each bath.

PLATING TANK AND COMPUTATION OF EFFECTIVE ELECTRODE SURFACE—The plating tanks used were of glass, rectangular in shape, and of approximately the following internal dimensions: 12 in. × 6 in. × 6 in., though some were deeper.

In general, if the bath is not large in cross-section in comparison with the area of the electrodes, the results obtained will not be reproducible. We tried experiments using a tank not much larger in cross-section than the electrodes. In that case the voltage required for a given current density, with electrodes 10 cm. apart, is very much greater than with a tank of considerably larger cross-section, other conditions being the same. This is largely due to the fact that with the smaller cross-section of tank the available solution between the electrodes is diminished.

For the most part, our electrodes were approximately 3 in. × 2 in. in surface, placed from 10 to 20 cm. apart, in the center of the rectangular plating tank above mentioned. If the electrodes were kept in place, the tank lowered away from them and substituted by a very large tank of the same solution, we found that the electromotive force across the electrodes for a given current density diminished by nearly 20 per cent. The leads of the electrodes were coated with a layer of insulating asphaltum, as described in the paragraph on electrodes. In the case of these experiments, therefore, the effective electrode area is something like 20 per cent less than the exposed surface.

Again, instead of submerging electrodes of the above size in the middle of the tank, in some of our experiments the electrodes were lowered into a tank to such a depth as to be just covered by the solution. It is obvious, in this case, as we found by test, that the electromotive force across the electrodes would diminish if the height of the bath around them were raised. This is true even though no greater area of electrode is thereby covered with solution, and although the leads are insulated with asphaltum. The reason is that, with the level of solution just covering the top of the electrodes, the electrical field between the upper portion of the electrodes was limited by the surface of electrolyte, as compared with what it was with the electrodes immersed in the center of a large body of electrolyte..

Consequently had our experiments been performed in an ideally large tank, the electromotive forces would have been smaller for the same current densities. We preferred to use a bath approximating to the conditions of plating practice, and have in all cases noted, in the tables to follow, the values of current density, electromotive force, etc., just as observed, without correction.

Good practice for commercial nickel plating with many solutions, is to have about eight gallons of solution for each sq. ft. of anode surface. In our experiments we have not departed widely from this value, although we find different solutions require a somewhat different magnitude of this ratio for the best results.

THE PLATING EXPERIMENTS—The plating experiment itself consisted in noting changes in appearance of the solution and electrodes as the deposition progressed, as well as making a record of milliammeter, voltmeter and time readings at frequent intervals. The concentration of the bath was measured from time to time, and the physical properties of the resulting plate were studied. Wherever current efficiencies were desired, milliammeter readings were made at intervals at not more than two minutes. These readings were very constant in all cases, so that more frequent readings were not necessary. Also the cathode was carefully dried and weighed before and after the deposition. Precautions were taken so that conditions of weighing of the electrode before plating and after plating were identical.

Advantage was taken of the well-known fact, for the deposition of nickel and other metals, that the deposit is more adhesive when struck on initially at a higher potential than is to be used throughout the greater part of the plating run. Our practice was to diminish the resistance in series with the bath, so that an initial electromotive force of about 6 volts was used, sending very considerable currents through the bath during approximately the first thirty seconds of the run. The effect of this was uniformly satisfactory in causing the plates to adhere firmly.

After a sufficient plate had been deposited on the cathode it was removed from the bath, immediately washed in cold water, and then rinsed in boiling water until it came to a uniform temperature, after which it was dried in hot sawdust. This procedure was practiced throughout the plating experiments.

BUFFING AND FINISHING COBALT PLATES—The cathode after being removed from the plating bath and dried, is, in general, white and metallic, and requires but little buffing to produce a satisfactory mirror surface. Our practice has been to employ a large buffing wheel rotating at high speed which will "color" the work in one operation. Cobalt plates color more readily than nickel, and for commercial purposes should not require cutting with Tripoli, etc.

PREPARATION AND USE OF ELECTRODES

ANODES—Both cast and rolled anodes were used for these experiments, the cobalt employed analyzing as follows:

LAB	ANODES MADE		PERCENTAGE ANALYSES OF ANODES							
No.	No.	Size—Inches	Co	Ni	Fe	As	C	S	P	Si
H 218	2, cast	$3^{1}/_{2} \times 2 \times ^{1}/_{4}$	95.70	0.80	2.10	.....	0.040	0.043	0.004	0.050
H 219	4, cast	$3^{1}/_{2} \times 2 \times ^{1}/_{4}$	98.00	0.75	1.35	.....	0.060	0.042	0.007	0.067
H 221	4, rolled	$3^{1}/_{2} \times 2 \times ^{1}/_{4}$	95.63	0.75	3.72	0.048	0.052	0.029	0.005	.....

The cast anodes were poured in sand and smoothed down with an emery wheel to a finished surface.

The rolled anodes were made from ingots about 8 in. long and 1 sq. in. in cross-section, which were rolled down to plates of $^{1}/_{4}$ in. thickness, from which the anodes were finished.

IMPURITIES IN ANODES—Nickel anodes, as sold in the market, frequently contain in the neighborhood of 92 per cent nickel and $7^{1}/_{2}$ to 8 per cent iron. The iron is cast in the anode because pure nickel is not corroded rapidly enough under most conditions to furnish the necessary metal to the bath. Iron is a cheap material and has a solution tension enough greater than nickel to make it effective for the end in view. The greater solution tension of cobalt in the plating baths, as compared with nickel, renders practicable the use of a lesser amount of iron, or of no iron at all. Very pure cobalt anodes were readily dissolved in the solution under the conditions of many of our best plating tests. The freedom of the cobalt anode from iron no doubt has much to do with the diminished corrosion of the cobalt plate as compared with the nickel plates.

ROLLED *vs.* CAST ANODES—Cast anodes of both nickel and cobalt go into solution much more readily than the rolled anodes. With a number of each in a nickel or cobalt bath, the proportion between the two may be so chosen that the composition of the electrolyte remains constant as the anodes go into solution. If too large a proportion of cast anodes is used, the anodes dissolve with too great readiness and the bath may become alkaline. Conversely, if too large a proportion of rolled anodes is used, the solution of the anodes may not take place with sufficient readiness, and the bath may become acid and depleted in metal. The greater solubility of cobalt anodes in a number of the plating baths described in this paper, as compared with nickel anodes in the corresponding nickel bath, renders the use of a larger proportion of rolled anodes possible in the case of cobalt than is customary at present with nickel in the nickel plating trade. The greater solubilty of the cobalt anode is distinctly in its favor for practical plating purposes.

CATHODES—The cathodes for these experiments were of brass, iron or steel, and were usually $3^{1}/_{2}$ in. × 2 in. × $^{1}/_{4}$ in. in size. One side was given a high polish with emery and buffing wheels, and the other was covered with a thin coat of asphaltum varnish.

It is of the utmost importance in all plating work that the cathode be absolutely smooth and thoroughly cleansed from particles of dust, grease, etc. This was accomplished by the following procedure: Brass, steel or other stock, as required, was first machined down to the required size, after which it was smoothed down with an emery wheel and finished with an appropriate buffing wheel to a mirror surface. This left the surface with a certain amount of grease and adherent buffing material, which was removed by scrubbing with "Kalye" caustic solution. After thorough rinsing with water the electrode was immersed in dilute hydrochloric acid, or in dilute potassium cyanide solution and again thoroughly rinsed with water. It was then ready for use in the bath.

In addition to smooth plane cathodes, a number of them were prepared by cutting patterns and depressions on one side. These were used in the same manner as the smooth ones after cleansing and buffing as described.

PREPARATION OF SALTS

The ammonium sulfate, ammonium chloride, boric acid, citric acid, potassium citrate, tannic acid, sodium sulfite, sodium phosphate, ammonium tartrate, and magnesium sulfate used for these experiments were Merck's chemically pure, purchased from a supply house, as were the reagents used in the preparation of the cobalt salts.

All cobalt compounds used for these experiments were prepared at this laboratory, and the method of preparation of each is given as follows:

COBALT SULFATE was prepared by dissolving Co_3O_4 in HCl and adding an equivalent of H_2SO_4. The solution was then evaporated to drive off HCl and crystallize $CoSO_4.7H_2O$. The crystals were collected in the usual manner and heated in the presence of H_2SO_4 until SO_3 fumes disappeared and the salt became dehydrated. Or the collected crystals were recrystallized in the usual manner where dehydrated salt was not desired.

COBALT-AMMONIUM SULFATE was prepared by mixing hot solutions of cobalt sulfate and ammonium sulfate containing molecular proportions of each of the salts. As the cobalt ammonium sulfate is less soluble than either of the single salts, most of the crystallization was effected in the hot mixed solution. The crystals were collected and washed with alcohol.

COBALT CHLORIDE was prepared by dissolving Co_3O_4 in HCl, and after filtering off the excess CO_3O_4, crystallizing the salt and collecting and washing the crystals in the usual manner.

COBALT ETHYLSULFATE—Ethyl alcohol and concentrated sulfuric acid were heated together to form ethyl sulfuric acid. This was then neutralized with calcium carbonate and the calcium ethyl sulfate crystallized by evaporation of the solution after filtering off precipitated calcium sulfate. The crystals were re-dissolved and the calcium precipitated as calcium sulfate by adding sulfuric acid in molecular proportion, reforming ethyl sulfuric acid. Freshly precipitated cobalt hydroxide was added to this acid until it failed to dissolve any more. The cobalt-ethyl sulfate was crystallized by evaporation. The crystals were collected and washed in the usual manner.

SOLUBILITIES OF COBALT AND NICKEL SALTS

The relative solubilities of cobalt sulfate and nickel sulfate, and of cobalt-ammonium sulfate and nickel-ammonium sulfate are important in considering the greater conductivities of the cobalt solutions as compared with the corresponding ones of nickel. These solubilities are considered later when discussing the greater speed of cobalt plating, and as well in considering the saturation concentration of some of the baths employed, so that a brief table of solubilities at room temperature is given herewith.

Grams of salts dissolved by one liter of water		° C.	Comey(*a*)	Kraut(*b*)	This Lab.
$CoSO_4$	anhydrous	23	362	380	362.2
$NiSO_4$	anhydrous	23	405	379	363
$Co(NH_4)_2(SO_4)_2$	anhydrous	23	171	171	164
$Ni(NH_4)_2(SO_4)_2$	anhydrous	23	66	66	72.8

(*a*) A. M. Comey, "A Dictionary of Chemical Solubilities," MacMillan and Co., **1896**.

(*b*) Gmelin, Kraut's "Handbuch der anorganischen Chemie," **1909**, Vol. V, Sect. 1.

The salts actually used in making up the solutions were $CoSO_4.7H_2O$, $NiSO_4.7H_2O$, $CoSO_4.(NH_4)_2SO_4.6H_2O$ and $NiSO_4.(NH_4)_2SO_4.6H_2O$.

From the above table it is apparent that the solubilities of cobalt and nickel sulfates are not very different. These, however, do not lend themselves to satisfactory plating solutions without adding various other compounds to them. On the other hand, cobalt-ammonium sulfate is approximately 2.5 times as soluble as nickel-ammonium sulfate. As will be shown in the sequel, from the experiments performed, the saturated solution of this cobalt-ammonium sulfate offers an extremely rapid and satisfactory plating bath.

CURRENT DENSITIES

Unless specifically stated to the contrary, the current densities given in the tables to follow and throughout the text are cathode current densities; that is, they were computed by dividing the total current by the cathode area.

An approximate notion of the anode current density may be obtained from the following statement, although it is impossible to compute it with any degree of accuracy: At the beginning of each experiment, the anode was smooth and of approximately the same area as the cathode (see above), but as the experiment proceeded, the anode gradually increased in effective area, due to unequal corrosion of its surface. At the end of some of our experiments the anode area may have been more than twice that of the cathode.

In our conclusions and through the text of this paper we speak of allowable current densities with the various solutions, and we recommend certain ranges of current density which are permissible for the best plates. In every case these are cathode current densities, but are, of course, only valid with a sufficient anode area. We have conducted our experiments under conditions which might be called good standard practice for plating shops, which means, so far as anode area is concerned, that the anode area was in every case greater than, and in many cases, twice that of the cathode area.

EFFICIENCY TESTS

Efficiency tests were made in the usual manner by carefully weighing the quantity of metal deposited in a measured time and comparing it with the theoretical amount of metal which should have been deposited in accordance with Faraday's laws. The data for these tests for each important solution are given in Table VI, page 392.

AGING TESTS

With all the plating baths which were found to be satisfactory or promising, both aging and efficiency tests were run. The aging tests were for the purpose of ascertaining the constancy of the bath during continued use for plating over a considerably longer period than was necessary for our experiments. The solution was analyzed for cobalt content and tested for acidity and alkalinity at intervals of 15 hours during plating runs of 100 or more hours duration. This was in addition to the series of runs already made with the given bath, operating with it to produce the plates studied. The results of these aging tests are given in Table VII, page 392.

LABORATORY EXPERIMENTS—ELECTRODEPOSITION OF COBALT

SERIES I—COBALT-AMMONIUM SULFATE SOLUTIONS

Langbein recommends for the nickel bath of the type *IA*, with an electrode distance of 10 cm., an electromotive force of 3 volts; he states that this will give a current density of 0.3 ampere per square decimeter.[1]

We wished to compare the cobalt solution *IA* with the corresponding nickel solution as regards their relative specific electrical conductivities or with regard to the electromotive force necessary to give a specific current density through each, other conditions being the same. An experiment was tried using solution *IA*, with which was compared the following nickel-ammonium sulfate solution:

Nickel sulfate, $NiSO_4$	Ammonium sulfate, $(NH_4)_2SO_4$	Water
30.9 grams	26.3 grams	1000 cc.

Using the proper current to obtain a current density of 0.3 amp. per sq. dm., with the cobalt solution *IA*, it was found that the potential difference between the electrodes was 0.88 volt. With the identical electrodes and with the same distance between them, namely 10 cm., using the nickel solution, the potential difference between the electrodes was 2.1 volts. Thus we have the very great difference between 0.88 volt and 2.1 volts required to give the same current density with these two solutions, other conditions being equal, which means that the cobalt solution is of very much lower specific electrical resistance than the nickel solution.

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[1] Langbein, "Electro-Deposition of Metals," 6th Edition Revised, p. 252.

Thus, in the first series of experiments with cobalt-ammonium sulfate and nickel-ammonium sulfate, we found a result which ran uniformly throughout our plating experiments, *viz.*, that the conductivity of the cobalt bath was considerably higher than that of the corresponding nickel bath.

The last 90 hours plating with Solution I*A* were with a current density of 0.60 amp. per sq. dm. It was, therefore, clear that this solution was not changing rapidly, and that the anode was dissolving satisfactorily. The slight increase in concentration was accounted for by evaporation. Very similar results were obtained with iron and steel cathodes in place of the brass ones.

Bath I*A* was not thought sufficiently important to warrant a similar series of experiments being made with the corresponding nickel bath for comparison.

The last 90 hours plating with Solution I*B* were performed at a current density of 3.0 to 3.5 amp. per sq. dm. The cathode area was 34.0 sq. cm. This solution was neutral to litmus paper, but very slightly alkaline as shown by titration with $N/10$ HCl and litmus indicator. The solution remained absolutely constant and the cobalt anode dissolved satisfactorily.

A number of the plates from Solution I*B* were given a very severe bending test to study their adhesive qualities. In every case the plates stuck to the cathode after being bent backwards and forwards at an angle of nearly 180°, in a manner equal to, if not better than, that of the best nickel plates with which we are familiar, subject to a similar test. Even after the surface of the metal base had started to break, the cobalt plate still continued to cover the furrows and ridges formed.

The data of the plating experiments for Solution I*B* show this solution to be remarkable for the extremely high-current densities, at which satisfactory plates may be obtained. We find no record of nickel plating being accomplished, except under special conditions, such as with rotating cathodes, at anything like the same speed.

It is fairly well recognized that any improvement in the chemical composition of solutions for nickel plating, in order that a faster rate of deposition may be brought about, would have to be based upon a higher concentration of the nickel ion in the solution. The inventors of "Prometheus," "Persels" and other salts for concentrated nickel solutions, no doubt had this in mind. These new baths are of comparatively recent invention, and there is considerable diversity of opinion as to their merits.

The practical plater knows that he can carry in his plating bath 12 oz. of double nickel salt per gallon of water in the summer, and about 9 oz. of the same salt per gallon in the winter, without danger of frequent crystallization. Taking the higher of these figures, we have a bath equivalent to about 80 grams $(NH_4)SO_4.NiSO_4.6H_2O$ per liter. This solution contains approximately 1.5 per cent metallic nickel. On the other hand, using the Prometheus salts as bought on the market, as much as 2 lbs. may be dissolved to the gallon of water without danger of crystallization in the summer. Since this Prometheus salt contains about 28 per cent of $NiSO_4$, this bath will contain approximately 2.6 per cent of metallic nickel in solution. This tremendously increased metal content of the latter bath accounts for the greater speed at which plating is possible with it.

Comparing the cobalt solution I*B* with this, we note that it contains 200 grams of $CoSO_4.(NH_4)_2SO_4.6H_2O$ to the liter, so that its concentration in metallic cobalt is approximately 3.0 per cent. We would, therefore, expect this solution to be a very rapid plating one, faster than the other, as we find it, but the figures do not account for the great difference between the solutions. It has the advantage of being free from magnesium sulfate, boric acid and the like, which are very considerable and necessary constituents of all the concentrated fast plating nickel solutions. Moreover, we find with all solutions of this type that the cobalt bath is a much more rapid plating one than the nickel bath, taking them at the same concentration. Experiments conducted under conditions of present plating practice demonstrated that Solution I*B* was capable of plating cobalt satisfactorily at several times the speed that the Prometheus salt was capable of plating nickel (see Series I). This comparison was for the best condition for each that was known to the practical plater in charge of the plating establishment in question, and to us as a result of these experiments.

CONCLUSIONS: 1—Cobalt plates from these cobalt-ammonium sulfate solutions, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface. They take a very high polish, with a beautiful luster, which although brilliantly white, possesses a slightly bluish cast.

2—The specific electrical conductivity of these cobalt-ammonium sulfate solutions is very much higher than that of the corresponding nickel solutions.

3—All of these cobalt plates within the current density ranges described as satisfactory, are as smooth, adhesive and generally satisfactory as the best nickel plates.

4—Solution I*A* does not lend itself to extremely fast plating like I*B*, but satisfactory plates may be obtained with it at current densities up to 0.80 amp. per sq. dm.

5—Solution I*A* may be used at higher current densities than the corresponding nickel solution, for which Langbein recommends a current density of 0.30 amp. per sq. dm.

6—Solution I*A* does not change appreciably in cobalt content or in acidity when used over long periods of time at the recommended current densities.

7—Solution I*B*, which is a nearly saturated solution of $CoSO_4.(NH_4)_2SO_4$, containing 200 grams of $CoSO_4.(NH_4)_2SO_4.6H_2O$ to the liter of water, yields satisfactory cobalt deposits at all current densities up to 4 amp. per sq. dm., *i. e.*, 37.2 amp. per sq. ft. This very rapid plating was performed in a manner similar to that of common plating practice.

8—There is no nickel bath operating in the manner of the usual commercial plating procedure at anything like as high a current density as cobalt bath I*B*. More specifically, the allowable current density with which an adherent, firm, smooth, white, hard plate may be obtained with Solution I*B*, without sign of pitting or peeling, and yet which may be readily and satisfactorily finished, is four times that for which the same results may be obtained with the fastest commercial nickel solutions.

9—Both baths I*A* and I*B* may be used for plating on the usual surface, including brass, iron and steel. No preliminary coating of copper is necessary when plating with these baths on iron and steel.

10—Solutions I*A* and I*B* may both be used with a large proportion of rolled anodes without becoming acid or depleted in metal.

11—Solution I*B* does not change appreciably in cobalt content or in acidity when used over long periods of time at the high recommended current density.

12—The current efficiency of Solution I*B* is extremely high at a current density of 1 ampere per sq. dm. The mean of our measurements, which agree very well among themselves, gave a value of 98.0 per cent. The current efficiency of Solution I*B* is as high at 3 amp. per sq. dm. as is common for the best nickel solutions that are used in nickel plating practice at very much lower current densities. The average of three current efficiency measurements with Solution I*B*, at 3 amp. per sq. dm., which measurements agreed very well among themselves, was 90.5 per cent.

13—Solution I*C* is intermediate in concentration between I*A* and I*B* and its properties, as regards speed and quality of the plates to be obtained therefrom, are correspondingly intermediate. It is not nearly so rapid or as satisfactory at high current densities as *IB*.

14—Solution *IB* should be run neutral, for these plates are adherent, firm, smooth, white, hard, yet easily buffed to an excellent finish. When operated slightly alkaline it yields plates which are grayish in color, which peel, pit, and show blisters. When operated acid it yields plates that, while fairly adherent, firm and smooth, are dark and freakish.

15—Solution *IB* requires very little, if any, aging to put it in condition, but yields satisfactory plates almost from the start.

16—The "throwing" power of Solution *IB* is remarkably satisfactory.

17—The anodes in Solution *IB* are remarkably free from the coating that characterizes nickel anodes.

Solution *IB* showed so many superior qualities that it seemed highly worth while to develop it further, and particularly to study it under exact commercial conditions. This work is reported later under "Commercial Tests," page 394.

SERIES II—COBALT-AMMONIUM SULFATE SOLUTIONS WITH AN EXCESS OF AMMONIUM SULFATE

Series II was prepared with the view of increasing the conductivity of Solution I by adding a relatively larger amount of ammonium sulfate.

Solution II does not give good results above 0.90 amp. per sq. dm.

With an unboiled solution, very dark, unsatisfactory plates were obtained at current densities between 0.30 and 0.62 amp. per sq. dm.

This solution was not thought of sufficient importance to warrant making a series of tests with rolled anodes, or aging and efficiency tests.

CONCLUSIONS: 1—Cobalt plates from this cobalt sulfate and ammonium sulfate solution, with an excess of ammonium sulfate, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface, within the narrow range recommended for them. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

2—The specific electrical conductivity of Solution II is considerably higher than that of the corresponding nickel solution.

3—Solution II is not a fast-plating solution, and can be used only at current densities up to about 0.90 amp. per sq. dm. This bath is not nearly so rapid nor so satisfactory as others described.

4—Solution II is an analog of one proposed by Langbein for nickeling, of which he says that the nickel deposit piles up, especially in the lower portion of the object; that is, the lower part of the cathode becomes dull, burned or over-nickeled. This takes place with the nickel solution at current densities about 0.35 amp. per sq. dm., and consequently the cobalt solution is a very great improvement, as regards speed, on the corresponding nickel solution.

5—Solution II requires to be boiled at the outset to yield satisfactory plates. Otherwise the plates are dark, even at low current densities.

6—Solution II, after operating a number of hours, tends to become acid. This acid may be neutralized with ammonia, and the solution re-acidified with boric acid, to yield satisfactory plates. However, on this account and for others mentioned, this solution is not nearly as satisfactory as some others described, since it is not self-sustaining.

SERIES III—COBALT-AMMONIUM SULFATE WITH AN EXCESS OF AMMONIUM SULFATE AND CITRIC ACID

A bath which was formerly in extended use for nickel plating is prepared by boiling 34.5 grams nickel sulfate, with 50.3 grams ammonium sulfate and adding 4.2 grams citric acid to the liter of water. Analogous to this, Solution III*A* was made up, when it was found to be not very satisfactory; 1.7 grams sodium sulfite were added to the liter, making Solution III*B*. No reagent was added during the experiments with the solutions of Series III, either to neutralize them or for any other purpose.

Solution III*A* was not thought to be of sufficient importance to warrant running a series of experiments with rolled anodes.

The last 90 hours plating with Solution III*B* was at a current density of 1.0 amp. per sq. dm. The cathode area was 34.0 sq. cm. The cobalt content and alkalinity of this solution were remaining approximately constant.

For comparison with Solutions III*A* and *B*, a set of runs on the corresponding nickel bath, Solution III*C*, was made.

Solution III*D* resembled III*A*, but was considerably less concentrated in cobalt and ammonium sulfates.

Solution III*D*, after being used for plating approximately 35 hours, became somewhat alkaline. In comparison, Solution III*C*, the corresponding nickel bath, was tested after running with the same current for an identical time. It was found to be practically in the same condition as regards alkalinity as at the start. Cast anodes were used in both of these baths throughout these runs, which were made partly for the purpose of testing the relative solubility of the anodes. This result confirmed a conclusion to be generally drawn from all our experiments, that in baths of this type the cast cobalt anodes are more soluble than the cast nickel anodes.

Solution III*E* is more than twice as saturated in cobalt sulfate as III*A*, and more than three times as saturated in cobalt sulfate as III*D*. The last 45 hours of plating with Solution III*E* was at a current density of 3.0 amp. per sq. dm. The 45 hours preceding this was at a current density of 4.75 amp. per sq. dm. This solution was gradually becoming more alkaline and its cobalt content increasing. The solution was obviously changing too rapidly to be satisfactory, but with an increased number of rolled anodes replacing cast ones, it might be used.

CONCLUSIONS: 1—Cobalt plates from the solutions of Series III on brass and iron, are firm, adherent, hard and uniform and may readily be buffed to a satisfactory finish, within the current density range recommended. They take a very high polish, with a beautiful luster, which, although brilliantly white, posseses a slightly bluish cast.

2—Solutions III*A*, *B* and *D* do not lend themselves to extremely fast plating, but satisfactory plates may be obtained from them at current densities up to 0.80, 1.0 and 0.80 amp. per sq. dm., respectively.

3—Solution III*B* maintained itself substantially constant as regards cobalt content and alkalinity during 114 hours of plating. Its current efficiency is satisfactorily high.

4—Solution III*E*, which is very much more concentrated in cobalt than the other solutions of this series, yields satisfactory plates at all current densities up to 1.5 amp. per sq. dm.

5—Solution III*E*, when used with cast anodes, gradually becomes more concentrated in metallic cobalt content, and increasingly alkaline. For this reason this solution can be used only with care, and is probably not satisfactory for general commercial plating purposes.

6—The current efficiency of Solution III*E* is extraordinarily high as compared with that of the usual commercial nickel plating solutions.

7—The current efficiencies of all the solutions of Series III are high and well over 90 per cent at the recommended current densities.

8—A number of experiments with Solution III*C* and Solution III*E* were run simultaneously, with the same current density, electrode distance and electrode area. The E. M. F. across the nickel bath was from 2 to 2.5 times as great as that across

TABLE I—EXPERIMENTAL DATA OBTAINED WITH SOLUTIONS OF SERIES I AND II

SOLUTION IA	SOLUTION IB	SOLUTION IC	SOLUTION II
Co and NH_4 in molecular proportions $CoSO_4$ $(NH_4)_2SO_4$ Water Bath 30.9 g. 26.3 g. 1000 cc. 3 liters Somewhat more than 1/3 saturated Analogous to nickel plating solution recommended by Dr. Langbein	Co and NH_4 in molecular proportions $CoSO_4(NH_4)_2SO_4.6H_2O$ Water 200 g. [= 145 g. $CoSO_4(NH_4)_2SO_4$] 1000 cc. Solution nearly saturated No additions to maintain neutrality Sp. gr. at 15° C. = 1.053	Co and NH_4 in molecular proportions $CoSO_4$ $(NH_4)_2SO_4$ Water Bath 40.0 g. 34.0 g. 1000 cc. 2.5 liters Intermediate in concentration between IA and IB	Co and NH_4 not in molecular proportions $CoSO_4$ $(NH_4)_2SO_4$ Water 16.7 g. 56.7 g. 1000 cc. Not nearly saturated with $Co(NH_4)_2(SO_4)_2$ Neutralized with NH_4OH, if too acid Boiled in preparation and prior to using

Sol. No.	Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Electr. dist. Cm.	Cathode area Sq. cm.	Plating time Hr.	Min.	Character of Deposit
IA—CAST ANODES—BRASS CATHODES								
	6/ 8	0.30	2.45	46	27.3	2	30	Fairly bright, hard, pitted at bottom.
	8	0.30	2.75	45	27.3	1	0	Light gray, somewhat pitted at bottom.
	22	0.30	0.75	10	27.3	2	0	Bright and smooth, not lustrous.
	25	0.45	0.83	10	27.3	4	0	Heavy metallic, lustrous, slightly spotted.
	27	0.50	0.80	10	27.3	3	0	Metallic, lustrous, streaked and spotted.
	24	0.60	1.06	10	27.3	2	0	Metallic, uniform, not lustrous.
	25	0.80	1.27	10	27.3	3	0	Uniform, metallic, lustrous.
	27	0.90	2.03	20	27.3	1	30	Bright, smooth, bottom rough but not burned.
	26	1.0	1.52	10	27.3	1	30	Uniform; lower corners burned, dull color.
	30	1.0	2.25	20	27.3	1	30	Uniform, extremely bright, thoroughly satisfactory surface when polished.
Solution boiled								
	7/ 3	1.0	2.45	20	27.3	2	30	Uniform, bright; edges slightly burned.
	23	1.25	2.00	10	27.3	1	15	Dark; badly burned at edges, bright in center.
	23	1.50	2.10	10	27.3	1	15	Burning more marked than preceding.
ROLLED ANODES—BRASS CATHODES								
	16	0.80	2.0	10	37.0	1	0	Exceptionally good; white, uniform.
	17	1.0	2.0	17	37.0	1	0	Slightly burned at upper edges.
	17	1.0	2.75	17	37.1	1	0	Clean, smooth, bright; peeled upon heating in boiling water for a few minutes.
ROLLED ANODES—ZINC CATHODES								
	17	0.50	0.83	10	30.1	1	0	Very rough surface, unlike anything obtained on brass or steel. Under microscope metal appeared to be deposited in small irregular masses and not to be polished.
IB—CAST ANODES—BRASS CATHODES								
	7/17	0.75	1.0	17	37.1	1	30	Bright, uniform, glossy; little buffing gave satisfactory surface.
	17	1.0	1.5	19	37.1	1	30	
	21	1.0	1.5	24	23.7(a)	1	0	Good, smooth, bright plate over entire surface.
	8/ 3	1.0	1.70	19	23.7	2	0	Very satisfactory; hard, bright, easily buffed.
	7/18	1.2	1.95	19	37.1	1	0	Bright, uniform, glossy; little buffing gave satisfactory surface.
	22	1.2	1.7	24	23.7(a)	1	0	Beautiful smooth plate over entire surface. High and low spots evenly coated.
	22	1.5	2.05	24	23.7(a)	2	0	Very smooth and bright, beautiful finish after slight buffing. Uniform thickness on high and low spots. Plate 0.062 mm. thick.
	30	1.5	1.20	10	Polished steel knife	1	30	Bright, smooth, even, hard, satisfactory.
	8/ 5	1.5	2.1	16	37.1	1	30	Beautiful, bright, smooth; easily buffed to mirror surface.
	7/22	1.7	2.4	24	23.7(a)	1	15	Very smooth and bright. Beautiful finish after slight buffing. Uniform thickness on high and low spots.
	23	1.8	2.55	24	23.7(a)	2	45	
	24	2.0	2.85	24	28.0(a)	2	15	Beautiful, white, hard, lustrous; no sign of burning or scaling.
	28	2.2	3.35	24	27.3(a)	1	30	
	28	2.5	3.75	24	25.0	2	45	Very smooth, even, hard; white, beautiful, satisfactory finish after slight buffing. No signs of burning.
	28	2.7	2.25	23	22.2	1	15	
	31	3.5	3.0	22	20.0(a)	1	30	
	31	4.0	2.9	20	18 (a)	1	0	
	8/ 3	4.5	4.9	20	27.5	1	30	Fairly uniform and bright; darkened at edges. Began to peel at one corner.
	3	4.5	3.0	10	27.5	1	30	Similar to last; burning slightly marked, but no peeling.
	3	4.5	2.95	10	27.5	1	0	Similar to previous; burning not quite so marked. Buffed satisfactorily; slightly pitted, due to gas bubbles.
ROLLED ANODES—BRASS CATHODES								
	9/ 1	0.39	0.44	10	26.2	2	0	Smooth, uniform, white; readily buffed to mirror surface.
	8/31	0.61	0.55	10	26.7	2	0	
	5	1.0	1.6	16	37.0	24	0	Very bright and metallic; split at one place; easily removed from cathode. Plate 0.34 mm. thick at edge, 0.24 mm. at center.
	9/ 2	1.0	0.77	10	27.0	1	0	Smooth, uniform, white; readily buffed to mirror surface.
	8/ 4	1.5	2.2	16	37	16	0	Beautiful, bright, smooth; began to separate from cathode at one corner.
	9/14	2.0	1.30	10	26.5	0	45	Very even, smooth; good luster when polished.
	15	3.0	1.32	10	20.0	0	20	White; good luster when polished; somewhat rough on bottom, showing heavier deposit there; also small furrows from gas streaks.
	14	4.0	1.35	10	11.7	0	15	Splendid white deposit; cracked a short distance in one place.
	15	4.0	1.35	10	11.7	0	25	Good, white; rough on bottom, showing heavier deposit there; also very small furrows from gas streaks.
	8/ 4	4.25	4.25	20	27	1	15	Burned, but not so badly as 4.5 amperes current density.
	4	4.5	4.60	18	27	1	0	Burned along edges.
IC—The electromotive force across the electrodes was progressively increased so that a series of plates was obtained at current densities from 0.30 to 1.25 amp. per sq. dm. in the manner shown in the data for Solutions IA and IB. (See descriptive text.)								
II—CAST ANODES—BRASS CATHODES								
	9/18	0.31	0.91	10	39.4	1	15	Good, white, even, smooth; required almost no buffing to give fine luster.
	18	0.56	1.18	10	33.6	1	15	Good, white, uniform; fine luster when polished.
	18	0.60	1.25	10	33.6	0	45	
	18	0.75	1.35	10	38.7	0	45	
	24	0.90	1.27	10	38.7	4	0	Bright, evenly deposited; not lustrous.
	25	1.0	1.30	10	38.7	3	0	Smooth and bright; somewhat spotted.
	27	1.0	1.55	10	38.7	3	0	Dark; bright with buffing.
This run immediately followed one at current density 1.4. After the former the solution was found rather too acid and was neutralized with ammonia and slightly acidified with boric acid.								
	29	1.0	2.10	20	38.7	2	0	Dark; polished brightly.
	6/29	1.0	2.10	20	27.3	2	0	Dark; buffed to satisfactory brilliant surface.
	7/ 2	1.0	1.4	10	27.3	2	0	Badly burned over entire surface.
	3	1.0	1.95	20	27.3	2	0	Very black with rough, grainy surface. Burned at sides and at bottom.
	13	1.0	2.05	15	39.3	2	0	Very poor; black and polished with difficulty.
	14	1.0	2.05	15	....	1	30	Very unsatisfactory; black and grainy.
Bath stirred by bubbling air through it.								
	15	1.0	1.42	15	....	1	30	Not hard; burned on sides; generally unsatisfactory.
	6/26	1.4	1.95	10	27.3	3	0	Dark and badly burned.

(a) When cobalt plate was dissolved off in nitric acid, grooves lost their plate first, showing thinner deposit there than on higher places.

the cobalt bath. This is evidence, as noted throughout these experiments, of the greater conductivity of the cobalt solutions.

9—Solution IIIC is very concentrated in nickel salt, and is more satisfactory than the corresponding cobalt solution of the same concentration. However, the corresponding cobalt solution is not nearly saturated. The comparison with an equally saturated similar cobalt solution, IIIE, is in favor of the cobalt solution, for it will operate at higher current densities than IIIC, and yields a plate which is just as satisfactory in appearance and harder.

10—These solutions operated alike plating on iron, steel and brass, for which metals only the above conclusions apply.

11—Cobalt anodes are more readily soluble than nickel anodes in the solutions of Series III, and consequently a larger

TABLE II—EXPERIMENTAL DATA OBTAINED WITH SOLUTIONS OF SERIES III AND IV

G. per l. water	SOL. III*A*	III*B*	III*D*	III*E*	III*C*
$CoSO_4$	34.5	34.5	25.7	78.5	34.5 g. $NiSO_4$
$(NH_4)_2SO_4$	50.3	50.3	31.5	129.7	50.3
Citric acid	4.2	4.2	4.5	13.7	4.2
Addition	None	1.7 g. Na_2SO_3	None	None	None
Total bath (l.)	1.0	3.0	....	....	3.0

SOLUTION IV*A*

Grams per liter water			Total
$CoSO_4$	$(NH_4)_2SO_4$	NH_4Cl	bath
23.5	20.0	30.0	2.5 l.

No additions to solution
Sp. gr. = 1.043 or 6.0° Bé

SOLUTION IV*B*

Grams per liter water				Total
$CoSO_4$	$(NH_4)_2SO_4$	NH_4Cl	Boric acid	bath
23.5	20.0	18.2	9.5	2.5 l.

Slightly acid to litmus. NH_4OH added, then boric acid to slight acidity

Sol. No.	Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Electr. dist. Cm.	Cathode area Sq. cm.	Plating time Hr.	Plating time Min.	Character of Deposit
III*A*—CAST ANODES—BRASS CATHODES								
	6/10	0.20	1.5	10	27.3	1	30	Uniform, very dark; susceptible to bright polish with buffing.
	25	0.50	1.25	10	27.3	3	0	Black but smooth.
	29	0.50	1.39	20	27.3	1	0	Slightly dark; buffed to beautiful bright, clean surface.
	30	0.80	2.13	20	27.3	1	30	Scaly, peeling easily; not satisfactory.
	25	1.0	2.35	10	27.3	1	30	Uniformly black and unsatisfactory.
III*B*—CAST ANODES—STEEL AND BRASS CATHODES								
	7/20	0.30	1.06	10	Steel, 60.0	1	15	Satisfactory and adherent.
	10	0.30	0.65	15	Brass, 27.3	2	0	Very smooth, hard; buffed to bright, silvery white finish.
	20	0.40	1.0	10	Steel, 60.0	1	15	Satisfactory smooth, adherent.
	27	0.40	1.0	10	Brass, 31.5	2	30	Smooth, uniform; slightly dark in color; peeled at edges after removal from bath.
	6/30	0.50	1.25	20	27.3	1	30	Bright, hard, good color after polishing. No signs of pitting.
	7/ 3	0.50	0.86	..	27.3	1	30	Extremely bright, smooth; free from all flaws; buffed to beautiful surface.
	8/ 3	0.80	0.96	10	39.3	2	0	Very white, uniform; satisfactory except for slight scaling on one side.
	7/11	0.80	1.35	15	27.3	1	30	Very smooth, even; buffed to satisfactory surface.
	13	1.0	1.65	15	27.3	1	30	Scaled off; unsatisfactory.
	2	1.0	2.07	20	27.3	3	0	Clean, hard, uniform; buffed to beautiful surface.
	6/26	1.36	1.86	10	31.5	3	0	Smooth, uniform; dark in color.
	26	1.7	2.1	10	24	1	30	Unsatisfactory; split.
ROLLED ANODES—BRASS CATHODES								
	17	1.0	2.5	15	37	1	0	Clean, smooth; black.
III*C*—CAST ANODES—BRASS CATHODES								
	7/16	0.30	1.25	10	Steel, 39.3	1	30	Scaled easily.
	13	0.34	1.28	10	Brass, 39.3	1	30	White and uniform.
	31	0.50	1.45	10	39.4	2	0	Satisfactory except for pitting; easily polished.(*a*)
	22	0.50	1.45	10	39.3	1	30	Brilliant white; buffed satisfactorily. Decidedly softer than one from Co Bath III*E* same date, which was run and buffed simultaneously.
	22	0.50	1.45	10	39.3	1	30	
	23	0.90	2.35	10	46.6	1	0	Bright metallic, lustrous. Readily buffed to satisfactory mirror. Whiter and softer than Co plate Solution III*E*, run simultaneously.
	14	1.0	2.15	10	39.3	1	30	Bright, pitted.
	14	1.0	2.6	10	39.3	1	30	Bright, pitted on surface; beautiful surface after buffing.
	14	1.0	2.6	10	37.1	1	30	Satisfactory except for few small pits.
	24	1.0	2.36	10	39.3	1	30	Darkness on edges; buffed satisfactorily.
	24	1.0	2.36	10	39.3	1	30	White; difficult to polish to satisfactory mirror surface; slightly pitted.
	25	1.07	2.56	10	39.3	1	30	Scaled slightly at lower edge.
	28	1.25	2.60	10	39.4	1	45	Dull color; buffed to satisfactory mirror surface with difficulty.
	29	1.50	2.75	10	27.3	2	0	Dull and burned.
	14	1.5	2.75	10	27.3	1	30	Bright with pits and scaling at bottom.
ROLLED ANODES—BRASS CATHODES								
	31	0.50	2.85	10	39.3	2	0	Very satisfactory; white; readily polished to mirror surface.
	31	0.80	3.30	10	39.3	2	0	
III*D*—CAST ANODES—BRASS CATHODES								
	7/14	0.30	1.06	15	37	3	0	Black; buffed satisfactorily, except for small pin holes.
	7	0.50	1.36	15	37	3	0	Dark; buffed satisfactorily.
	7	0.50	1.33	15	37	3	0	
	7	0.70	1.80	15	37	3	0	Bright but slightly rough.
	11	0.90	1.89	15	37	3	0	Dull and pitted. Current density too great.
	11	0.90	1.90	15	37(*b*)	3	0	
	17	1.0	....	15	37	1	0	Clean, smooth; dark.
	7	1.0	2.02	15	37	3	0	Very dull; current density too high.
	7	1.0	2.0	15	37	3	0	Dull and pitted. Current density too great.
	13	1.0	2.0	15	37(*b*)	3	0	
III*E*—BRASS CATHODES								
	7/21	0.50	0.76	10	39.3	2	0	Very bright uniform.
	22	0.50	....	10	39.3	2	0	Bright, satisfactory.(*c*)
	28	0.62	0.87	10	Steel, 20	3	0	Dark gray; metallic luster; very little buffing produced mirror surface. Satisfactory in all respects.
	22	0.70	0.90	10	Brass, 39.3	2	0	Plate bright and satisfactory.(*d*)
	21	0.80	0.82	10	39.3	2	0	Very smooth; somewhat dark; polished to brilliant mirror surface.(*e*)
	23	0.80	0.97	10	39.3	2	0	
	23	0.90	1.0	10	46.6	1	0	Satisfactory, readily buffed to mirror surface.(*f*)
	21	1.0	1.03	10	39.3	2	0	Very smooth, somewhat dark; polished to brilliant mirror surface.
	24	1.0	1.05	10	39.3	2	0	Scaled off when put in boiling water.
	24	1.0	1.05	10	39.3	2	0	Dark though lustrous with no sign of scaling.
This plate was darker than corresponding Ni plate as removed from the bath. See III*C*, July 24th, 1.0 amp., although the Ni plate required more polishing to produce a mirror surface.								
	25	1.07	1.19	10	39.3	2	0	Rather dark; showed signs of burning.
	28	1.25	1.31	10	39.3	1	45	Dark gray. Very little buffing produced mirror surface.
	29	1.5	1.35	10	27.3	2	0	Somewhat dark, readily buffed to perfect mirror surface.
Co plate considerably harder than corresponding Ni plate when both were ground.								
	31							Bath becoming alkaline, which was neutralized by small addition of citric acid.
IV*A*—CAST ANODES—BRASS CATHODES								
	9/21	0.50	0.85	10	34.6	2	0	Good, smooth, uniform; little buffing produced mirror surface.
	6/11	0.55	0.65	10	27.3	3	0	
	9/21	0.75	0.94	10	25.8	1	0	Good, white; uniform and velvety. Readily buffed to mirror surface.
	6/26	1.0	1.1	10	24.0	1	30	
	9/21	1.0	1.45	10	35.5	1	0	Uniform, but gray. Good finish when polished; somewhat gas-pitted.
	6/25	1.1	1.2	10	24.0	2	45	Good, smooth, uniform; velvety, took brilliant silvery polish.
	14	1.1	1.15	10	27.5	2	0	Good, smooth, uniform over entire surface; velvety.
This run was to determine nature of deposit at twice the current density recommended for similar Ni bath.								
	25	1.65	1.75	10	31.5	1	30	Even, uniform, slightly dark in center; buffed to very satisfactory surface.
	26	1.9	1.92	10	31.5	3	0	Not satisfactory, somewhat burned on edges.
IV*B*—CAST ANODES—IRON CATHODES								
	8/ 4	0.50	0.90	10	45.4	0	40	Gray, very smooth and bright; readily buffed to satisfactory mirror surface.
CAST ANODES—BRASS CATHODES								
	6/12	0.55	0.75	10	23.3	3	0	Hard and uniform; much whiter than solution IV*A*.
	9/21	1.0	1.77	10	36.0	1	0	Good, uniform, white. Satisfactory finish with little buffing.
	6/12	1.10	....	10	27.3	3	0	Hard and uniform, much whiter than IV*A*.
	9/22	1.25	1.67	10	28.1	1	0	Good; slightly dark at edges. No burning at this current density.
	6/14	1.5	2.5	12	30.0	1	0	Bright at first; blackened along edges, showing signs of burning.
	9/22	1.5	2.27	10	34.8	0	30	Very dark and badly burned at edges.
	6/27	1.6	2.22	20	31.5	2	30	Smooth, not uniform. Brighter nearer bottom than top.
	6/26	1.65	1.86	10	24.0	2	0	Smooth, uniform; somewhat whiter than plate Series IV*A*, June 26th, $N. D._{100} = 1$. Somewhat dark at edges.
	7/29	1.70	2.15	10	27.3	1	30	Unsatisfactory, grainy and burned. Gas at cathode.

(*a*) It is difficult to get a plate free from hydrogen pits from this bath except at very low current densities.

(*b*) In polishing this plate the extreme hardness of the Co deposit as compared with Ni was particularly noticeable. The same result was noticed to marked extent throughout these plating experiments.

(*c*) Considerably harder than Ni plate run at same time, see III*C*, July 22nd, 0.50 amp.

(*d*) Considerably harder than Ni plate run at same time, see III*C*, July 22nd, 0.70 amp.

(*e*) Same, see III*C*, July 23rd, 0.80 amp.

(*f*) Not as white when removed from bath as Ni plate run simultaneously, see III*C*, July 23rd, 0.90 amp. Co plate much harder than corresponding Ni plate.

proportion of rolled cobalt anodes may be used than is the case with nickel.

SERIES IV—COBALT-AMMONIUM SULFATE, AMMONIUM CHLORIDE SOLUTIONS

The baths of Series IV were prepared in a manner similar to that described under Series I.

It is stated in the literature[1] that baths containing chlorides or nitrates are not suitable for nickeling over iron. They are, however, well adapted to the rapid light nickeling of cheap brass articles. Bath IV is the cobalt analogue of one sometimes used in nickeling practice for work of this lighter kind.

CONCLUSIONS: 1—Solution IV*A* yields satisfactory cobalt plates on brass and iron at all current densities up to about 1.5 amp. per sq. dm.

2—The plates of Series IV*A* buffed to a brilliant surface, similar to that described under 3 below.

3—Solution IV*B* gave satisfactory plates at all current densities up to 1.25 amp. per sq. dm. on brass and iron which are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

4—Solutions IV*A* and *B* are moderately rapid plating baths, but not nearly as rapid as Solutions I*B* and XIII*B*.

5—Solution IV*B* is considerably more rapid than the corresponding nickel bath, the latter working best at a current density of about 0.55 amp. per sq. dm.[2]

6—These solutions operated alike plating on iron, steel and brass, for which metals only the above conclusions apply.

7—The cobalt content and the neutrality of Solution IV*B* do not change appreciably with prolonged usage.

8—The current efficiency of Solution IV*B* is satisfactorily high, the average value of three measurements, agreeing well among themselves, being 92.6 per cent.

9—Solution IV*B*, with boric acid, yields somewhat whiter plates than IV*A*, but IV*A* may be operated at a somewhat higher current density.

SERIES V—COBALT CHLORIDE, AMMONIUM CHLORIDE SOLUTIONS

A bath was prepared analogous to the nickel-ammonium chloride bath which has been largely favored for nickeling over zinc. This solution is also used for dark nickeling.

CONCLUSIONS: 1—Solution V was not found to be satisfactory for obtaining a bright characteristic cobalt plate at any current density up to 1.0 amp. per sq. dm., either with rolled or cast anodes, plating on brass and iron. This refers to plating in the normal manner and without agitation of the solution. This solution could be used on brass and iron if dark cobalting were required.

2—Rolled anodes are required for a satisfactory deposit with the nickel analogue of this solution. They improve the deposit in the case of cobalt, but it is by no means satisfactory, either in speed or quality of deposition, as compared with other solutions, such as I*B* and XIII*B*.

3—Solution V may be used satisfactorily to cobalt on zinc, provided there is a sufficient mechanical agitation to remove hydrogen bubbles from the surface of the cathode. With this provision the cobalt plates are firm, adherent, hard and uniform, and of a polished appearance as removed from the solution.

SERIES VI—COBALT-AMMONIUM SULFATE, BORIC ACID SOLUTIONS

Solution VI*A* is analogous to a solution recommended by Weston for nickel baths. It has, however, never found extended usage in commercial plating for the reason that the nickel solution, after working faultlessly for a comparatively short time, begins to fail, yielding a blackened deposit.

Solution VI*B* is the nickel solution corresponding to the cobalt solution VI*A*. After Solution VI*A* was found to be unsatisfactory, its metal content was increased by further addition of cobalt sulfate. This solution was called VI*C*. In addition a much more concentrated solution of the same series, VI*D*, was prepared and studied.

CONCLUSIONS: 1—Solution VI*A* does not yield a satisfactory plate at any current density, plating with cast anodes, up to 1.0 amp. per sq. dm. The plates are dark and spotted and hydrogen is evolved. At current densities in the neighborhood of one amp. per sq. dm. or higher, the plates are badly burned and pitted. With rolled anodes there is a slight improvement at moderate current densities, that is, in the neighborhood of 0.50 amp. per sq. dm.

2—Solution VI*B*, which is the nickel analogue of VI*A*, gave very bright, clean, satisfactory plates at current densities up to 0.50 amp. per sq. dm. At current densities greater than this the plates are burned.

3—This nickel solution, VI*B*, is not nearly so fast as some of the cobalt solutions elsewhere described in this paper.

4—Solution VI*C*, which is a more concentrated solution of the type of VI*A*, operated satisfactorily at a higher current density than VI*A*, that is, up to 1.0 amp. per sq. dm. This conforms to the general conclusion throughout this work that the more concentrated cobalt solutions, which are likewise those from which plates may be obtained with the greatest speed, are the most satisfactory for practical plating purposes.

5—Solution VI*D* is not to be compared in speed with I*B*, from which it differs only by the addition of the boric acid. Solution VI*D* yields a satisfactory white cobalt plate at all current densities up to 1.25 amp. per sq. dm.

6—The current efficiencies with all solutions of Series VI are high and satisfactory, the average being better than 90 per cent.

7—These solutions operate alike plating on iron, steel and brass, for which metals only the above conclusions apply.

8—The cobalt plates from Series VI, wherever they are pronounced satisfactory, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

SERIES VII—COBALT-AMMONIUM SULFATE, COBALT CARBONATE, BORIC ACID SOLUTIONS

This solution was prepared by boiling cobalt-ammonium sulfate crystals and cobalt carbonate in water until the evolution of CO_2 gas ceased, and until the solution was no longer acid to blue litmus. After settling, any undissolved cobalt carbonate was removed by filtration or decantation, and the boric acid added. After further boiling for a short time, the solution was allowed to cool and was ready for plating purposes. If the solution is too acid it may be neutralized with ammonia.

Solution VII can be used with rolled anodes, or rolled anodes with a small proportion of cast ones. The proportion of cast to rolled anodes used in this bath can be established by frequent testing of the acidity of the bath. For this purpose the following should be noted: Blue litmus paper should always be reddened, indicating the presence of boric acid; congo paper should not be turned blue, for if it does, it indicates the presence of free sulfuric acid in the bath. Red litmus paper should remain red for if it turns blue the bath has become alkaline and further addition of boric acid is required.

After plates from Solution VII*A* were found to be unsatisfactory, yielding dark deposits at current densities in the neighborhood of 1 amp. per sq. dm., sodium sulfite was added to the

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[1] Langbein, "Electro-Deposition of Metals," 6th Edition Revised, p. 254.

[2] *Ibid.*, p. 253.

TABLE III—EXPERIMENTAL DATA OBTAINED WITH SOLUTIONS OF SERIES V, VI AND VII

SOLUTION V

Grams per liter water		Total
$CoCl_2$	NH_4Cl	bath
54.8	54.8	2.5 l.

Dissolved in lukewarm water
NH_4OH added to neutrality or very slight acidity. No additions afterwards.

G. per l. Water	SOL. VI*A*	VI*C*	VI*D* (I*B* + Boric Acid)	VI*B*
$CoSO_4$	14.8	38.6	$Co(NH_4)_2(SO_4)_2.6H_2O$	14.8 g. $NiSO_4$
$(NH_4)_2SO_4$	12.6	32.9	200.0	12.6
Boric acid	18.8	38.8	37.2	18.8
Total bath (l.)	2.5	2.5	All boric acid dissolved by continued agitation Perfectly clear after standing several days	2.5
Additions	None	None		None

SOLUTION	VII*A*	VII*B*
	G. per l. water	
$Co(NH_4)_2(SO_4)_2.6H_2O$	63.5	63.5
$CoCO_3$	5.3	5.3
Boric acid	31.7	31.7
Na_2SO_3	None	1.4
Total bath (l.)	3.5	3.5
Additions	None	None

Sol. No.	Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Electr. dist. Cm.	Cathode area Sq. cm.	Plating time Hr.	Plating time Min.	Character of Deposit
V—CAST ANODES—BRASS CATHODES								
	6/17	0.30	0.96	10	27.3	2	20	Dark gray.
	27	0.30	0.66	10	27.3	2	30	Dark, even; buffed satisfactorily.
	18	0.37	0.55	10	27.3	3	20	Dull gray, spotted and rough.
	18	0.37	0.55	10	27.3	3	20	
	20	0.50	0.75	10	27.3	3	20	Dark and spotted.
	22	0.50	0.69	10	27.3	2	30	Heavy black; buffed satisfactorily.
	29	0.90	1.76	20	27.3	2	0	Very dark, slightly pitted; buffed satisfactorily.
	7/15	1.0	1.15	11	37	1	0	Somewhat dull; buffed satisfactorily.
ROLLED ANODES								
	8/ 3	0.50	0.70	10	Iron, 45.4	1	15	Very smooth, bright, dark gray; readily buffed to mirror.
	7/17	0.8	1.0	15	Brass, 27.3	1	0	Smooth, bright, slightly pitted at bottom.
	17	1.0	1.1	16.5	27.3	1	0	Smooth, uniform, dark. Bright after buffing.
	8/ 5	1.0	0.95	10	Iron, 41.2	2	20	Smooth, dull gray, somewhat pitted; no sign of burning. Polished readily to mirror.
CAST ANODES PLATING ON ZINC CATHODES								
Mechanical agitation. Solution stirred mechanically to keep off hydrogen bubbles.								
	9/25	0.50	0.75	10	Cast, 26.6	1	30	Bright, almost as if buffed when removed from solution.
	24	0.50	0.76	10	26.6	1	15	Good white, uniform. Readily buffed to mirror.
	21	0.75	1.06	10	26.6	1	0	No agitation, poor plate, crystalline.
	25	0.75	0.85	10	26.6	1	15	Smooth, uniform, looked almost as if buffed when removed from solution.
	25	0.75	1.0	10	Sheet, 28.8	1	0	Very smooth on portion of cathode where agitation removed hydrogen bubbles; rough on part away from agitation where hydrogen clung.
	23	1.0	0.95	10	Cast, 26.6	1	0	Kept free of gas bubbles by rubbing for 10 min. Plate satisfactory and smooth. At end of hour without further brushing off of bubbles, plate rough and crystalline.
	24	1.0	0.95	10	26.6	1	0	Solution stirred mechanically to keep off H bubbles, but in spite of this, at this current density, gas pits appeared at top and bottom.
	24	1.0	0.95	10	26.6	1	0	
	24	1.0	0.95	10	26.6	1	0	
	22	2.0	1.48	10	26.6	0	30	Decidedly crystalline; very poor. Gas formed and adhered to cathode.
VI*A*—CAST ANODES—BRASS CATHODES								
	6/13	0.30	0.96	10	27.3	2	20	Lustrous, but dark; not very smooth.
	15	0.60	1.70	10	27.3	2	20	Lustrous, but spotted; hydrogen gas given off freely.
	27	0.63	1.25	10	31.5	2	30	Smooth, fairly lustrous, but dark. Split on edges.
	30	0.90	3.5	20	27.3	2	0	Unsatisfactory, pitted and burned.
	30	1.0	3.27	20	27.3	2	0	Badly burned and unsatisfactory. Current density too great.
	15	1.0	3.6	15	24.0	1	30	Badly burned at edges.
ROLLED ANODES—BRASS CATHODES								
	7/16	0.5	2.0	15	37.3	1	30	Bright, smooth, uniform plate.
	16	0.8	2.3	13	37.3	2	0	Unsatisfactory, burned along edges, peeled.
	16	0.8	2.5	15	27.1	1	0	
VI*C*—CAST ANODES—BRASS CATHODES								
	7/20	0.50	0.94	10	27.3	2	0	Very smooth, bright, satisfactory; required very little buffing to finish.
	23	0.70	1.12	10	27.3	2	0	Dull metallic color; buffed satisfactorily. Showed few pits near bottom.
	8/ 4	1.0	1.95	10	39.3	1	30	Gray, but readily buffed to satisfactory finish.
	5	1.5	2.15	10	27.3	2	0	Dull and burned in places.
VI*D*—BRASS CATHODES								
	9/25	0.51	1.0	10	35.5	1	0	Good, even, uniform, gray; good luster when buffed.
	25	0.75	1.35	10	34.1	1	30	Smooth, uniform; good luster when polished.
	26	1.0	2.85	10	34.3	1	0	Good, smooth, uniform, gray; good luster when polished.
	10/ 1	1.0	1.25	10	34.3	1	0	
	1	1.25	1.4	10	32.6	1	0	
	1	1.25	1.38	10	34.6	1	0	
	9/28	1.5	1.35	10	35.3	1	0	Uniform, dull white; tendency to split at bottom and edges.
	28	1.5	1.92	10	37.5	1	30	Uniform, smooth, gray; tendency to peel at edges.
	29	1.5	1.87	10	33.8	1	0	Uniform, light gray; split at edges.
	10/ 2	1.5	1.74	10	33.8	1	0	Uniform, rough, gray and porous; impossible to buff.
	2	1.75	2.11	10	17.8	0	30	Uniform, gray; badly gas-pitted.
VI*B*—CAST ANODES—BRASS CATHODES								
	7/15	0.30	1.55	10	27.3	2	0	Very white, even; so glossy when removed from solution almost no buffing required.
	15	0.50	2.0	10	27.3	2	0	Very bright, even, with no trace of burning.
	29	0.60	2.27	10	39.3	1	30	Bright in center but signs of burning at edges.
	29	0.80	2.36	10	39.3	1	30	Bright in center but burned at edges and corners.
	28	1.0	3.01	10	39.3	1	30	Very dark and grainy. Marked burning over entire surface, especially at edges.
VII*A*—CAST ANODES—BRASS CATHODES								
	7/ 3	0.35	....	20	27.3	2	0	Bright, even, without flaw; buffed satisfactorily.
	3	0.50	1.50	20	27.3	2	0	Very bright, smooth plate without flaws; buffed brightly.
	9	0.50	1.55	20	39.3	2	30	Surface granular; unsatisfactory.
	10	0.50	1.53	20	39.3	2	30	Rough and unsatisfactory; did not polish readily.
	4	0.70	2.7	20	27.3	2	0	Smooth, flawless, white but not lustrous. Buffed satisfactorily.
	6	1.0	2.5	10	27.3	2	0	Burned at sides and bottom, unsatisfactory. Current density too great.
	7	1.0	2.7	15	27.3	2	0	Burned at edges, unsatisfactory. Current density too great.
	7	1.0	3.30	15	39.3	2	30	Heavy but dull and granular. Burned.
	9	1.0	3.25	15	39.3	2	30	Burned and unsatisfactory.
	11	1.0	4.15	15	27.3	2	0	Scaly and unsatisfactory.
Solution rapidly becoming more alkaline with use.								
VII*B*—CAST ANODE—BRASS CATHODE								
	7/11	1.0	2.05	15	27.3	2	0	White, even, somewhat burned at edges.
Solution rapidly becoming more alkaline.								
ROLLED ANODES—BRASS CATHODES								
	17	0.50	1.21	10	27.3	2	0	Even and satisfactory.
	17	0.50	1.15	10	27.3	2	0	Satisfactory, bright, requiring little buffing.
	17	0.80	1.95	10	27.3	2	0	Satisfactory and bright.
	18	0.90	2.20	10	27.3	2	0	Black, burned.

bath to see if the deposit would be brighter. This latter solution is Bath VII*B*.

CONCLUSIONS: 1—Solution VII*A* gives bright, satisfactory plates, at low current densities in the neighborhood of 0.35 amp. per sq. dm., as is true of the corresponding nickel solution.

2—Solution VII*A* does not lend itself for rapid plating; at current densities over 0.80 amp. per sq. dm., the plates are burned.

3—The addition of sodium sulfite to Solution VII*A*, as in Solution VII*B*, does not materially increase the current density at which satisfactory bright plates may be obtained. These solutions are not to be compared for rapid plating with some of the others described and styled satisfactory, as I*B* and XIII*B*.

4—The solutions of Series VII become alkaline so rapidly with cast anodes that rolled anodes should preferably be used with them. In general, cobalt solutions improved by addition of sodium sulfite are not sufficiently constant with prolonged use to have the self-supporting characteristic required by most plating establishments.

TABLE IV—EXPERIMENTAL DATA OBTAINED WITH SOLUTIONS OF SERIES VIII, IX, X, XI AND XII

G. per l. water	SOL. VIII*A*	VIII*B*
$CoSO_4$	26.3	40.5
NH_4Cl	17.6	17.6
Potassium citrate	17.6	17.6
Total bath (l.)	2.5	1.0

SOLUTION	Grams per liter			Total bath
IX		$CoHPO_4$	$Na_4P_2O_7$	
		7.58	66.1	3.5 l.
X	$CoSO_4$	$(NH_4)_2SO_4$	$MgSO_4$	
	26.6	22.6	33.8	2.5 l.

SOLUTION	Grams per liter water		Tannic acid	Total bath
XI	$CoSO_4$	NH_4 tartrate		
	25.0	41.7	0.28	3.5 l.
XII	$CoSO_4$	Tartaric acid	KOH	
	52.7	27.8	6.8	3.5 l.

Sol. No.	Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Electr. dist. Cm.	Cathode area Sq. cm.	Plating time Hr.	Min.	Character of Deposit
VIII*A*—CAST ANODES—BRASS CATHODES								
	10/1	0.30	0.67	10	34.8	2	0	Good, uniform, bluish white, buffed readily to mirror.
	1	0.50	0.97	10	33.1	2	0	
	6/30	0.50	1.95	20	27.3	3	0	Beautiful bright, hard, smooth, after polishing.
	7/15	0.50	1.15	13	37.1	1	30	Dark, buffed satisfactorily.
	10/ 2	0.95	1.50	10	40.8	1	30	Smooth, uniform, gray, readily buffed to mirror.
	2	1.0	1.36	10	34.1	1	0	Smooth, uniform, gray, buffed satisfactorily.
	15	1.5	2.4	10	35.3	1	0	Uniform, gray, showing burning.
	15	1.75	2.0	10	30.6	0	45	
VIII*B*—CAST ZINC CATHODE								
	9/22	0.26	0.95	10	26.6	2	0	Crystalline in most parts, with small patches of smooth plate.
BRASS CATHODES								
	10/ 2	0.50	1.07	10	39.6	2	0	Uniform, smooth, gray, readily buffed to mirror.
	9/22	1.0	1.97	10	34.7	1	0	Good, smooth, uniform, somewhat dark, taking a good polish when buffed.
	10/ 1	1.0	1.4	10	34.7	1	0	
	1	1.25	1.75	10	33.4	1	0	Uniform, smooth, white, buffing to mirror.
	9/23	1.5	2.67	10	35.0	..	30	Good, smooth, uniform, dark gray, taking a good polish. Slightly burned at edges.
	10/ 1	1.5	2.15	10	34.8	1	0	Uniform, smooth, white, slightly pitted at top and burned at edges. Not readily buffed.
	2	1.75	2.35	10	34.8	1	0	Smooth, uniform, gray, slightly burned on edges and difficult to buff.
CAST ZINC CATHODES								
	5	0.20	0.80	10	26.6	3	0	Smooth, uniform, metallic, dark gray. Buffed readily to mirror.
Mechanical agitation of solution near cathode.								
	10	0.50	1.03	10	26.6	2	0	
	6	0.75	0.95	10	25.6	3	0	Very rough, scaly, unsatisfactory.
	9/21	1.0	1.4	10	26.6	1	0	No agitation. Poor, very decidedly crystalline.
IX—CAST ANODES—BRASS CATHODES								
	7/ 3	0.50	3.30	10	27.3	1	30	Coated with precipitate which easily washed off. Satisfactory and readily buffed.
	9/29	0.50	3.03	10	33.4	2	0	Dark streaked. Gelatinous cobalt compound precipitate on surface of cathode.
	30	0.75	3.68	10	34.1	2	0	Dark, lustrous, streaked. Gelatinous precipitate as in last.
	7/ 4	0.80	3.65	10	27.3	2	0	Bright, satisfactory except for few black spots, which buffed off easily.
	6	1.0	4.80	10	27.3	1	30	Smooth, even, covered with bluish precipitate. Satisfactorily buffed.
	7	1.0	5.0	20	27.3	1	45	Black, streaked and unsatisfactory.
	9/30	1.0	4.35	10	40.0	1	30	Dark, streaked and unsatisfactory. Gelatinous precipitate on cathode.
X—CAST ANODES—BRASS CATHODES								
	7/29	0.30	0.70	10	39.3	1	30	White, metallic, easily buffed to mirror.
	9/29	0.30	0.75	10	36.6	2	0	Good, white, uniform; readily buffed to mirror.
	30	0.40	0.87	10	32.2	2	0	
	30	0.50	1.03	10	35.2	1	30	
	7/ 6	0.50	1.54	15	48.1	2	0	Bright, evenly coated, except few streaks in metal portion. Readily buffed to satisfactory mirror.
	16	0.50	1.1	14	37.1	1	30	Bright, uniform, over entire surface. Readily buffed to satisfactory mirror.
	29	0.50	1.15	10	46.6	2	0	White, metallic and easily buffed to mirror.
	9/30	0.60	1.17	10	34.3	1	30	Bright, uniform, over entire surface. Readily buffed to satisfactory mirror.
	7/ 7	0.70	1.70	15	48.1	2	0	Bright, evenly coated, except few streaks in middle portion. Readily buffed to satisfactory mirror.
	9/30	0.70	1.34	10	34.8	1	30	Good, uniform, white, requiring little buffing.
	7/ 7	0.70	1.30	15	48.1	1	30	Satisfactory, white, smooth and even. Readily buffed to satisfactory mirror.
	15	0.90	2.25	15	37.1	1	0	Bright and smooth at center, somewhat burned at edges.
	7	1.0	2.25	15	48.1	1	30	Bright, rough and uneven on lower portion, no burning apparent.
	7	1.0	2.05	15	39.3	15	0	Very thick, rough, dark, full of small holes, but adherent.
	9	1.0	2.10	15	39.3	3	0	Pitted and somewhat burned.
ROLLED ANODES—BRASS CATHODES								
	16	0.5	1.0	14	37.1	2	0	Bright, smooth, uniform, over entire surface.
	16	0.8	1.05	15	37.1	1	0	Bright, smooth, over entire surface.
	17	1.0	2.25	17	37.1	1	0	Fairly smooth and bright, not very uniform in appearance, some parts darker than others.
	17	1.0	2.15	17	37.1	1	0	Very smooth, bright and uniform.
XI—BRASS CATHODE								
	7/ 7	0.30	1.5	25	41.2	1	30	Dark, absolutely unsatisfactory.
Solution XI continually precipitated a cobalt compound both when in use and upon standing idle. It gave the same unsatisfactory deposit as in the run shown above, at the several current densities tried.								
XII—CAST ANODES—BRASS CATHODES								
	7/ 6	0.30	1.17	20	37.1	2	0	White, uniform and velvety. Readily buffed to mirror.
	10/ 1	0.30	1.25	10	39.5	2	0	
	9/29	0.39	1.25	10	33.6	2	0	Smooth, uniform, dark; buffed to satisfactory mirror.
	30	0.50	1.45	10	34.6	2	0	Uniform, smooth, gray; buffed to satisfactory finish.
	10/ 1	0.50	1.40	10	34.8	2	0	
	2	0.50	1.53	10	41.2	2	0	
	9/30	0.75	2.03	10	39.1	1	30	Uniform, smooth, gray; buffed satisfactorily.
	7/13	1.0	3.6	15	37.0	1	30	Very even, smooth, and satisfactory.
	10/ 2	1.0	2.18	10	32.6	1	0	
	2	1.25	2.55	10	32.9	1	30	
	3	1.50	2.86	10	30.9	0	45	
	15	1.50	3.5	10	34.6	1	0	
	15	1.96	4.25	10	30.7	0	30	Good, smooth, white, nearly polished as removed from solution.
	12	3.87	6.0	10	34.0	0	15	
	12	4.0	3.95	10	14.2	0	30	
	15	5.0	....	10	13.0	0	20	
	16	6.0	....	10	13.0	0	15	
	16	7.0	6.0	10	9.9	0	10	
	17	8.0	4.9	10	10.1	0	5	
	17	10.0	6.0	10	10.6	0	7	
	17	12.0	5.5	10	11.5	0	5	Burned at edges.
	17	15.6	5.8	10	9.3	0	5	Badly burned at edges—splitting.
ROLLED ANODES—BRASS CATHODES								
	7/16	1.0	3.0	14	37.0	1	30	Smooth and uniform, but dark. Solution from which this plate was taken had been operated for 48 hours.

5—The solutions of Series VII operated alike plating on iron, steel and brass, for which metals only the above conclusions apply.

6—The cobalt plates from Series VII, wherever they are pronounced satisfactory, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactory finished surface. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

SERIES VIII—COBALT SULFATE, POTASSIUM CITRATE, AMMONIUM CHLORIDE SOLUTIONS

This bath is analogous to one recommended by Langbein,[1] C. H. Proctor,[2] and W. Pfanhauser,[3] and which is reported to be particularly satisfactory for plating on copper and zinc.

[1] Langbein, "Electro-Deposition of Metals," 6th Edition Revised.

[2] *Metal Industry*, **1911**, p. 353.

[3] W. Pfanhauser, "Elektroplattiring," **1900**.

TABLE V—EXPERIMENTAL DATA OBTAINED WITH SOLUTIONS OF SERIES XIII, XIV, XV AND XVI

G. per l. water Sol.	XIII*A*	XIII*B*	XIII*C*
$CoSO_4$	181.2	312.5	312.5 g. $NiSO_4$
NaCl	11.35	19.6	19.6
Boric acid	37.8	Nearly to saturation	
Total bath (l.)	4.0	1.5	....
Sp. gr. 15° C.	....	1.25	....
Saturated with Co	No	Yes	....

SOL.	Grams per liter of water				Total bath
XIV	$CoSO_4$	$(NH_4)_2SO_4$	$MgSO_4$	H_3BO_3	
	37.5	21.7	3.3	12.1	3.5 l.
XV	$Co(C_2H_5)_2(SO_4)_2$	Na_2SO_4	NH_4Cl		
	100.0	10.0	5.0		2.0 l.

G. per l. water	SOL. XVI*A*	XVI*B*	XVI*C*
$CoSO_4$	90.7	90.7 ($NiSO_4$)	150.0
$(NH_4)_2SO_4$	27.6	27.6	150.0
NH_4Cl	15.0	15.0	$CoSO_4$
Boric acid	5.2	5.2	11.3 g.
Addition	NH_4OH to neutrality (see text)		

Sol. No.	Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Electr. dist. Cm.	Cathode area Sq. cm.	Plating time Hr.	Plating time Min.	Character of Deposit
XIII*A*—CAST ANODES—BRASS CATHODES								
	7/10	0.70	1.56	23	37.1	1	30	Rather dark; little buffing required to finish satisfactorily; greatly resembled Ni in color.
	10	0.70	1.56	23	37.1	1	30	
	10	0.97	2.0	15	37.1	2	0	Fairly smooth and uniform, but dark.
	11	1.0	1.8	16	37.1	2	0	
	11	1.0	1.87	15	37.1	1	0	Good, smooth, uniform, bright, somewhat streaked on upper half of plate.
	14	1.0	1.45	10	37.1	1	30	Very smooth and uniform on lower half; badly streaked in upper portion.
	14	1.0	1.85	15	37.1	1	0	
	14	1.0	1.7	13	37.1	1	0	Solution stirred continuously by bubbling air through near cathode. Plate brighter and more metallic looking than last runs, but badly split and peeled.
	15	1.0	1.9	12	37.1	0	45	Very poor, dark streaked and peeling.
XIII*B*—BRASS CATHODES								
	10/ 2	0.50	1.02	10	33.6	3	0	Uniform, rough, dark. Impossible to polish without grinding.
	2	0.75	1.23	10	32.6	1	30	Smooth, uniform, gray, buffed to satisfactory finish with difficulty.
	3	1.0	1.53	10	34.0	1	0	Uniform, dark gray, difficult to buff.
	5	1.25	1.75	10	34.0	1	0	
	6	1.50	1.25	10	32.0	1	0	Uniform, smooth, gray, buffed more readily than preceding plates with this solution.
	6	5.46	5.5	10	34.8	0	30	Good, smooth, white, buffed readily to mirror.
	6	6.0	....	10	32.7	0	10	Good, smooth, white, buffed readily to mirror.
	10	6.15	6.0	10	32.7	0	15	
After severe aging test described below								
	8	8.0	4.83	10	17.6	0	12	
	9	8.0	6.0	10	Iron, 20.0	0	10	Good, smooth, white, buffed readily to mirror. This plate was given a severe bending test, being doubled on itself backwards and forwards to an angle of 180 degrees. The metal furrowed and split on surface and end, but plate clung absolutely.
	9	8.0	6.0	10	Iron, 20.0	0	10	
	8	8.8	6.5	10	Iron, 22.5	0	12	Good, smooth, white, buffed readily to mirror.
	10	8.88	5.90	10	Brass, 20.0	0	15	Good, smooth, white, buffed readily to mirror.
After severe aging test.								
	8	9.77	6.5	10	Iron, 22.5	0	12	
	15	10.7	6.3	10	1.81	0	20	
	8	10.0	....	10	Brass, 17.6	0	5	
	8	14.6	6.5	10	14.7	0	5	
Best obtained with this solution to date, although all plates at current densities from 6 amperes up were good.								
	13	16.5	5.7	10	10	0	5	Good, smooth, white, readily buffed to mirror. Excellent plate.
	6	17.5	6.85	10	10.6	0	5	
BRASS CATHODES—HEAVY PLATE								
	6–7	5.35	6.0	10	32.8	15	15	Firm, adherent, massive, showing no tendency to split or curl. Smooth in center, with nodules at edges. Weight approximately 37 grams, thickness approximately 1 mm.
The area of the effective cathode increased from 32.8 sq. cm. at the start, to approximately 40.0 sq. cm. at the end of the run. This latter figure is not sufficiently accurate to admit of exact computation, but the figures show in a general way that the current efficiency was very high.								
	7	16.5	5.5	10	10.0	17	30	Firm, adherent, massive, showing no tendency to split or curl. Weight, about 30 grams.
	13	5.26	6.0	10	Circular, 18.9	67	0	Firm, adherent, massive, showing no tendency to split or curl; about 5 mm. thick.
Plate on brass cathodes with grooves, depth 1.62 mm. to 7.0 mm. to study "throwing" property of this solution.								
	7	9.0	5.5	10	18.3		5	Good, smooth, uniform, white. All grooves satisfactorily covered, and satisfactorily buffed to mirror finish.
	7	3.77	5.5	10	Block 60.1 total surface		10	
	7	3.83	5.5	10			20	
In last two, grooves faced toward anode, but entire block, back as well as grooves, satisfactorily covered to admit of severe and satisfactory buffing after only 10 minutes' plating.								
XIII*C*—BRASS CATHODES								
	10/15	3.95	5.3	10	33.8	0	20	Good, smooth, uniform, nearly polished as removed from solution.
	15	5.9	3.7	10	13.5	0	15	Smooth, white, but splitting at edges.
	15	7.76	....	10	12.5	0	10	
XIV—CAST ANODES—BRASS CATHODES								
	10/ 1	0.50	1.05	10	32.4	2	0	Uniform, smooth, white, readily buffed to mirror.
	1	1.25	1.92	10	35.3	1	0	
	2	1.50	2.20	10	35.3	1	0	
	2	1.75	1.68	10	18.5	0	45	
	2	2.0	1.55	10	11.1	1	30	
	2	2.5	1.77	10	11.3	1	30	
	3	3.0	2.47	10	17.2	0	30	
	5	3.0	3.32	10	19.6	0	20	Uniform, smooth, white, slightly burned on edges.
	3	3.51	2.88	10	16.8	0	30	Uniform, smooth, white, readily buffed to mirror.
	5	4.0	2.98	10	13.3	0	20	Uniform, smooth, white, slightly burned on edges.

XV—A number of cobalt depositions were made with Solution XV at various current densities, both with and without mechanical agitation and for varying lengths of time. Mechanical agitation caused the plates to crack. One of the depositions was continued for a period of eight 24-hour days; a uniform, dense, hard, satisfactory plate was found. This deposit was made on a plate approximately half a millimeter thick at a current density of 0.30 amp. per sq. dm. It was, of course, not as hard a deposit as some of the heavy plates deposited from Bath XIII*B* at very much higher current densities.

XVI*A* and XVI*B*—Solution XVI*A* and its nickel analogue XVI*B*, in an extended series of experiments were found to give satisfactory plates at low current densities, but to fail by splitting and burning when current densities of 1.0 amp. per sq. dm. or more were reached.

Solution XVI*C* was found to precipitate a red compound on the anode.

A very much greater hardness of the cobalt plate than the nickel plate was particularly noticeable throughout.

Langbein specifies for the nickel solution on copper and copper alloys a current density of 0.45 amp. per sq. dm., and on zinc a current density of 0.8 to 1 amp. per sq. dm.

CONCLUSIONS: 1—Cobalt plates from the solutions of Series VIII, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

2—Neither Solution VIII*A* nor *B* lends itself to fast cobalt plating like Solutions I*B* and XIII*B*. Solution VIII*A* yields satisfactory deposits at all current densities up to 1.0 amp. per sq. dm., while VIII*B*, which is more concentrated in cobalt sulfate, yields satisfactory plates at all concentrations up to 1.25 amp. per sq. dm. These figures are for plating on brass and iron.

3—Solution VIII*B* may be used for plating on zinc at low current densities up to 0.50 amp. per sq. dm., particularly if the solution near the cathode is agitated.

SERIES IX—COBALT PHOSPHATE, SODIUM PYROPHOSPHATE SOLUTIONS

Langbein[1] recommends a solution containing nickel phosphate 15.8 grams, sodium pyrophosphate 66.1 grams, and water 1000 cc. for dark nickeling upon iron, brass and copper. This is supposed to be particularly serviceable where darker tones of nickel are required for decorative purposes. It was found in trying to prepare the analogous cobalt phosphate solution that the solubility of the cobalt phosphate was lower than that of nickel phosphate.

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[1] Langbein, "Electro-Deposition of Metals," 6th Edition Revised, p. 258.

Solution IX is saturated in cobalt phosphate. The cobalt phosphate prepared for this bath was made by mixing two solutions, one containing 30.0 grams $CoSO_4.7H_2O$ in 3.4 liters of warm water, and the other containing 24.9 grams sodium phosphate in 3.4 liters of warm water. These two solutions were mixed, with constant stirring, and the precipitated cobalt phosphate filtered off. These quantities yielded 15.8 grams cobalt phosphate. The final bath was prepared by dissolving the sodium pyrophosphate in warm water, and adding the cobalt phosphate, which dissolved up to the quantity indicated in Bath IX as determined by analysis but not up to the quantity recommended by Langbein for nickel.

TABLE VI—CURRENT EFFICIENCY TESTS—ALL CATHODES BRASS

NUMBER OF Series	NUMBER OF Solution	NUMBER OF Run	Run lasted Min.	Current density Amp. per sq. dm.	Cathode area Sq. cm.	Average amperes through bath	GRAMS COBALT DEPOSITED b Theory	GRAMS COBALT DEPOSITED c Actual	Current efficiency b ÷ c Per cent
I	*B*	1(*a*)	60	1.0	29.2	0.300	0.331	0.323	97.7
		2	60	1.0	47.4	0.475	0.523	0.5133	98.2
		3	60	3.0	29.5	0.907	0.996	0.911	91.5
		4	60	3.0	20.0	0.599	0.659	0.5952	90.3
		5	60	3.0	20.0	0.598	0.659	0.5906	89.7
III	*B*	1(*a*)	30	1.0	20.5	0.250	0.138	0.1340	97.3
		2	60	1.0	32.6	0.328	0.361	0.3563	98.6
	C	1	60	1.0	24.2	0.242	0.266	0.2473	92.8
		2	60	1.0	40.0	0.400	0.440	0.4063	92.2
	E	1	45	0.80	40.0	0.321	0.265	0.2619	98.8
		2	60	0.80	40.0	0.321	0.353	0.3514	99.4
IV	*B*	1(*a*)	60	1.0	36.5	0.368	0.405	0.3736	92.3
		2	60	0.42	43.4	0.182	0.200	0.1895	95.0
		3	60	1.0	51.0	0.512	0.563	0.5144	91.2
VI	*B*	1	45	0.50	40.0	0.200	0.165	0.1397	84.8
		2	60	0.50	40.0	0.201	0.221	0.2133	96.4
		3	63	0.50	63.5	0.365	0.420	0.3702	87.8
		4	63	0.50	68.6	0.344	0.378	0.3512	98.0
	C	1	60	0.50	72.0	0.357	0.393	0.3723	94.6
		2	60	0.50	72.0	0.361	0.397	0.3717	93.7
		3	60	1.0	39.2	0.394	0.433	0.4097	94.6
		4	60	1.0	40.0	0.402	0.442	0.4184	94.6
XIII	*B*	1	60	1.2	35.0	0.435	0.478	0.4812	100.0
		2	60	1.0	32.4	0.324	0.356	0.3563	100.0
		3	60	5.0	18.2	0.922	1.012	1.009	99.6
XIV		1	60	1.0	51.0	0.513	0.564	0.5484	97.2
		2	60	1.0	40.0	0.402	0.442	0.4255	96.3

(*a*) Asphaltum on back of cathode, all others polished on both sides.

CONCLUSIONS: 1—Solution IX is more satisfactory than the corresponding nickel phosphate solution for the purpose of dark cobalting for decorative purposes. The voltage required for moderate current densities is extremely high as compared with that required for other cobalt solutions described as satisfactory.

TABLE VII—AGING TESTS OF BEST PLATING SOLUTIONS. DATA (EXCEPT XIII*B*) BEGUN ON AUG. 26TH AFTER RUNS RECORDED IN TABLES I TO V

SOLUTION I*A* After plating Hrs.	SOLUTION I*A* G. Co. per 100 cc.	SOLUTION I*B* After plating Hrs.	SOLUTION I*B* G. Co. per 100 cc.	SOLUTION III*B* After plating Hrs.	SOLUTION III*B* G. Co. per 100 cc.	SOLUTION III*E* After plating Hrs.	SOLUTION III*E* G. Co. per 100 cc.	SOLUTION III*E* Acidity of solution	SOLUTION IV*B* After plating Hrs.	SOLUTION IV*B* G. Co. per 100 cc.	SOLUTION XIII*B* Date October	SOLUTION XIII*B* Hrs. additional run	SOLUTION XIII*B* Grams cobalt deposited	SOLUTION XIII*B* At cur. dens. Amp. per sq. dm.	SOLUTION XIII*B* G.Co per 100 cc.
31	0.94	80	2.54	24	1.11	26	1.72	Neutral	16	0.76	6	2	..	....	8.55
46	0.94	95	2.58	39	1.10	41	1.81	Very sl. alk.	31	0.80	7	15¼	37	5.35	8.40
61	0.95	110	2.52	54	1.14	56	1.95	Sl. alk.	46	0.74	8	17.5	30	16.5	8.20
76	0.94	125	2.55	69	1.10	71	2.12	Neutral	..	....	8	5 min.	..	15.4	(*b*)
Diluted to original volume				...	1.11	86	1.95	Sl. alk.	61	0.75	9	15	40	11.0	8.30
87	0.96	140	2.58	84	1.12	101	1.99	> Alk.	77	0.96	10	16	..	5.0	7.95
102	0.97	155	2.60	99	1.13	116	2.11	> Alk.	..	....	13	67	..	5.26	7.59
117	0.99	170	2.62	114	1.14	131	2.17	> Alk.	..	....	13	5 min.	..	16.25	(*b*)
Neutral solutions throughout tests				Very slightly alkaline throughout					Neutral throughout (*a*)		Strongly acid to litmus throughout tests				

(*a*) Solution IV*B* was neutral to litmus paper and slightly alkaline by titration with *N*/10 HCl and litmus indicator.
(*b*) Good, smooth, white plate obtained; buffed readily to a mirror surface. (Note severe anode current densities and good behavior of solution.)

2—Cobalt phosphate, in the presence of sodium pyrophosphate, as indicated in Solution IX, is less soluble than the corresponding nickel salt. This is the only case among those studied in which the cobalt bath could not be made more concentrated in metallic cobalt than the corresponding nickel bath, with consequent greater electrical conductivity and correspondingly higher permissible current density for plating.

SERIES X—COBALT-AMMONIUM SULFATE, MAGNESIUM SOLUTIONS

CONCLUSIONS: 1—Cobalt plates from Solution X on brass and iron are firm, adherent, hard and uniform, and may be readily buffed to satisfactory mirror surface. They take a very high polish with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

2—The soft yellowish tinge which is observed when plating with the nickel analogue of Solution X was not found with the cobalt solution. On the contrary, the plates are beautifully white and hard.

3—The specific electrical conductivity of Solution X is very much higher than that of the corresponding nickel solution.

4—All of the cobalt plates deposited at current densities between 0.25 and 0.75 are as smooth, adhesive and generally satisfactory as the best nickel plates.

5—Solution X does not lend itself to extremely fast plating as do Solutions I*B* and XIII*B*, but satisfactory plates may be obtained with it at current densities up to 0.75 amp. per sq. dm. Solution X may be used at very higher current densities than the corresponding nickel solution, for which a current density of 0.20 amp. per sq. dm. is recommended.

SERIES XI—COBALT SULFATE, AMMONIUM TARTRATE, TANNIC ACID SOLUTIONS

Neutral ammonium-tartrate is obtained by saturating a solution of tartaric acid with ammonia. The cobalt salt should also be neutral. The solution was prepared by dissolving the ingredients in water, boiling for about fifteen minutes, adding water to make desired quantity and filtering.

CONCLUSION: Solution XI is not satisfactory for cobalt plating under the usual conditions of plating practice.

SERIES XII—COBALT SULFATE, POTASSIUM TARTRATE, TARTARIC ACID SOLUTIONS

The cobalt sulfate, tartaric acid and caustic potash were dissolved in water and then mixed, adding sufficient water to make the bath.

CONCLUSIONS: 1—Cobalt plates from Solution XII, which is simple cobalt sulfate in the presence of potassium tartrate with an excess of tartaric acid, on brass and iron, are firm, adherent, hard and uniform and may be readily buffed to a satisfactorily finished surface. They take a very high polish with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

2—All of the cobalt plates from this solution within the current density ranges described as satisfactory, are as smooth, adhesive and generally satisfactory as the best nickel plates.

3—Solution XII is an extremely fast-plating solution when compared with the fastest nickel solutions. It yields satisfactory plates at all current densities up to 11.0 amp. per sq. dm.

4—Solution XII may be used for plating on brass, iron and steel, for which cathodes alone these conclusions apply.

5—There is no nickel bath, of which we are aware, operating in the manner of the usual plating practice at anything like as high a current density as the cobalt solution XII.

SERIES XIII—COBALT SULFATE, COBALT CHLORIDE, BORIC ACID SOLUTIONS

Solution XIII*A* is analogous to one suggested to us by Mr. W. S. Barrows, foreman of the plating department, Russell Motor Car Company, Toronto, Ontario, as being satisfactory and rapid for nickel plating.

CONCLUSIONS: 1—The extreme importance of proper concentration of cobalt sulfate solutions is shown by the results of this series. Solution XIII*A* is unsatisfactory for plating purposes at all current densities tried. Solution XIII*B*, which is a more concentrated solution of the same type, is the most completely satisfactory solution, for a great variety of purposes, which we have found. We know of no solution, plating with nickel, which begins to compare with Solution XIII*B* for the range of work which it will do, and for the extreme high current densities at which it will operate. It is possible to get a plate in three minutes or less with Solution XIII*B*, which will stand all the usual physical commercial tests, and which will buff as satisfactorily as a plate which has taken one hour in the usual nickel-plating baths.

2—Cobalt plates from this simple cobalt sulfate solution in the presence of sodium chloride and boric acid, Bath XIII*B*, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactorily finished surface. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

3—The specific electrical conductivity of Solution XIII*B* is much higher than that of the corresponding nickel solution.

4—Solution XIII*B* does not yield the best cobalt plates at low current densities, that is, in the neighborhood of 0.50 to 1.0 amp. per sq. dm., which is a common range for nickel-plating work. Solution XIII*B* begins to plate most satisfactorily at a current density in the neighborhood of 3.5 amp. per sq. dm., and continues to give satisfactory plates at all current densities up to 26.4 amp. per sq. dm. This is equivalent to a current density of over 240 amp. per sq. ft., and even at this speed, the limit of the solution has not yet been reached.

5—All of these cobalt plates within the wide current density range described as satisfactory for Solution XIII*B*, are as smooth, adhesive and generally satisfactory as the best nickel plates.

6—Solution XIII*B* does not change appreciably in cobalt content nor in acidity when used over long periods of time at current densities as high as 1 amp. per sq. dm. It showed only a very gradual diminution in cobalt content under the most severe conditions of the aging test described in Table VII. We know of no other cobalt solution and of no nickel solution which would stand up under the conditions of this aging test.

7—There is no nickel bath of which we are aware operating in the manner of the usual commercial plating procedure at anything like as high current density as Bath XIII*B*.

8—Solution XIII*B* may be used for plating on brass, iron and steel, for which cathodes the above conclusions apply.

9—Solution XIII*B* may be used to deposit a heavy cobalt plate. These plates may apparently be deposited to any desired thickness, and they are firm, adherent, massive, of extreme hardness and show no tendency to curl or split.

10—Heavy plates may be obtained from Solution XIII*B* to much better advantage than from Solution XV, which has been particularly patented for the purpose with nickel; that is, heavy deposits may be obtained from Solution XIII*B* at current densities of 5 or 6 amp. per sq. dm., whereas Solution XV must be operated at low current densities in the neighborhood of 0.30 amp. per sq. dm. If a current density of above 6 amp. per sq. dm. is used with Solution XIII*B* for heavy deposits, under the conditions in dimension of our baths, it was found that trees were formed on the cathode.

11—Our experiments show that Solution XIII*B* "throws" very satisfactorily.

12—Among the satisfactory properties of this remarkable solution should be mentioned an extremely high current efficiency, which we found at 1.0 and 5.0 amp. per sq. dm. to be almost 100 per cent.

13—Solution XIII*C*, which is the nickel analogue of Solution XIII*B*, yielded satisfactory plates to about 5 amp. per sq. dm., but showed splitting at current densities greater than that. Nickel solution XIII*C* does not possess the remarkable qualities of its cobalt analogue XIII*B*, although in many respects it is an improvement on standard nickel solutions.

14—Solution XIII*B* requires very little aging; it operates satisfactorily almost from the start.

15—Solution XIII*B* is so remarkable in its properties that it was thought highly worth while to develop it further under commercial conditions. See COMMERCIAL TESTS, p. 394, *et seq.*

SERIES XIV—COBALT SULFATE, AMMONIUM SULFATE, MAGNESIUM SULFATE, BORIC ACID SOLUTIONS

CONCLUSIONS: 1—Cobalt plates from Solution XIV, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed to a satisfactory mirror surface. They take a very high polish with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

2—Solution XIV yields satisfactory plates at all current densities up to about 3 amp. per sq. dm.

3—The current efficiency of Solution XIV is satisfactorily high, being in the neighborhood of 96 to 97 per cent under the conditions of our experiments.

4—All of the cobalt plates from Solution XIV within the current density range described as satisfactory are as smooth, adhesive and generally satisfactory as the best nickel plates.

SERIES XV—COBALT ETHYLSULFATE, SODIUM SULFATE, AMMONIUM CHLORIDE SOLUTIONS

This solution is the cobalt analogue of a nickel solution patented by Dr. G. Langbein & Co., Leipzig, Germany.[1] The inventor claims for this solutiom that very dense, hard, uniforn, deposits of nickel may be obtained from it, and particularly "deposits of any desired thickness can be produced if the bath be constantly agitated by mechanical means or by the introduction hydrogen." It, of course, is not permissible to agitate this bath with air, as that would cause oxidation.

CONCLUSIONS: 1—Dense, hard, uniform deposits of cobalt may be obtained from a cobalt-ethylsulfate solution made up like Solution XV, without mechanical agitation, provided that the current density be low, not exceeding 0.30 amp. per sq. dm.

2—For heavy depositions of cobalt, where density, hardness and speed of deposition are important, Solution XV is not nearly as satisfactory as Solution XIII*B*. However, the cobalt-ethylsulfate solution deposits cobalt more satisfactorily than the corresponding nickel-ethylsulfate solution deposits nickel.

SERIES XVI—COBALT SULFATE, AMMONIUM SULFATE, AMMONIUM CHLORIDE, BORIC ACID SOLUTIONS

In making this solution it was reasoned, as in many instances already reported, that a greater current density might be used if the metal content were increased. This solution, contrary to a number of others reported, would not, however, admit of very great increase in cobalt content without giving disturbing effects of crystallization in the bath.

Current efficiency runs were made with these solutions, which show them to be in the neighborhood of 90 per cent, but they were not thought of sufficient importance to warrant a careful study.

CONCLUSIONS: 1—Plates from Solution XVI*A* and the corresponding nickel solution are both satisfactory at current densities below 1 amp. per sq. dm. At higher current densities both solutions fail.

2—A solution of the type of Series XVI cannot be prepared in much greater concentration than XVI*A*, without obtaining troublesome crystallization. Therefore, Series XVI does not offer a highly concentrated rapid plating cobalt solution.

3—Cobalt plates from Solution XVI*A*, on brass and iron, are firm, adherent, hard and uniform, and may be readily buffed

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[1] Kaiserliches Patenamt, *Patentschrift*, No. 134,736 Kl 48*a*, Sept. 18, 1902.

TABLE VIII—COMMERCIAL EXPERIMENTS WITH COBALT SOLUTION I*B* AT THE RUSSELL MOTOR CAR CO. PLANT

SOLUTION I*B*—Cobalt-ammonium sulfate, 5 lbs. Water, 6 gals. Acidity, neutral. Specific gravity, 1.050

Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Elec. dist. In.	CATHODE Material	CATHODE Area Sq. in.	Plating time Hr.	Plating time Min.	Anode area Sq. in.	CHARACTER OF DEPOSIT
9/10	8.6	3.75	5	Steel	15	0	1/2	28	Blackened in 30 sec.
	3.4	3.25	5		45	0	40	56	Poor; buffed easily; blisters appeared, long and narrow in form; small pinholes on some portions. Slightly burned on lower ends.
11	2.3	1.25	5	Brass hub cap	15	0	5	28	Slow, spotted, streaked, very dark.
11	4.3	2.0	5		15	0	5	90	Deposition rapid. Plate spotted, not uniform. Cathode not covered at end of run.
12	3.9	2.5	5		15	0	5	90	
12	3.3	3	5	Steel	10	0	30	28	Good, firm adherent; very hard and smooth. Color similar to nickel before buffing. Colored easily and to good finish of slightly bluish tone.
12	3.5	2.75	5		36	0	15	90	Did not cover; streaked, very hard, brittle.
12	3.3	3	5	Brass	15	0	50	28	Good color. Porous spots in casting, refused to cover at edges. Indented portions of cathode not coated. Spot beneath slinging wire bare.
14	3.0	2.5	5		15	1	0	28	Struck the piece with nickel for 30 seconds. Cobalt deposit began readily and uniformly. Color darkened quickly, imperfect in spots, rough and streaked.
	3.0	2.5	5	Steel	12	0	15	28	Deeper portions of piece not covered.
	2.3	2	5		4	0	5	14	Plate scaled, chipped. Deeper portions not covered.
Solution rendered slightly alkaline									
	3.0	2.5	5		12	0	15	28	Plate peeled badly. Several tests were made with similar results.
Solution rendered slightly acid									
15	1.6	1.5	5		40	0	15	42	Color very dark, otherwise a good plate; buffed easily; did not cut through.
15	1.0	1.5	5		40	0	5	42	Color very dark, buffed to good finish.
15	2.3	1.5	5		36	1	0	42	Surface covered instantly and in good condition. Gas liberated more freely than heretofore, but no indication of pinholes or streaks. Color very dark, resembling burnt nickel deposit. When dried it had a velvety appearance. Soft to the touch, buffed easily on soft wheel.
15	3.0	2	5	Brass	45	0	30	56	Very dark. Surface covered with minute blisters or pits, which disappeared when buffed. Surface covered quickly and completely. Color satisfactory after buffing.
15	3.0	2	5	Steel	40	0	30	56	Very dark, buffed easily and to good finish. Very hard plate, superior to 1-hour nickel from Prometheus solution.
16	Tests made during the following ten days resulted in similar plates; 6 lbs. cobalt salts were then added to the bath. Sp. gr. 12° Bé. No further additions were made—acidity, very slightly acid. After aging treatment the solution was practically neutral.								
28	2.1	1.75	5		36	0	25	42	Surface covered well, gas not as free as formerly, deposit marred by circular mark entire length and breadth of cathode. Color darker than nickel, hard and fine grained.
29	3.9	2	8	Brass	12	0	5	28	Surface covered splendidly and color very good; withstood very hard buffing, but required only light treatment to finish. Very satisfactory results.
Electrolyzed solution for 32 consecutive hours with an average current of 10 amp. at 2 volts—90 sq. in. anode surface. Added 24 drops liquid ammonia. Temperature 70° F., sp. gr. 1.085. Anode coated with brownish red film when at rest. Salts creep to hooks and remain moist. Solution neutral. Slight sediment at bottom of tank.									
10/3	2.8	2	5	Steel	28	24	0	90	Smooth, hard, adherent; No evidence of cracks or burning. Thickness approximately 1/32 in.
3	3.7	2.25	5	Steel tube	18	2	0	56	Smooth, white, hard plate. Drew the tube from 1 in. diameter to 5/8 in. with no damage to deposit.
3	4.0	2.25	5	Brass	24	0	10	56	Equal portions were nickel- and cobaltplated for 1 hour. The two coatings were then buffed with same stroke. Repeated trials cut the nickel through before the cobalt. In no case did the cobalt expose the brass. *Very convincing test.*
8	3.7	2	5		12	0	15	28	Good color, buffed easily to splendid finish; bending, hammering, twisting did not crack nor loosen plate.
8	4.2	3.5	8	Sheet steel	72	1	0	90	The cathode consisted of six pieces steel hooked to wire frame. Plate good color, smooth, hard; did not crack when bent or twisted. Buffed to good finish.
14	4.5	4	8	Steel	72	1	0	90	Deposit began with current density of 30 amp. per sq. ft. and gradually increased to 42. After a 10-minute run with this current density, plate began to show signs of darkening. This, however, was not considered serious until expiration of 20 minutes. Entire surface finished easily on soft buff. While the plate was not a good specimen from a commercial viewpoint, the remarkable efficiency of the bath was clearly demonstrated.
15	5.2	4.5	8		72	1	0	90	Same cathode as last test, arranged differently in frame. Plate gray but not burned; adherent, hard, smooth; did not break when bent; buffed easily to good finish.
16	5.2	4.5	8	Cast iron	12	1	0	14	This cathode was a piece of stove casting. Plate on one side only, and of splendid color over entire surface, the backgrounds being equally as white as average nickel plate. When buffed the piece could not be detected from nickelplated piece except by our acquaintance with the fact.
31	Current densities as high as 6.3 amp. per sq. dm. were employed in several tests, but the results were not such as to merit recording. The solution at this date was proving very efficient in every detail.								

NOTE.—To transform amperes per square decimeter to amperes per square foot, multiply by 9.3.

to a satisfactory surface, within current density range recommended. They take a very high polish, with a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

4—The cobalt plates from Solution XVI*A* are very much harder than the nickel plates from its analogue, XVI*B*. This is noticeable throughout all our plating experiments, but is particularly striking in this case where the plates were obtained in series and simultaneously.

5—The specific electrical conductivity of Solution XVI*A* is very much higher than that of the corresponding nickel solution XVI*B*.

6—The current efficiencies of both nickel and cobalt solutions of the type XVI*A* are in the neighborhood of 90 per cent under the conditions of our experiments.

ACKNOWLEDGMENT

The numerous analyses in connection with these experiments were made by Mr. Russell C. Wilcox, and during the summer of 1914 a number of plating experiments were run by Mr. C. S. Allin. The authors acknowledge with thanks their indebtedness to these gentlemen.

COMMERCIAL TESTS WITH SOLUTIONS I*B* AND XIII*B*

The results with Solutions I*B* and XIII*B* were thought by the authors to be so unusual and of sufficient importance to warrant verification and further development under standard commercial conditions. We therefore arranged with the Russell Motor Car Company of Toronto, Ontario, and particularly with Mr. W. S. Barrows, *Foreman Electro-Plater* with the same company, to have a plating tank operated under standard commercial conditions at their plant, using Solutions I*B* and later Solution XIII*B*.

Mr. Barrows has had twenty years' experience with all sorts of electro-plating work, to which he has particularly devoted himself. He has considered these two cobalt solutions entirely from the point of view of commercial practicability and value.

COMMERCIAL REPORT ON SOLUTION I*B*

Salts identical with those used in this laboratory were sent by the authors to Mr. Barrows, with instructions for making up Solution I*B* identical with that used by us and described on page 384.

ANODES—Cobalt anodes were cast at this laboratory of the size (7 in. × $2\frac{1}{2}$ in.) required by Mr. Barrows for his tank, and sent him for use in these experiments. The anodes used in a bath had a surface of approximately 1 sq. ft. area. They analyzed as follows:

Co	Ni	Fe	As	P	S	C
98.75	None	1.35	None	0.0067	0.052	0.061

Mr. Barrows, in collaboration with the authors, tested Solution I*B* for plating purposes, during the months of August and September, 1914. The plating was accomplished under standard commercial conditions on copper, brass, iron, steel, tin, German silver, lead and Britannia metal. Various articles, such as brass castings, sheet brass, steel stampings, skates, automobile hubs, etc.—articles of very different shapes and sizes—were plated under exactly the same general conditions as for nickel plating practice at the Russell Motor Car Company.

The tests were made in a still solution, *i. e.*, without agitation of any kind, and the resulting plates were subjected to the most severe practical tests. This work was regarded by Mr. Barrows purely from the commercial viewpoint, and with this in mind, he particularly tested and studied the following points: the color of the plate, the uniformity and freedom from defects of the plates, the allowable speed of plating without pitting or burning (*i. e.*, the maximum allowable current density), the solubility of the anodes, the required voltage, the "throwing" properties of the bath (*i. e.*, its ability to cover the deeper parts of the object in a satisfactory manner), the solubility of the salts, the hardness of the plates, the ease of "coloring" the plate on a buff, the efficiency of the plating solution, the time required for aging of the bath, the adhesiveness of the plate to the cathode under bending and hammering tests, the general cleanliness of the bath, the corrosion of the plate, and many other special features.

In a letter to one of the authors, dated November 2nd, Mr. Barrows gives a very complete report of his commercial tests of Solution I*B*. This letter follows in full as received, and serves admirably to cover this portion of the work.

To DR. HERBERT T. KALMUS:

After preparing a cobalt plating solution according to your formula for Bath I*B*, and having used this bath daily during the past eight weeks, plating a great variety of copper, brass, iron, steel, tin, German silver, lead and Britannia metal articles of different shapes and sizes under exactly the same conditions as met with in general nickel plating at the factory of the Russell Motor Car Company, West Toronto, and after regarding the characteristics of this particular solution absolutely from a commercial viewpoint, I can heartily confirm any statement you have made to me regarding this remarkable solution. This bath was equipped with cobalt anodes, 98.75 per cent cobalt, which were sent to me from your laboratory.

The runs made have varied from 5 minutes to 24 hours, and in each case the bath has proved wonderfully efficient.

The cobalt plates obtained were smooth, white and fine grained, very adherent and uniform. In fact, the surfaces of these deposits, after several hours' run, were so very smooth and uniform that a 4 inch cotton buff colored them to a mirror finish quite easily. We use 14 inch and 16 inch buffs to color 3-hour deposits of nickel.

To test the hardness of the cobalt as compared with nickel, with reference to either buffing or polishing with emery, we plated strips of brass, one-half the surface with cobalt and one-half with nickel, always giving the nickeled portion the thickest plate. Then buffing or polishing across the two deposits, we found invariably that the nickel was removed from the brass before the cobalt, and in some cases in one-half the time.

Though so hard and firm, these plates color beautifully with little effort, and require the use of much less buffing composition than comparatively thin plates of nickel. Automobile parts of irregular shape were plated from 10 to 20 minutes, and finished on a 6-inch buff operated at 3,000 R. P. M. without the slightest evidence of a defect in the plating. To accomplish this with our fastest nickel baths would require at least 60 minutes of plating.

As a protective coating for iron or steel surfaces, I am convinced that a comparatively thin plate of cobalt will prove equally as effective as a thick plate of nickel from an ordinary double sulfate nickel bath, and the time and power required for the production of such plates is decidedly in favor of the cobalt.

The deposits are also very adherent, no difficulty having been experienced in this respect, although tests were made repeatedly by bending, hammering and burnishing.

One of the weak points of several so-called rapid nickel plating solutions, which we have tried commercially, is their poor "throwing" powers, *i. e.*, they do not deposit the nickel readily in the indentations or cavities of the cathode. The cobalt solution I*B* meets this requirement in a most efficient manner; the deposits on the distant portions of the cathode withstand the tests imposed in every case.

Another most important feature of this solution, which should commend itself to every practical plater and manufacturer of plated wares, is the extremely high current density at which this solution may be employed without danger of pitting the plated surface. I have plated with this cobalt solution, I*B*, satisfactorily and under commercial conditions, at a current density of 42 amp. per sq. ft. This is $4\frac{1}{5}$ times the speed of our fastest commercial nickel solutions.

As a further test, we plated steel tubes of 1 in. diameter for two hours, with a current density of 27 amp. per sq. ft., and then drew the tubes down to $\frac{5}{8}$ in. diameter without injuring the deposit. Though extremely hard, the ductility of the deposited metal proved remarkable.

All of our tests have been made in a still solution, without agitation of any kind, and the plates were subjected to the most severe treatment considered practical for high-grade metallic coatings on the various metals heretofore mentioned.

We are also of the opinion that the anodes in the cobalt bath I*B* will remain free from coatings, such as characterize average anodes used in nickel baths, and that the cost of maintenance will be practically nothing compared to double sulfate nickel solutions.

I can assure you that my experience thus far with these cobalt solutions has been intensely interesting, and I sincerely believe that their use commercially would revolutionize the art of electro-plating such wares as are now nickelplated.

The simplicity of its composition, its self-sustaining qualities, the remarkable speed of deposition, together with the several points mentioned previously, should appeal to the commercial requirements of this progressive age.

WALTER S. BARROWS

November 2, 1914

COMMERCIAL REPORT ON SOLUTION XIII*B*

After the completion of the test on Solution I*B* by Mr. Barrows, salts identical with those used by the authors were sent to him, with instructions for preparing Bath XIII*B*, identical with that described on page 393.

TABLE IX—COMMERCIAL EXPERIMENTS WITH COBALT SOLUTION XIII*B* AT THE RUSSELL MOTOR CAR CO. PLANT

SOLUTION XIII*B*—Cobalt sulfate crystals, 26 lbs. 10$^1/_2$ oz. Salt (NaCl), 15$^1/_2$ oz. Water, 4$^3/_4$ gals. Boric acid, 3 lbs. Sp. gr., 28.5° Bé. Temperature, 64° F. Acidity, strongly acid

Date 1914	Cur. Dens. Amp. per sq. dm.	E. M. F. Volts	Elec. dist. In.	Cathode Material	Cathode Area Sq. in.	Plating time Hr.	Plating time Min.	Character of Deposit
11/2	6.5	4.25	5.0	Brass	12	0	5	Smooth, hard, firm, very adherent; stood bending test and twisting. Buffed on 12 in. cotton buff wheel at 3600 R. P. M. with pressure approximately same as for heavy nickel plate. No evidence of cutting through; splendid results.
	4.4	3.5	5.0	Steel	28	1	0	Mottled, burnt, impossible to buff or polish to a satisfactory surface. Solution full of floating particles of boric acid.
	3.2	3.5	5	Brass	42.5	1	0	Mottled, cloudy plate at edges, center quite brilliant, but difficult to color. Poor plate.
		(Filtered solution)						
5	3.5	5	5	Brass hub cap	70		30	Very heavy, dirty gray; flaked on sides; burnt at edges; rough and impossible to color. Inside well covered (2$^1/_2$ in. deep).
6	9.0	4	5	Brass	12		5	Gray, streaked.
	12.0	6	5		12		5	Whiter, better than last test.
	13.1	4.5	2.5		4		2	White, tough at center, edges badly burnt.
	21.4	6	5	Copper	4		2	Excellent. Good thickness, corners cracked only slightly. Deposit could be felt with finger nail; buffed to good color. Did not crack when bent double.
6	20.0	6.5	5		4	0	2	
9	6.9	4.5	5		9	0	15	Smooth, hard, white, adherent. Buffed to good finish.
11	8.3	4	5	Corrugated steel	9.5	0	10	Best plate thus far. Buffed to mirror finish over entire surface. Deepest grooves in good condition.
11	4.2	3.5	5	Thick steel	28	0	50	Appeared satisfactory when removed from bath, but scaled at center when dipped in hot water.
12	8.6	9	5	Brass	16.5	0	1	Smooth, uniform, white plate; withstood hard buffing. Colored easily to mirror finish.
12	8.6	8	5	Brass hub cap	45	0	1	Smooth, white plate, buffed to excellent finish. No evidence of a defect.
12	19.4	8	5	Perforated brass	8	0	2	Beautiful results; high and low spots perfect.
12	19.4	8	5	Same piece		0	1	Cleaned the piece just plated and plated on the first deposit without stripping. No indication of trouble from this source.
12	9.7	6	5	Same piece		0	5	Splendid plate, colored by rubbing with flannel cloth, afterwards stood severe buffing test.
12	10.7	3	5	Same piece		0	15	Dull, muddy color when removed from bath, buffed readily to good luster. Background not as white as when higher voltage was used.
17	16.8	6	5	Cast iron	18	0	1	Burnished the piece with 400 lbs. steel balls for 15 minutes; good finish. No evidence of wearing through deposit. Placed the casting in acidulated water (15 to 1) for 36 hours, wiped dry. No evidence of defective coating; casting remained in good condition.
17	17.1	6.5	5	Embossed brass	12	0	1	Buffed on 10 in. wheel at 3600 R. P. M., excellent finish. Did not cut through letters or raised parts.
17	19.4		5	6 of same	72	0	1	Excellent plate.
17	26.4		5	Brass	2.5	0	1	Splendid plate; hard, yet pliable. Plated 200 of these pieces in same manner, in 1 doz. lots.
17	16.9		5	Polished lead	12	0	5	Adherent plate, hard, smooth and good color, buffed readily. Did not break when bent. Cut lead in pieces without scaling deposit.
18	16.8		5	Britannia metal	30	0	5	Very satisfactory plate, adherent and white.
18	16.8		5	Steel skate blade	33.3	0	5	Not as white as desired, but otherwise very good plate.
19	17.0	6	5	German silver	10	0	2	Excellent plate.
19	16.8	6.5	5	Tin	15	0	5	This deposit stood every conceivable abuse, and was easily colored on small buff.
20	16.3		5	Brass hub cap	45	0	3	Buffed to a beautiful finish. Required very severe buffing on wheel revolving at 1500 R. P. M. to cut through; apparently equal to a 1 hour nickel deposit.
20	17.0		5	Brass	10	0	1	Plated 100 pieces, and buffed them ready for stock in 1 hour.
20	17.0		5		60	0	1	
23	16.8	6	5	Steel tube	18	0	15	Drew tube from 1 to $^3/_4$ in., buffed same and found perfect, then drew tube to $^5/_8$ in., buffed again and still perfect.
23	11.6	6	5	Cathodes—Oxidized silver-faced Britannia metal 14 sq. in. anode surface	12	15	15	The die was merely washed with alcohol, rinsed in water and placed in cobalt bath. A current of 15 amp. was passed through the bath for 10 minutes, while the cathode was kept constantly moving. Current then reduced to 9 amp. and cathode closely watched during the following hour. Bath switched to battery circuit and allowed to remain undisturbed during the night. Resulting deposit was quite smooth at center, edges rough but solid; face of die in fine condition. The finest lines perfect. The deposit did not curl nor lift from the master die during run. Deposit about $^3/_{32}$ in. Extraordinary results for die work.
24	21.1	6.5	5	$^1/_{32}$ in. brass	4	0	5	Splendid plate, beautiful color after buffing.
24	16.8	6.5	2.5	Brass	12	0	5	Firm, tough, adherent plate, white in color, began to darken at edges, oiled off edges with emery, then buffed entire surface to splendid finish.
25	20.0	6.5	5	Brass	4	0	10	Adherent, white, smooth plate, buffed very easily to good finish.

NOTE—To transform amperes per square decimeter to amperes per square foot, multiply by 9.3.

ANODES—Cobalt anodes, identical with those used for Solution I*B* (p. 395), were furnished from this laboratory.

Tests were made of this solution in the manner and from the same point of view as those for Solution I*B*.

In a letter to one of the authors, dated December 1st, Mr. Barrows gives a complete report of his commercial tests of Solution XIII*B*. This letter follows in full as received:

To DR. HERBERT T. KALMUS:

After thoroughly testing Cobalt Plating Bath XIII*B*, made according to your formula, I take pleasure in submitting the following report:

I found the bath very simple to prepare and at once began to operate the solution with high current densities. The results obtained were exceedingly gratifying. Evidently Bath XIIIB will require no prolonged aging treatment, as splendid, white, hard, perfect deposits were obtained with extremely high current densities within 3 hours after bath was prepared.

The experiments have been varied and the tests of plates severe and deliberate; the results have invariably been such as to cause me to regard Cobalt Bath XIII*B* the greatest achievement in modern electro-plating improvements.

The operation of the bath is positively fascinating: the limit of speed for commercial plating is astonishing, while the excellence of the plates produced is superior to those of nickel for many reasons.

The efficiency of the freshly prepared solution, together with the self-sustaining qualities of the bath, are without a parallel in any plating solution of any kind I have ever used.

Thin embossed brass stampings were plated in Bath XIII*B* for only one minute, then given to a buffer who did not know the bath existed and who was accustomed to buffing 1$^1/_4$ hour nickel deposits on these same stampings. This man buffed the cobalt plates upon a 10-in. cotton buff wheel revolving at 3000 R. P. M. The finish was perfect with no edges exposed. These stampings have been plated in two dozen lots for one minute, and from a total of 500 stampings we have found but three stampings imperfect after buffing. Each stamping is formed to a spiral after finishing without injury to the deposit. Grey iron castings with raised designs upon the surface were plated 1 minute in Cobalt Bath XIII*B*, then burnished with 400 lbs. of $^1/_8$ in. steel balls for $^1/_4$ hour without the slightest injury to the cobalt coating, as was proven by a 36-hour immersion in 15 oz. of water acidulated with 1 oz. of sulfuric acid.

While attempting to reach the limit of current densities which would be practical with this bath, XIII*B*, I have plated brass automobile trimmings with a current density of 244 amp. per sq. ft. These pieces were plated in lots of 6, and a total of 100 were plated, buffed and ready for stock in 1 hour's time. No unusual preparation was made for the run and the work was performed by one man. The size of piece plated was $1^{1}/_{2}$ in. × 5 in.

Automobile hub caps were plated 3 minutes in Cobalt Bath XIII*B* and buffed to a beautiful luster of deep rich bluish tone by use of a 7-in. cotton buff revolving at 1200 R. P. M. The deposits were ample for severe treatment usually received by such articles. Comparative tests of these deposits were made as follows: Same style castings plated in double sulfate nickel solution one hour were suspended as anodes in a solution of equal parts muriatic acid and water; sheet lead cathodes were used and a current of 200 amperes at 10 volts passed through the bath. The nickel was removed from the castings in 30 seconds, while 45 seconds time was required to remove the cobalt plates.

The above-mentioned plating tests were made with still solution, no form of agitation being employed. By aid of mechanical agitators these current densities could be greatly exceeded with highly satisfactory results.

These cobalt plates were very hard, white and adherent and colored easily with slight effort.

Several plates were produced upon sharp steel surgical instruments; these instruments finished perfectly and, owing to the hardness of the cobalt plate, only a thin deposit was required to equal the best nickel deposits which we received as samples. Cobalt deposits should prove especially valuable for electroplating surgical instruments, since non-adherent thick deposits are very dangerous for this class of work.

Owing to the unusual mild weather in this locality during the past month, I have not concluded the test with cobalt plates on highly tempered nickel steel skate blades, but judging from appearances and various severe indoor tests we do not hesitate to report success in this direction. A 3-minute deposit from Bath XIII*B* resists corrosion equally as long as a one-hour nickel deposit; the finish is even superior to nickel, while every test employed during the process of manufacturing the nickel-plated article has proved equally ineffective with cobalt plates; therefore by reason of the effectiveness of thin cobalt deposits we believe cobalt plates should prove wonderfully efficient on skates or any keen-edged tool requiring a protective metallic coating.

The runs made with Bath XIII*B* have varied from one minute to $15^{1}/_{2}$ hours, and in each case the results were remarkable. Electrotypes were reproduced $^{1}/_{16}$ in. thick. Electro-dies were faced with cobalt $^{1}/_{8}$ in. thick, the electrotypes being graphite covered wax and lead moulds, while the dies were made on oxidized silver-faced Britannia metal.

The deposits from Cobalt Bath XIII*B* were very adherent and pliable; by proper regulation of the current, beautiful white, hard, tough plates may be produced quickly on any conducting surface.

The "throwing" powers of Cobalt Bath XIII*B* make possible its employment for plating deeply indented or grooved articles such as reflectors, channel bars or articles with projecting portions.

We also obtained the best plates with extremely high current densities, although plates finished with 75 amp. per sq. ft. were of good color and easily buffed. The production of excellent plates with a current density of 150 amp. proved particularly easy, and densities in this neighborhood were employed for the greater portion of our tests.

Cobalt Bath XIII*B* will produce excellent, hard, white, tough plates absolutely free from pits or blemish at a current density of 150 amp. per sq. ft. and under ordinary commercial conditions. This is 15 times the speed of our fastest commercial nickel solution.

Furthermore, the anode tops and hooks remain free from creeping salts. The solution retains its original clean appearance and the anodes dissolve satisfactorily with no slime nor coating formed; brushing or cleaning anodes therefore will be unnecessary. The anodes used with this bath were 98.75 per cent cobalt which were sent me from your laboratory. The bath at the commencement of our tests was strongly acid to litmus, and has remained unchanged throughout our experiments. The specific gravity of the solution when freshly prepared was 1.24 and is the same today.

The rich, deep, bluish white tone of the cobalt plates upon polished brass surfaces is particularly noteworthy; this feature should assist greatly in making cobalt deposits very popular for brass fixtures, trimmings and plumbers' supplies.

My experience with Cobalt Bath XIII*B* is by no means at an end. I intend to continue its use until present supplies are exhausted and then equip a larger bath if supplies are obtainable. As a commercial proposition I am satisfied it is wonderfully efficient and economical.

Taking into account the difference in cost of cobalt as compared with nickel, I am satisfied the metal costs for plating a given quantity of work with cobalt would be considerably less than for nickel plating a like quantity.

Furthermore, the use of Cobalt Bath XIII*B* equipped with automatic apparatus for conveying parts through the bath would reduce the labor cost 75 per cent, and such apparatus would be practical for a greater variety of wares than is now the case with nickel.

We cannot speak too highly of Cobalt Bath XIII*B*, and confidently believe its future history will surpass the history of any electro-plating bath now in general use.

In conclusion, please accept my warmest congratulations upon your successes with cobalt solutions. Heartily appreciating the opportunity of testing these solutions, I desire to sincerely thank you, kind sir, for the benefits derived therefrom.

WALTER S. BARROWS

December 1, 1914

GENERAL CONCLUSIONS FROM COMMERCIAL TESTS ON COBALT PLATING SOLUTIONS

1—Several cobalt solutions were found to be suitable for electro-plating with cobalt under the conditions of commercial practice. Best among these are the following:

SOLUTION I*B*

Cobalt-ammonium sulfate, $CoSO_4.(NH_4)_2SO_4.6H_2O$, 200 grams to the liter of water, which is equivalent of 145 grams of anhydrous cobalt-ammonium sulfate, $CoSO_4.(NH_4)_2SO_4$, to the liter of water. Sp. gr. = 1.053 at 15° C.

SOLUTION XIII*B*

Cobalt sulfate, $CoSO_4$	312 grams
Sodium chloride, NaCl	19.6 grams
Boric acid	Nearly to saturation
Water	1000 cc.

Sp. gr. = 1.25 at 15° C.

2—Cobalt plates from these solutions, on brass, iron, steel, copper, tin, German silver, lead and Britannia metal articles, of different shapes and sizes, deposited under conditions identical with those met with in general nickel plating practice, are firm, adherent, hard and uniform. They may be readily buffed to a satisfactorily finished surface, having a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

3—The electrical conductivity of these solutions is considerably higher than that of the standard commercial nickel solutions, so that, other things being equal, they may be operated at a lower voltage for a given speed of plating.

4—Solution I*B* is capable of cobalt plating on the various sizes and shapes of objects met with in commercial practice at a speed at least 4 times that of the fastest satisfactory nickel solutions.

5—Solution XIII*B* is capable of cobalt plating on the various sizes and shapes of objects met with in commercial practice at a speed at least 15 times as great as that of the fastest satisfactory nickel solutions.

6—Plates from both of these solutions on various stock pieces satisfactorily withstood the various bending, hammering and burnishing tests to which commercial nickel work is ordinarily submitted.

7—These two very rapid cobalt solutions are remarkable for their satisfactory throwing power; *i. e.*, they readily and satisfactorily deposit the cobalt in the indentations of the work.

8—These two rapid solutions operate at these high speeds in a perfectly still solution without agitation of any kind.

9—These solutions are both cleaner, *i. e.*, freer from creeping salts and precipitated matter, than the standard commercial nickel baths.

10—The cobalt deposited at this rapid speed is very much harder than the nickel deposited in any commercial nickel bath. Consequently a lesser weight of this hard cobalt deposit will offer the same protective coat as a greater weight of the softer nickel deposit. Considering Solution XIII*B*, operating at 150 amp. per sq. ft., on automobile parts, brass stampings, etc., a sufficient weight of cobalt to stand the usual commercial tests, including buffing and finishing, is deposited in 1 minute. With the best nickel baths it takes 1 hour at about 10 amp. per sq. ft. to deposit a plate equally satisfactory. Therefore, the actual weight of metal on the cobalt plate must be approximately one-quarter that of the nickel.

11—For many purposes, under the condition of these rapid plating solutions, one-quarter the weight of cobalt, as compared with nickel, is required to do the same protective work. Consequently, if nickel is worth 50 cents per lb., in the anode form, cobalt could be worth nearly $2.00 per lb., in the same form, to be on the same basis, weight for weight, of metal. In addition there are other advantages of cobalt in saving of labor, time, overhead, etc.

12—A smaller plating room would handle a given amount of work per day with cobalt than with nickel.

13—With these very rapid plating solutions, by the use of mechanical devices to handle the work, the time required for plating, as well as the labor costs, may be tremendously reduced. Solution I*B*, and, particularly, Solution XIII*B*, are so rapid as to be revolutionary in this respect.

14—Obviously, the cost of supplies, repairs, etc., would be less with cobalt plating than with nickel plating, as the size of the plant for a required amount of work is less.

15—The voltage required for extremely rapid cobalt plating is greater than that for most nickel plating baths; it is not so great but that the machines at present in use may in general be operated. For the same speed of plating, the cobalt solution requires much the lower voltage.

16—For a given amount of work the power consumption for this rapid cobalt work is less than that for nickel. This is obvious, because the total amount of metal deposited in the case of cobalt is very much less, whereas the voltage at which it is deposited is not correspondingly greater.

17—Ornamental work on brass, copper, tin or German silver would require only a 1-minute deposit. Even wares exposed to severe atmospheric influences, or friction, could be admirably coated with cobalt in Bath XIII*B* in 15 minutes. The tremendous possibilities of this solution are not to be completely realized unless mechanical devices are applied to reduce hand labor to a considerable extent.

18—Thick deposits from these solutions are vastly superior to any that we have seen produced from nickel solutions. The tendency to distort thin cathodes is less pronounced, while electrotypes and electro-dies have been given a superior thick deposit in a most satisfactory manner. The lines were hard, sharp and tough and the surface smooth. Nickel does not equal cobalt for excellence of massive plates.

19—Many of these tests were passed upon by uninterested skilled mechanics at the plant of the Russell Motor Car Company, who invariably reported in favor of the cobalt as above.

20—Both Baths I*B* and XIII*B* are substantially self-sustaining, once they are put into operating condition, and the amount of aging required to do this is very much less for them than that for the present commercial nickel baths.

A number of automobile parts, and a large number of skates, cobaltplated, were turned out at the plant of the Russell Motor Car Company under Mr. Barrows' direction, and many of the skates have now (February 6, 1915) been under observation in actual use for several months. On this date Mr. Barrows reported that skates plated from Solution XIII*B*, many of which had had extremely hard usage in the hands of boys, etc., were showing up with surprising satisfaction. There is absolutely no stripping of the plate along the edge of the skate, either before or after use, which, unfortunately, is not uncommon with nickelplated skates. Furthermore, the cobaltplated skates seem to be decidedly superior to the nickelplated skates as regards their resistance to corrosion. Another very noticeable feature about the cobaltplated skates is that they are very free from scratches after rough usage as compared with nickel; that is to say, the cobalt plate is decidedly harder than the nickel plate. Most of the skates in question were plated in 3 minutes at 90 to 100 amp. per sq. ft. Nickel plates at the same plant are plated in 1 hour at about 4 amp. per sq. ft. There is apparently considerably more cobalt metal plate on these skates than need be to make them equivalent to nickelplated skates.

The authors take great pleasure in expressing their thanks to the Russell Motor Car Company for their collaboration, and particularly to Mr. W. S. Bar-

rows for the careful, vigorous and painstaking manner in which he has subjected the solutions and plates to the various tests that were required to establish their commercial importance and value.

RESEARCH LABORATORY OF APPLIED
ELECTROCHEMISTRY AND METALLURGY
QUEEN'S UNIVERSITY, KINGSTON, ONTARIO

THE FUSIBILITY OF COAL ASH IN VARIOUS ATMOSPHERES[1]

By A. C. FIELDNER AND A. E. HALL

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INTRODUCTION

In connection with a general study of the fusibility of coal ash under various fuel-bed conditions, at the Pittsburgh Experiment Station of the Bureau of Mines, considerable experimental data have been obtained concerning some of the factors affecting the softening temperature of ash when molded in the form of Seger cones. It was realized that the so-called "fusing temperature" tests made by this method were likely to give exceedingly variable results in different laboratories, as numerous investigators have shown in the case of Seger pyrometric cones, which are of much simpler composition than coal ash. Indeed, L. S. Marks[2] has recently called attention to differences as great as 390° C. which were obtained on the same sample of ash by two different commercial laboratories. It, therefore, seems advisable to present in some detail the results that have been obtained in our investigation in order that fuel chemists may fully appreciate the empirical nature of the test.

RELATION OF SOFTENING TEMPERATURE OF ASH TO MELTING TEMPERATURE OF EUTECTIC

A complex mixture of oxides and silicates like coal ash has no single, definite melting point. On slowly heating a sample of ash it successively shrinks, sinters and then gradually softens into a more or less viscous slag. From the viewpoint of clinker formation, we wish to know the temperature at which the ash may form a slag of sufficient fluidity to flow or agglomerate in the fuel bed. Since this temperature is probably below the temperature of complete melting of the ash, *i. e.*, the lowest temperature at which the melt on sudden cooling is all converted to glass, the "softening" or "flowing" temperature of the ash when made in the form of a cone seems a more likely indicator of clinkering tendencies.

The deformation of a cone is also a rough measure of viscosity, which undoubtedly is a very important factor. It must, however, be kept in mind that the deformation of the cone does not afford a melting point or any other fixed transformation based on any change of state. As pointed out by Day and Shepard,[3] a cone made of silicate mixtures, which are capable of forming eutectics, begins to weaken as soon as the eutectic begins to melt; its further progress is then governed entirely by the relative quantity of eutectic present and its viscosity after melting. If the constituents of the ash are such as to form a relatively large proportion of thinly fluid eutectic, the deformation point of the cone will lie close to the melting point of the eutectic; on the other hand, if there is a large excess of some refractory component, such as silica or aluminum silicate, or if the eutectic is viscous, the excess component will form a rigid skeleton which is not pulled down by the flowing eutectic. In the latter case the deformation point will approach more nearly the melting point of the rigid component.

FACTORS INFLUENCING THE SOFTENING POINT

The rate of deformation is also influenced by the rate of heating. Reactions between different constituents take place before their melting points are reached. Some of these reactions are slower than others. Also some constituents have a slow time-rate of melting, as, for example, silica and feldspar. These substances can be heated above their melting points and yet remain in a crystalline form for some time. It is obvious, then, that the deformation temperature of an ash cone must be affected by (1) rate of heating; (2) size, shape and inclination of cone; (3) fineness of ash; and (4) nature of atmosphere in which the cone is heated.

INFLUENCE OF IRON OXIDES

On account of the presence of iron oxide in considerable quantities in many ashes, the nature of the atmosphere in which the ash cone is heated has a marked influence on the softening point. Under suitable conditions iron may exist as metallic iron, pure or alloyed with carbon, as ferrous oxide (FeO), magnetite (Fe_3O_4), or ferric oxide (Fe_2O_3). On complete combustion at low temperatures, the pyrite in coal is converted to Fe_2O_3. According to Walden,[1] ferric oxide (Fe_2O_3) dissociates at 1350° C., when heated in air at atmospheric pressure, into magnetite (Fe_3O_4) and oxygen. Therefore, in determining the softening temperature of an ash cone in an atmosphere of air (no reducing gases present), we are dealing with the formation of slags in which the iron component enters the reaction as ferric oxide or magnetite. Peters[2] states that "ferric oxide forms compounds with silica which require a high temperature for their fusion, and is consequently an unwelcome base for slags; although this substance is an almost invariable constituent of oxidized ores, it seldom makes any trouble in the blast furnace, for the reason that it is easily reduced by the fuel gases to ferrous oxide (FeO).........

"In the more neutral atmospheres of the reverberating smelter, however, it is likely to cause delay by combining with silica, making it more difficult to melt the slag."

On the other hand, if the ash cone is heated in a slightly reducing atmosphere of hydrogen or carbon monoxide, the ferric oxide is reduced to ferrous oxide

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[1] Published by permission of the Director U. S. Bureau of Mines.

[2] L. S. Marks, "The Clinkering of Coal," *Power*, **40** (1914), 932–4.

[3] A. L. Day and E. S. Shepard, "The Lime-Silica Series of Minerals," *Am. J. Sci.*, [4] **22** (1906), 267. Also a full discussion of the theory of Seger cones, see "The Physical Chemistry of Seger Cones," by R. B. Sosman, *Trans. Am. Ceram. Soc.*, **15** (1913), 482–498.

[1] P. T. Walden, "On the Dissociation Pressure of Ferric Oxide," *J. Am. Chem. Soc.*, **30**, 1350.

[2] Edward Dyer Peters, "Principles of Copper Smelting," Hill Pub. Co., New York, **1907**, pp. 399–400.

which is a strong fluxing agent. Steffe[1] found the following formation temperatures for various ferrous silicates:

Formation temperature	° C.
$4FeO.SiO_2$	1158–1174
$2FeO.SiO_2$	1162–1183
$4FeO.3SiO_2$	1162–1181
$FeO.SiO_2$	1158–1171
$2FeO.3SiO_2$	1321–1334

The viscosity of ferrous-silicate slags is lower than when the iron component enters the reaction in the ferric form, as shown by Greiner;[2] so the conclusion seems logical that in general lower softening temperatures may be expected if the atmosphere surrounding the cone is able to reduce all the iron to the ferrous state before fusion begins, but not to metallic iron, for in the latter event one of the most active fluxing constituents is removed from the system. Most ashes have already an excess of high-melting constituents like silica and alumina, so that any considerable reduction of iron oxide to metallic iron would tend to increase the refractory effect of the silica and alumina. Hence, lower softening temperatures may be expected in tests made in gas furnaces where some reducing gases come in contact with the ash, while higher results should be found both in furnaces where air only surrounds the cone and in carbon or graphite electric furnaces where strongly reducing atmospheres reduce the iron oxides to metallic iron.

EXPERIMENTAL

In the following experiments the authors have studied the effect of various factors in the softening temperature of ash, by making tests on a considerable number of different ashes in different types of furnaces such as are in more or less common use for the purpose. Before giving the results obtained in each furnace, the coals tested and general method of operation will be described.

TABLE I—DESCRIPTION AND ORIGIN OF SAMPLES

				LOCATION OF MINE		
SAMPLE NO.	LAB. NO.	DESCRIPTION	BED	NEAREST TOWN	COUNTY	STATE
1	15840	Bituminous	Coal Creek	Fraterville	Anderson	Tenn.
2	15841	Bituminous	American	Parrish	Walker	Ala.
3	15842	Bituminous	Sterling	Manring	Claiborne	Tenn.
4	15843	Bituminous	Jellico	Jellico	Campbell	Tenn.
5	15844	Bituminous	Mingo	Fork Ridge	Claiborne	Tenn.
6	15845	Bituminous	Coal Creek	Oliver	Morgan	Tenn.
7	15846	Bituminous	Mary Lee	Red Star	Walker	Ala.
8	15847	Bituminous	Nickel plate	Jefferson	Jefferson	Ala.
9	15848	Bituminous	Thompson	Marvel	Bibb	Ala.
10	16018	Bituminous	Red stone	Lemely Jct.	Barbour	W. Va.
11	16019	Bituminous	Pittsburgh	Morgantown	Monongalia	W. Va.
12	16243	Bituminous	No. 5	Booneville	Warrick	Ind.
13	16583	Semi-bituminous	Pocahontas No. 3	Simmons	Mercer	W. Va.
14	16584	Semi-bituminous	Pocahontas No. 3	Bramwell	Mercer	W. Va.
15	16585	Semi-bituminous	Pocahontas No. 3	Elk Ridge	McDowell	W. Va.
16	16586	Semi-bituminous	Pocahontas No. 3	Big Four	McDowell	W. Va.
17	16587	Semi-bituminous	Pocahontas No. 3	Jenkin Jones	McDowell	W. Va.
18	16589	Semi-bituminous	Pocahontas No. 3	Boissevain	Tazewell	Va.
19	17081	Anthracite (buckwheat)	....	....	....	Pa.
20	17189	Anthracite (buckwheat)	....	Shenandoah	Schuylkill	Pa.
21	17534	Anthracite (buckwheat)	....	....	Luzerne	Pa.
22	17590	Anthracite (buckwheat)	....	Shamokin	Northumberland	Pa.
23	18248	Anthracite (buckwheat)	....	....	....	Pa.
24	14762	Anthracite (buckwheat)	....	....	....	Pa.
25	17563	Semi-bituminous	Georges Creek	Lonaconing	Alleghany	Md.
26	7244(*a*)	Semi-bituminous(*c*)	Pocahontas No. 3	Pocahontas	Tazewell	Va.
27	7305(*a*)	Semi-bituminous(*c*)	Pocahontas No. 3	Pocahontas	Tazewell	Va.
28	7308	Semi-bituminous(*c*)	Pocahontas No. 3	Pocahontas	Tazewell	Va.
29	7309(*b*)	Semi-bituminous(*c*)	Pocahontas No. 3	Pocahontas	Tazewell	Va.
30	18193	Semi-bituminous	Pocahontas No. 3	Pocahontas	Tazewell	Va.
31	18198	Semi-bituminous	Pocahontas No. 3	Pocahontas	Tazewell	Va.
32	18203	Semi-bituminous	Pocahontas No. 3	Pocahontas	Tazewell	Va.
33	18349	Semi-bituminous	Pocahontas No. 3	Pocahontas	Tazewell	Va.
34	18350	Semi-bituminous	Pocahontas No. 3	Pocahontas	Tazewell	Va.
35	18208	Semi-bituminous	Lower Kittanning	Ebenburg	Cambria	Pa.
36	18296	Semi-bituminous	....	Bering River Field	....	Alaska
37	18297	Semi-bituminous	....	Bering River Field	....	Alaska
38	18298	Semi-bituminous	....	Bering River Field	....	Alaska
39	18302	Semi-bituminous	....	Bering River Field	....	Alaska
40	18308	Semi-bituminous	....	Bering River Field	....	Alaska
41	18310	Semi-bituminous	....	Bering River Field	....	Alaska
42	18312	Semi-bituminous	....	Bering River Field	....	Alaska
43	18300	Semi-bituminous	....	Bering River Field	....	Alaska
44	18303	Semi-bituminous	....	Bering River Field	....	Alaska
45	18306	Semi-bituminous	....	Bering River Field	....	Alaska
46	18348	Semi-bituminous	....	Bering River Field	....	Alaska
47	18347	Semi-bituminous	....	Bering River Field	....	Alaska
48	18350	Semi-bituminous	....	Bering River Field	....	Alaska
49	12690	Bituminous	Pittsburgh	Greensburg	Westmoreland	Pa.
50	12691(*b*)	Bituminous	Pittsburgh	Greensburg	Westmoreland	Pa.
51	7228(*a*)	Bituminous	Pittsburgh	Marianna	Washington	Pa.
52	7230	Bituminous	Pittsburgh	Marianna	Washington	Pa.
53	7141(*a*)	Bituminous	Pittsburgh	Marianna	Washington	Pa.
54	7458(*b*)	Bituminous	Pittsburgh	Carnegie	Allegheny	Pa.
55	13316	Sub-bituminous	....	Batan	....	Philippine Island
56	7548(*b*)	Lignite	....	Rockdale	Milan	Texas
57	7381(*a*)	Lignite	....	Rockdale	Milan	Texas
58	7490(*a*)	Lignite	....	Lytle	Medina	Texas
59	7494(*a*)	Lignite	....	Lytle	Medina	Texas
60	7522(*b*)	Lignite	....	Calvert	Robertson	Texas
61	7534	Lignite	....	Calvert	Robertson	Texas
62	7536(*a*)	Lignite	....	Calvert	Robertson	Texas
63	7159(*a*)	Peat briquettes	....	Elizabeth City	Pasquotauk	N. C.

(*a*) Clinker from gas producer. (*b*) Clinker from boiler furnace. (*c*) Bone coal.

The description and origin of the coal samples are given in Table I, and the analyses of the ashes and partial analyses of the coals in Table II. As may be

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[1] Herman Steffe, "On the Formation Temperature of a Few Ferro-Calcic Slags and of a Few Ferrous Slags Free from Calcium, the Knowledge of which is Significant for the Smelting of Lead Ores," Dissertation, Berlin, **1908**.

[2] E. Greiner, "Ueber die Abhängigkeit der Viscosität in Silikat schmelzen von ihrer Zusammensetzung," Inaugural Diss., Jena, **1907**, p. 55.

seen from an inspection of these tables, the series of fuels tested include anthracite, bituminous, semi-bituminous, sub-bituminous, lignite and peat; the compositions of the ashes cover a fairly wide range, silica varying from 12.3 to 76.0 per cent; alumina from 8.6 to 34.7; ferric oxide from 3.8 to 69.7; lime from 0.6 to 18.6; and magnesia from 0.2 to 10.0 per cent.

The coal samples were ground to 60 mesh with crusher, rolls and ball mill as described in our Technical Paper 8.[1] The 60 mesh material was spread out on shallow, 6-inch, fireclay roasting dishes, and completely ashed with occasional stirring in a muffle furnace at a temperature not exceeding 750° C. All of the ash was finally put through a 100 mesh screen and thoroughly mixed.

TABLE II—PERCENTAGE ANALYSES OF ASH AND DRY COAL

Sample	ANALYSES OF ASH									DRY COAL	
No.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SO_3	S	Ash
1	35.7	23.5	32.9	1.2	3.2	1.1	0.3	1.1	0.5	3.1	10.8
2	47.3	34.6	9.8	1.8	1.3	0.4	2.1	2.5	0.1	1.7	17.4
3	55.8	33.5	5.0	0.9	1.5	0.7	0.5	2.2	0.1	0.8	15.6
4	43.3	31.4	13.6	1.6	4.2	1.4	0.6	2.9	1.4	1.5	8.6
5	42.2	30.6	19.0	1.2	1.3	1.0	1.3	2.9	0.2	1.4	7.5
6	12.3	12.2	69.7	0.4	3.9	0.7	0.3	0.6	0.2	5.8	8.2
7	54.1	34.7	4.5	1.5	1.2	0.9	0.6	2.5	0.2	0.7	17.7
8	46.8	28.7	18.0	1.4	0.6	0.9	1.6	2.4	0.3	2.3	12.7
9	54.8	27.0	7.0	1.3	4.3	1.7	0.3	3.1	1.4	0.6	17.5
10	38.4	24.2	22.4	1.1	7.7	0.9	0.3	1.9	3.8	2.1	7.9
11	50.4	24.0	20.4	1.4	1.7	0.2	1.0	1.0	0.3	2.7	10.9
12	37.1	17.6	35.9	0.7	3.2	0.9	0.4	1.8	2.3	5.8	11.5
13	54.8	27.0	7.8	1.6	1.6	1.5	2.2	1.9	0.5	0.7	8.0
14	54.8	29.2	6.9	1.8	1.4	0.6	1.9	2.1	1.0	0.7	7.5
15	54.1	24.8	9.4	2.3	4.0	1.4	1.0	0.8	2.8	0.6	7.1
16	37.2	25.5	11.8	1.5	12.6	1.9	1.4	0.4	5.6	0.6	5.9
17	51.1	25.2	10.1	1.8	5.1	1.6	0.8	0.9	3.1	0.6	6.8
18	51.8	25.0	9.0	2.0	4.0	1.5	1.3	0.8	4.3	0.7	5.6
19	56.1	31.4	5.0	1.9	1.0	1.0	0.7	3.1	0.5	0.7	21.5
26	68.9	21.4	4.5	2.6	2.0	0.7	0.6	0.5	...	0.6	17.2
27	69.4	21.5	4.8	2.0	1.6	0.8	0.5	1.4	...	0.7	14.8
28	64.7	23.2	4.7	2.6	1.2	0.8	0.3	0.5	1.5	0.7	14.8
29	69.6	19.7	5.2	2.2	2.0	0.4	0.4	0.5	...	0.7	14.1
49	54.7	32.9	8.9	...	1.6	0.9	0.6	0.2	...	0.9	11.1
51	54.5	27.0	12.1	1.8	1.5	0.4	0.5	1.9	...	1.7	11.4
52	53.2	26.0	15.8	1.4	1.0	0.7	0.3	1.6	0.4	1.7	11.4
53	54.6	25.7	12.4	1.4	4.3	0.6	0.6	1.3	...	1.4	12.5
54	56.8	28.2	11.3	1.2	1.0	0.8	0.6	1.6	...	1.8	12.3
55	15.2	8.6	13.3	...	18.1	10.0	5.3	1.8	26.9	...	8.2
56	47.9	23.7	5.5	2.0	18.6	3.3	0.4	0.2	...	1.5	16.6
57	46.2	24.3	6.2	1.8	18.5	3.0	0.6	0.5	...	1.5	15.5
58	43.2	16.9	7.1	1.6	12.2	1.7	0.2	0.3	16.0	2.2	19.1
59	52.5	21.5	8.8	1.6	14.4	2.4	0.5	0.2	...	2.2	19.1
60	47.5	29.1	5.3	2.0	14.0	2.2	0.4	0.3	...	1.4	18.6
61	39.3	24.8	3.8	1.9	14.9	1.7	0.2	0.4	12.5	1.4	16.6
62	46.5	28.4	5.2	2.0	16.1	2.3	0.7	0.2	...	1.4	16.6
63	76.0	11.7	4.5	1.0	2.8	3.1	1.0	0.9	...	1.4	32.3

PREPARATION OF CONES

Sufficient ash to make the desired number of cones was transferred to an agate mortar, moistened with 10 per cent dextrin solution and worked into a plastic mass with a spatula or pestle. After moistening the brass mold (Fig. 1) with kerosene to prevent sticking, the plastic material was firmly pressed into it with a knife spatula, and the surface struck off smooth to make a neat solid triangular pyramid. The cone was then pushed out of the mold by applying a small knife blade at the base. With a little practice and proper lubrication of the mold this can be done at once after molding without waiting for the cone to dry.

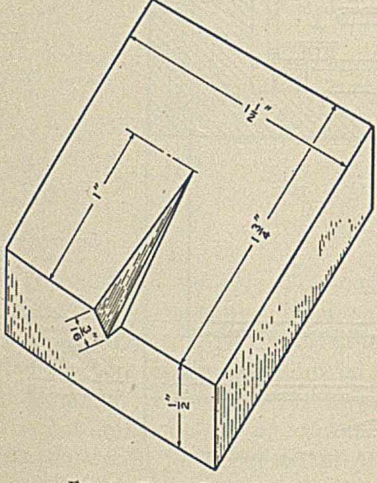

FIG. 1—BRASS CONE MOLD

After drying, the cones were mounted in a refractory base made up of a mixture of two parts of kaolin to one part of alumina (Al_2O_3). This mixture was moistened with water to make it workable and enough taken for the base to be made and spread upon a sheet-iron plate. A small hole was made into which the cone was set and the base material worked around the bottom of the cone so that it would be firmly set at the desired inclination in the base. The iron plate was then put on a hot-plate and the mounted cones dried slowly until all water was driven off. The dextrin was then burned out by igniting the mounted cones in a muffle, after which they were ready for use. In the earlier experiments the cones were made directly from the 100 mesh ash; later it was found that grinding the ash to an impalpable powder (or at least to pass 200 mesh) made a more substantial and more easily molded cone than 100 mesh material. Four different sizes of cones were used:

No. 1, side of base 1/4 inch, height 1 inch
No. 2, side of base 1/4 inch, height 1 1/2 inches
No. 3, side of base 3/16 inch, height 1 inch
No. 4, side of base 1/2 inch, height 2 1/2 inches

GENERAL METHOD OF HEATING

The general procedure in making a softening temperature determination was the same with all the furnaces used, though necessarily the details varied in the different furnaces. The test piece was put into the cold, or nearly cold, furnace and the furnace was heated at the rate of 10 to 15° per minute up to a point not less than 200° C. below the probable softening point, at which point the rate (usually 2 or 5° per minute) which had been adopted for that particular determination was begun. Temperature readings were taken every 5 minutes, and more frequently when approaching the softening temperature. Observations of the appearance of the cone were made at least as often as temperature readings were taken, special care being taken to note any deformation or warping due to shrinking before actual softening began. The point of initial softening or deformation was taken as the temperature where the first noticeable bending, rounding at the top, or swelling of the cone took place. Warping of the cone due to shrinkage was not considered as the beginning of fusion.

The softening point, deformation point, or "fusion point" so-called, was taken as the temperature where the apex of the cone had bent over to touch the base, or, failing to bend, had fused down to a lump or ball. Sketches (Fig. 2) were made of the appearance of the cone at the initial and final deformation points and at several intermediate points of deformation, with the corresponding temperatures. Immediately after reading the temperature corresponding to complete deformation, the current or other source of heat was reduced so that the appearance of the cone could be verified by examination after removal from the furnace.

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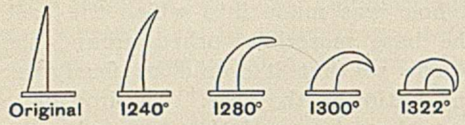
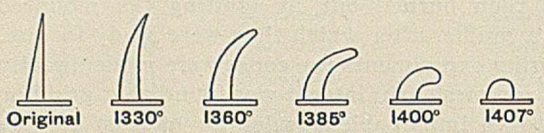
[1] F. M. Stanton and A. C. Fieldner, "Methods of Analyzing Coal and Coke," *Technical Paper* 8, Bureau of Mines (1913), pp. 7–9.

TEMPERATURE MEASUREMENTS

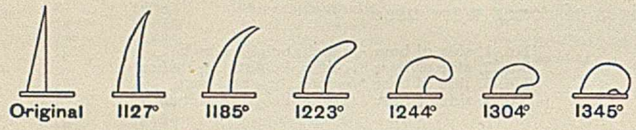
The temperature measurements were made in two ways: (1) by means of a Heraeus Pt-PtRh thermocouple with Siemens and Halske high-resistance millivoltmeter, in the platinum-resistance, Meker and muffle No. 2 furnaces, and the down-draft ceramic kiln; (2) by means of a Wanner optical pyrometer in the molybdenum, carbon-resistance, and Northrup furnaces. The thermocouple and millivoltmeter were standardized from time to time in the physical laboratory of the Bureau under the direction of Dr. J. K. Clement by comparison with a standard thermocouple. The cold junction was kept at the temperature of melting ice during standardization and during use in measuring temperatures. Further checks on the system of furnace and pyrometer were obtained by placing crystals of pure diopside[1] in the positions occupied by the ash cones and noting the temperature of melting; usually the crystal melted between 1381 and 1395° C. (corrected temperature readings). The melting point of diopside is 1391° C.[2]



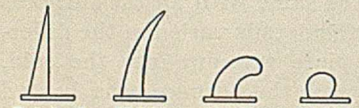
SAMPLE No.16 Good bend.



SAMPLE No.15 Bent and melted to a ball.



SAMPLE No.5 Bent and puffed.



SAMPLE No.11 Bent and melted to a ball.

FIG. 2—APPEARANCE OF ASH CONES AT VARIOUS STAGES OF SOFTENING

The Wanner pyrometer, which was originally standardized by the Reichsanstalt, was rechecked by the Bureau of Standards after most of the work described in this paper was completed and found to conform to the original standardization. It was checked daily against the amyl acetate flame. As this pyrometer was used only with those furnaces which had strongly reducing atmospheres, it was possible to check the accuracy of the pyrometer readings and the black-body conditions of the furnace by placing thin strips of Kahlbaum's pure copper or Kahlbaum's pure nickel in place of the cones and noting the apparent melting temperature. This was done at least once a week, and at the beginning and the end of each series of tests. The results obtained in these checks will be given in the discussion pertaining to each furnace.

RESULTS OBTAINED IN DIFFERENT FURNACES

A—MEKER MUFFLE FURNACE NO. 29

This furnace (Fig. 3) is a simple gas muffle furnace. It consists of a sheet-iron shell, with a refractory fireclay lining. The muffle *a* is of magnesite and rests on the front of the furnace and on two points at the rear. Except that at the front it is entirely surrounded by the combustion space over the Meker burner *b*, which is supplied with two inlets, one for gas and one for air under pressure, the gas burns under and around the muffle and the products of combustion pass out of the chimney. In order to attain the higher temperatures it was necessary to adjust the gas and air so that a slight flame issued from the chimney.

In operation, the cones *c*, generally four in number, were set in one base and the base raised about $^3/_{16}$ inch from the bottom of the muffle by small supports at each end. The front was closed by an asbestos board door, *d*, with a slit in it just large enough to admit the thermocouple *e*, which could be moved so that the couple could be placed very close to each cone as it went down. The thermocouple was protected from reducing gases by a glazed Marquardt tube 6 mm. in diameter and closed at one end. The maximum variation in temperature in moving the couple along the line of cones from one side of the muffle to the other was from 10 to 15° C. Inasmuch as four different cones were heated simultaneously it was not possible to begin the 2°-per-minute rate of heating at 200°

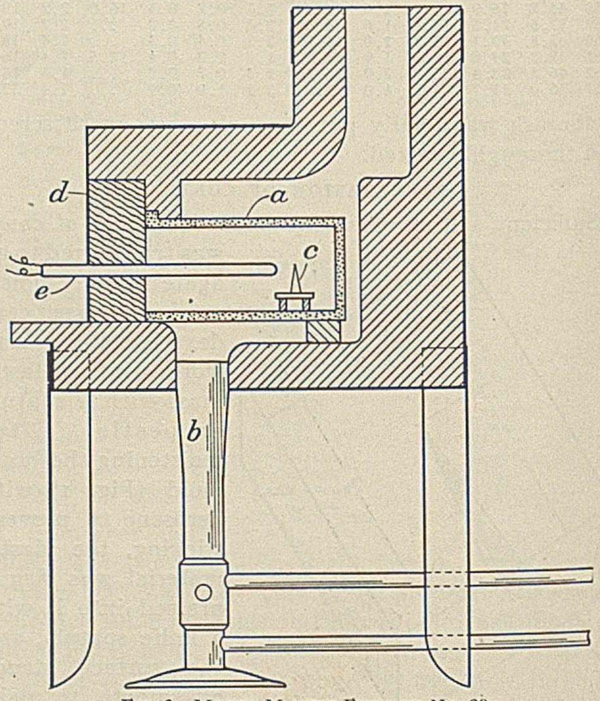


FIG. 3—MEKER MUFFLE FURNACE NO. 29

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[1] Obtained through the kindness of Dr. Arthur L. Day, Director of the Geophysical Laboratory.

[2] Arthur L. Day and R. B. Sosman, "The Melting Points of Minerals in the Light of Recent Investigations on the Gas Thermometer," *Am. J. Sci.*, [4] **31** (1911), 346.

below the approximate softening point of each cone. Usually the furnace was heated up to about 1000° C. in 1 hour. The rate was then decreased to 2° per minute until the last cone had fallen, provided it would soften in the possible range of the furnace: 1437° C. was the highest temperature that was reached, and in many cases, owing to fluctuating gas pressure, 1375° was the upper limit. Naturally the rate of heating at the higher temperatures was unavoidably reduced to 1 and even $^1/_5$° per minute. Natural gas and air at a pressure of about 15 pounds per square inch were available. No attempt was made to remove reducing gases from the muffle by circulating air, hence, variable quantities of reducing gases undoubtedly penetrated the magnesite muffle.

All the results obtained, using two different sizes of cones, are given in Table III.

TABLE III—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN MEKER MUFFLE FURNACE, USING TWO SIZES OF CONES

Rate of heating, 2° per minute; 100 mesh ash; cones inclined 35° from the vertical

Sample No.	Softening point Cone 1 $^1/_4$ in. × $1^1/_2$ in. ° C.	Softening point Cone 2 $^1/_4$ in. × 1 in. ° C.	Difference in duplicates of Cone 1	Difference in duplicates of Cone 2	Difference in average values of Cones 1 & 2	Average softening interval Cone 1 ° C.	Average softening interval Cone 2 ° C.
10	1235	....	...	..	....	115	...
11	1239	....	...	..	....	...	...
	1323	....	...	..	....	...	...
	1281	....	12	..	....	157	...
12	1275	....	...	..	....	197	...
13	1406	1298	...	..	....	...	...
	....	1248	...	..	....	...	...
	....	1273	...	50	133	48	49
14	....	1403	...	..	....	...	...
	....	1431	...	..	....	...	...
	....	1417	...	28	....	...	...
15	....	1200	...	..	....	...	...
	....	1171	...	..	....	...	...
	1307	1186	...	29	121	54	68
16	1233	1213	...	..	....	...	...
	1216	1211	...	..	....	...	...
	1225	1212	17	2	13	44	34
17	1278	1190	...	..	....	...	...
	1206	1174	...	..	....	...	...
	1242	1182	72	16	60	74	24
18	1271	1223	...	..	....	...	...
	1306	1185	35	38	+85	57	38
	1289	1204	...	..	....	...	...
1	1164	....	...	..	....	...	...
	1303	....	139	..	....	96	...
	1234	....	...	..	....	...	...
4	1265	1300	...	10	—40	...	13
	....	1310	...	..	....	...	...
	....	1305	...	..	....	...	...
5	1388	1376(a)	...	..	+12	8	45
6	1437	....	...	..	....	220	...
8	1357	1350	...	..	....	...	...
	....	1336	...	14	+14	...	46
		1343	...	..	....	...	...
9	1335	1309	...	18	+17	35	220
	....	1327	...	..	....	...	...
		1318	...	..	....	...	...
Average			55	23	+46	92	60

The $^1/_4$ inch by $1^1/_2$ inch cone gave more definite indications of softening than the $^1/_4$ inch by 1 inch cone as shown by the smaller softening interval (temperature range from initial to final deformation) and smaller differences in duplicate determinations. The softening points of the taller cone average 46° less, as would be expected on account of the greater bending moment.

B—MUFFLE FURNACE NO. 2

This furnace was a fireclay assay muffle set in a chamber made of firebrick and heated by a Buffalo Dental Company burner, using natural gas and compressed air.

The operation of this furnace was similar to that of the Meker muffle furnace, the front being closed by a door of asbestos board with a slit in it for the thermocouple. The essential difference between this furnace and the Meker furnace was in the size and texture of the muffle, it being larger: 8 inches long, 4 inches wide, and 3 inches high. Also the fireclay, being quite porous, permitted easier penetration of the furnace gases than the dense magnesite muffle of the Meker furnace.

TABLE IV—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN MUFFLE FURNACE NO. 2, USING TWO SIZES OF CONES

Rate of heating, 2° per minute; 100 mesh ash; cones inclined 35° from the vertical

Sample No.	SOFTENING POINT Cone 1 $^1/_4$in. × 1 in. ° C.	SOFTENING POINT Cone 2 $^1/_4$in. × $1^1/_2$in. ° C.	Difference in duplicates of Cone 2	Difference in average values	Average softening interval Cone 2 ° C.
1	....	1195	..	....	..
	....	1189	..	....	..
	....	1192	6	....	38
4	1276	1226	..	+50	19
5	....	1320	..	....	73
6	....	1320	..	....	...
	....	1316	..	....	...
	....	1318	4	....	153
8	....	1251	..	....	94
9	....	1242	..	....	...
	....	1325	..	....	...
	....	1284	83	....	85
10	1237	1212	..	....	...
	....	1186	..	....	...
	....	1199	26	+38	38
11	1268	1212	..	....	...
	....	1215	..	....	...
	....	1214	3	+52	34
12	....	1195	..	....	...
	....	1168	..	....	...
	....	1182	27	....	135
Average			25	+47	74

As shown in Table IV the average softening intervals, differences in average values of Cones 1 and 2, and differences in duplicates, are practically the same as those obtained in the Meker furnace. However, a striking difference is shown on comparing the softening points of those samples which were run in both furnaces, under apparently the same conditions; with but one exception the results of the muffle furnace No. 2 are from 13 to 92° lower than those of the Meker furnace, the average difference as given in Table V being 46°. (This difference is believed to be due to a greater reduction to ferrous iron due to the greater penetration of reducing-furnace gases through the walls of the porous fireclay muffle than through the denser magnesite muffle of the Meker furnace.) Both furnaces were usually operated with some flame appearing at the chimney, since it was only by this method of adjusting gas and air that the higher tempera-

TABLE V—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN MEKER FURNACE AND MUFFLE FURNACE NO. 2

Rate of heating, 2° per minute; 100 mesh ash; cones inclined 35° from the vertical

Sample No.	Size of cone Inches	SOFTENING POINT Muffle furnace No. 2 ° C.	SOFTENING POINT Meker furnace ° C.	Difference
4	$^1/_4$ × $1^1/_2$	1226	1310	—84
5	$^1/_4$ × $1^1/_2$	1320	1376	—56
8	$^1/_4$ × $1^1/_2$	1251	1343(a)	—92
9	$^1/_4$ × $1^1/_2$	1284(a)	1318(a)	—34
10	$^1/_4$ × 1	1237	1235	+ 2
11	$^1/_4$ × 1	1268	1281(a)	—13
			Average,	—46

(a) Average of two determinations.

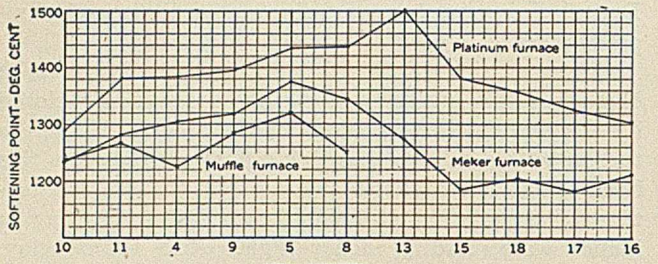

FIG. 4—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN MEKER FURNACE AND MUFFLE FURNACE NO. 2

tures could be attained at the desired rate of heating. As a matter of fact, the gray appearance of the base material, in which the cone was mounted, in many of the tests was in itself an evidence of reduction, since when heated under strictly oxidizing conditions it took on a slight reddish tint. The marked lowering of softening temperature by partial reduction is shown graphically in Fig. 4, where the muffle and Meker furnace results are compared with those obtained on the same ashes in a platinum-resistance furnace. Obviously no reduction could take place in the electric furnace. Differences of over 200° C. were found in some cones.

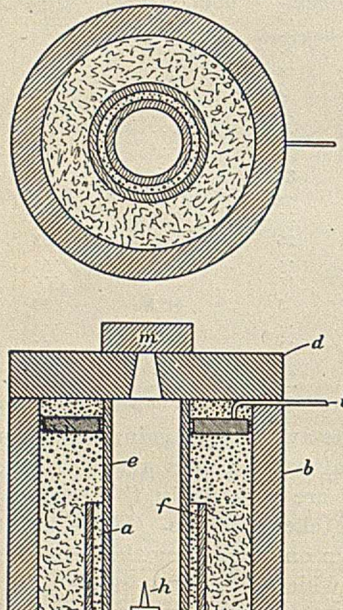

FIG. 5—Carbon resistance furnace: *b*, fireclay cylinder, 8 inches external diameter, 10 inches high, 1-inch wall; *d*, fireclay cover plate, 2 inches thick; *m*, fireclay plate covering peep-hole; *f*, alundum tube, 3-inch bore, 4 inches long, 5/16-inch wall; *e*, alundum tube, 2-inch bore, 9 inches long, 1/4-inch wall; *a*, granular carbon resistor consisting of electrode carbon crushed to pass a 6-mesh and remain on a 12-mesh screen; *i*, *i*, wrought-iron electrodes; *o*, granular carbon; *p*, magnesia insulating material; *l*, inverted alundum crucible; *h*, ash cone.

C—CARBON RESISTANCE FURNACE

On account of ease of construction and ability to attain high temperatures, various forms of granular carbon, graphite, or kryptol resistance furnaces are often used for determining the softening temperatures of refractory materials.[1] A furnace of this type was built as shown in Fig. 5. The resistor or heating element was the 1/4 inch thick annular ring of granular carbon, *a*, between the two concentric alundum tubes *e* and *f*. This heating zone was 4 inches high. The current of 20 to 50 amperes was regulated with a water rheostat, the temperature being measured with a Wanner optical pyrometer. A uniform heating zone was obtained by carefully packing the carbon between the exactly centered alundum tubes. After 10 or 15 runs, heating became irregular, due to oxidation of the resistor, which then necessitated repacking the resistor and sometimes renewal of the alundum tubes. In view of these difficulties, the interior of the furnace deviated somewhat from black-body conditions, which introduced an error in the absolute values of the temperature measurements. Observations of the melting points of copper and nickel indicated that this error was usually less than 30° at the copper point, and less than 50° C. at the nickel point.

All the softening temperatures determined in the carbon resistance furnace are given in Table VI. The rate of heating, fineness of ash, size and inclination of cone were the same as in the preceding series. The essential difference was a reducing atmosphere of carbon monoxide which reduced the ferric oxide of the ash more or less completely to metallic iron. Consequently, the softening points obtained bear little relation to those obtained subsequently in air as shown by comparison with the platinum-furnace series in Fig. 8; with but one or two exceptions the results are considerably lower (15° to 250° C.). A closer relation is shown between the carbon-furnace series and the two muffle-furnace series as plotted in Fig. 6.

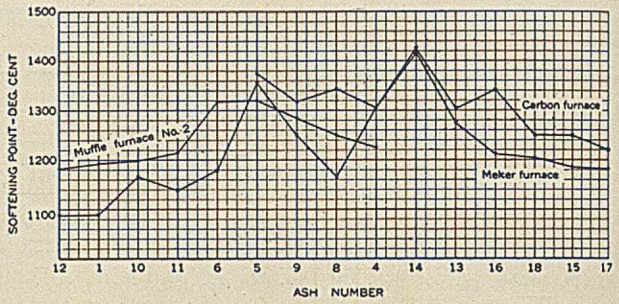

FIG. 6—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN THE CARBON RESISTANCE FURNACE, MEKER FURNACE AND MUFFLE FURNACE NO. 2

TABLE VI—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN THE CARBON RESISTANCE FURNACE, USING TWO SIZES OF CONES

Rate of heating, 2° per minute; 100 mesh ash; cones inclined 35° from vertical

	SOFTENING POINT IN ° C.								Maximum difference of determinations		Difference in average values of Cones 1 and 2	Average softening interval Cone 2, ° C.
	Cone 1 1/4 in. × 1 in. Individual determinations				Cone 2 1/4 in. × 1 1/2 in. Individual determinations							
Ash No.				Average				Average	Cone 1	Cone 2		
1	1100	....	....	1100	1076	1104	....	1090	....	....	+10	8
2	1675	1587	....	1631	1587	1562	1630	1593	88	68	+38	53
3	1570	1545	....	1558	1562	....	....	1562	25	....	−4	...
4	1335	1241	1494	1357	1182	1213	1210	....	253	....	....	...
	....	....	....	....	1210	1480	1540	1306	....	358	+51	70
5	1331	1371	1500	1401	1259	1263	1402	....	....	....	....	...
	....	....	....	....	1502	....	....	1356	169	243	+45	121
6	1260	1161	1199	1207	1179	....	....	1179	99	....	+28	18
7	1630	1695	....	1663	1645	1630	....	1638	65	15	+25	70
8	1185	1199	....	1192	1164	1167	....	1166	14	3	+26	56
9	1365	1271	1345	1327	1245	1271	1230	1249	94	41	+78	51
10	1185	1188	....	1187	1161	1173	....	1167	3	12	+20	31
11	1173	1206	....	1190	1123	1155	....	1139	33	32	+51	24
12	1084	1092	....	1088	1088	1088	....	1088	8	0	0	30
13	1380	1400	....	1390	1322	1331	1313	1322	20	18	+68	129
14	1520	1520	....	1520	1420	1427	....	1424	0	7	+96	136
15	1322	1300	....	1311	1274	1241	1234	1250	22	40	+61	83
16	1402	1385	....	1394	1350	1331	....	1341	17	19	+53	94
17	1267	1234	....	1251	1241	1210	1210	1220	33	31	+31	39
18	1331	1300	....	1316	1241	1255	1255	1250	31	14	+66	83
Average									+57	+58	+41	64
Average, excluding 4 and 5									+37	+23		

As in the muffle- and Meker-furnace tests, the 1/4 inch by 1 1/2 inch cone softened at from 10 to 90° lower in temperature than the 1/4 inch by 1 inch cone, the average difference being 41° and the former

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[1] A. V. Bleininger and G. H. Brown, "The Testing of Clay Refractories, etc.," Technologic Paper No. 7, Bureau of Standards, **1911**, p. 14; Zay Jeffries "Notes on the Gran-Annular Electric Furnace," *Met. and Chem. Eng.*, **12** (1914), 154–157.

cone giving better duplication. The average softening intervals and the average differences in duplicates of Cone 2 were practically the same as in the gas furnaces.

D—NORTHRUP FURNACE

The Northrup high-temperature electric furnace[1] has a cylindrical heater unit of Acheson graphite which is surrounded by a refractory cylinder and non-conducting material. The whole is enclosed in an air-tight monel-metal jacket. Carbon monoxide is formed by the oxidation of a thin-walled graphite cylinder which fits snugly within the heater unit; this reducing atmosphere protects the resistor from rapid oxidation. Fig. 7 is a vertical section through the heater unit with the ash cone in position for testing.

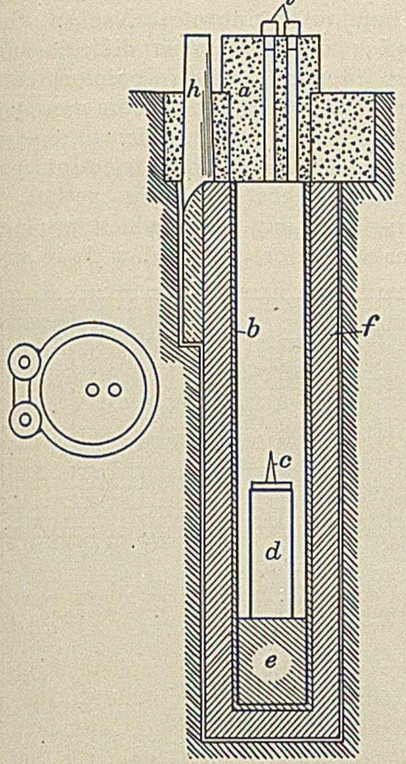

Fig. 7—Arrangement for softening-temperature test in Northrup furnace: *f*, graphite heater unit; *b*, graphite tube for protecting heater from oxidation, 1-5/8" internal diameter, $12^3/_4$ inches long; *e*, solid graphite cylinder, 2 inches high; *d* inverted alundum extraction capsule, 3 inches high; *a*, a refractory plug; *i*, *i*, observation holes, $^1/_4$ inch diameter

Temperature measurements were made with a Wanner optical pyrometer which was sighted directly on the cone and its base through the peep-hole *i* in the center of the cover plug *a*. The degree of accuracy of the temperature measurements is shown by the following melting points of copper and nickel obtained under test conditions:

Kahlbaum's pure copper M. p. = 1083° C.(*a*)	Apparent melting point	Kahlbaum's pure nickel M. p. = 1450° C.(*a*)	Apparent melting point
July 10, 1914............	1088	July 11, 1914..........	1448
July 14, 1914............	1088	July 22, 1914..........	1455
July 27, 1914............	1096	July 27, 1914..........	1447
Aug. 13, 1914............	1088		

(*a*) Provisional temperature scale used by Bureau of Standards.

A change of procedure was made in the Northrup-furnace series, in that the ash was ground to an impalpable powder and molded into a $^3/_{16}$ inch by 1 inch cone which was mounted vertically. It will be shown hereinafter in the discussion of the tests made in the molybdenum and platinum furnaces that the difference in softening points due to changing these factors is small, usually less than 30°, and, therefore, not sufficient to materially affect the comparison of the Northrup-furnace series with the other furnace series, to show the influence of different atmospheres.

Since both the Northrup and granular-carbon resistance furnace produced atmospheres of carbon monoxide, similar softening temperatures were expected in the two series; that such did not prove to be the case is shown in Table VII and Fig. 8. In 16 of 18 samples tested, the softening points in the Northrup furnace were higher than in the carbon furnace; the maximum was 396° and the average difference for the series was 134°. The check made on materials of known melting points, at various times during the course of these experiments, effectually rule out the possibility of attributing these large differences to errors of temperature measurement. The only explanation we have to offer is that in the carbon furnace the reduction of ferric oxide to metallic iron did not proceed as rapidly or as completely as in the Northrup furnace; in the latter furnace the ash cone is heated in a closed tube of graphite which excludes practically all air circulation so that only nitrogen, CO, and a fractional per cent of CO_2 would surround the ash at temperatures above 1100°. Such an atmosphere would reduce the ferric oxide to metallic iron and thus prevent the formation of a low melting ferrous silicate eutectic. On the other hand, the carbon furnace permitted air to leak into the heating space as shown by the appearance of carbon monoxide flames at the peep-hole and around the cover-plate. Sufficient carbon dioxide may, therefore, have been present to retard the reduction to metallic iron, thus leaving enough of the strongly fluxing ferrous oxide in the ash to form a low-melting fluid

TABLE VII—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN NORTHRUP GRAPHITE RESISTANCE FURNACE WITH THOSE OBTAINED IN CARBON RESISTANCE FURNACE

Reducing atmosphere of carbon monoxide; rate of heating, 2° per minute

	Softening point in ° C.			Softening interval, in ° C.	
Ash No.	Northrup(*a*) furnace	Carbon(*b*) furnace	Difference	Northrup furnace	Carbon furnace
1	1131	1090	+ 41	67	8
2	1645+	1593	+ 52	167	53
3	1502	1562	— 60	100	...
4	1360	1306	+ 54	181	70
5	1645	1356	+289	30	121
6	1455	1179	+276	355	18
7	1645	1638	+ 7	75	70
8	1562	1166	+396	392	56
9	1440	1249	+191	70	51
10	1385	1167	+218	72	31
11	1185	1139	+ 46	85	24
12	1080	1088	— 8	16	30
13	1520	1322	+198	18	129
14	1551	1424	+ 27	124	136
15	1427	1250	+177	140	83
16	1470	1341	+129	48	94
17	1390	1220	+170	95	39
18	1455	1250	+205	124	83
		Average,	+134	120	64

(*a*) Ash ground to an impalpable powder; $^3/_{16}$ inch by 1 inch cones in vertical position. Single determinations only.

(*b*) 100 mesh ash; $^1/_4$ inch by $1^1/_2$ inch cones inclined 35° from vertical; average of two or more determinations in most cases.

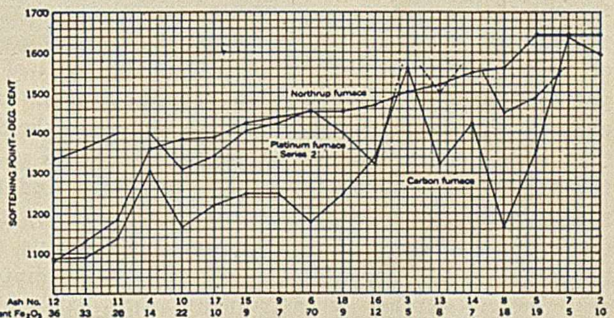

FIG. 8—COMPARISON OF SOFTENING TEMPERATURES OBTAINED IN NORTHRUP CARBON RESISTANCE AND PLATINUM FURNACES

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[1] E. F. Northrup, "A New High-Temperature Electric Furnace," *Met. and Chem. Eng.*, **12**, 31.

eutectic which caused the cone to collapse at a comparatively low temperature. Examination of polished sections of fused cones from both furnaces disclosed more metallic iron in those from the Northrup furnace.

(*To be concluded in June issue*)

BUREAU OF MINES, PITTSBURGH, PA.

PRACTICAL METHODS FOR THE DETERMINATION OF RADIUM[1]

I—INTERCHANGEABLE ELECTROSCOPE AND ITS USE

By S. C. LIND

Received January 4, 1915

The interest in radium-bearing ores and other radioactive products intermediate between ores and high-grade radium salts has become so general that the quantitative determination of radium has ceased to be a problem exclusively of the physicist or the radioactivitist. The time appears to have come when any good analyst or assayer should be prepared to make radium determinations, and it is the object of this paper to describe a modified form of electroscope as well as some methods which it is hoped may prove useful in this direction.

The "emanation-method," which will be fully described in Part II of this paper, is recognized as the most accurate method for determining radium in small quantities. The two difficulties against its general employment are at present the time required and the expense of the necessary apparatus. To obtain the highest degree of accuracy with present methods, accumulation of emanation in a closed volume for a month is required in many instances to insure that the quantity of emanation is proportional to the radium content. This delay of one month in obtaining the results is for practical purposes almost prohibitive.[2] Furthermore, only one determination per day can be conveniently carried out with one electroscope, so that in a laboratory where a number of daily determinations are to be made the initial expense for electroscopes becomes excessive.

To overcome this latter difficulty an electroscope of simple construction has been devised. All of its parts except the telescope can be made by any mechanic. Its chief advantage lies, however, in the fact that it is constructed in two easily detachable parts; the upper part, consisting of the telescope and leaf system, may be transferred to any number of separate discharge chambers. The latter are inexpensive and hence the interchangeable top permits one to employ any desired number of instruments with little additional expense.

Methods of shortening the time required for an analysis to a few days without sacrificing accuracy can also be attained and will be described with examples in a second paper.

The classes of substances which one has to analyze for radium, are, in America, chiefly the uranium ores, carnotite and pitchblende, and the crude radium-barium sulfates or chlorides of varying degrees of concentration of radium. The practice up to the present with respect to ores has been to estimate the radium from the uranium content, while buying and selling exclusively on the latter. Whatever uncertainty may have been involved, due to the supposed variability of the Ra/U ratio in carnotites appears to have been removed by the recent establishment of its constancy at normal value.[1] This would appear to justify more than ever the existing practice, but, on the other hand, it is incontestable that the accurate determination of uranium is difficult and time-consuming. It is the author's opinion that radium can be determined directly with more accuracy than uranium, and hence it is recommended to replace the uranium determination by a direct electroscopic measurement of radium by the emanation method.

Of course in dealing with any ore in which uranium has been removed or added, or the Ra/U ratio in any way disturbed, it becomes essential to determine radium directly. This applies also to crude sulfate or chloride, or any kind of mill products, and to any ore suspected of addition of uranium, or to one from which radium has been wholly or partly removed, or to any sample of ore to which a spurious addition of radium has been made.

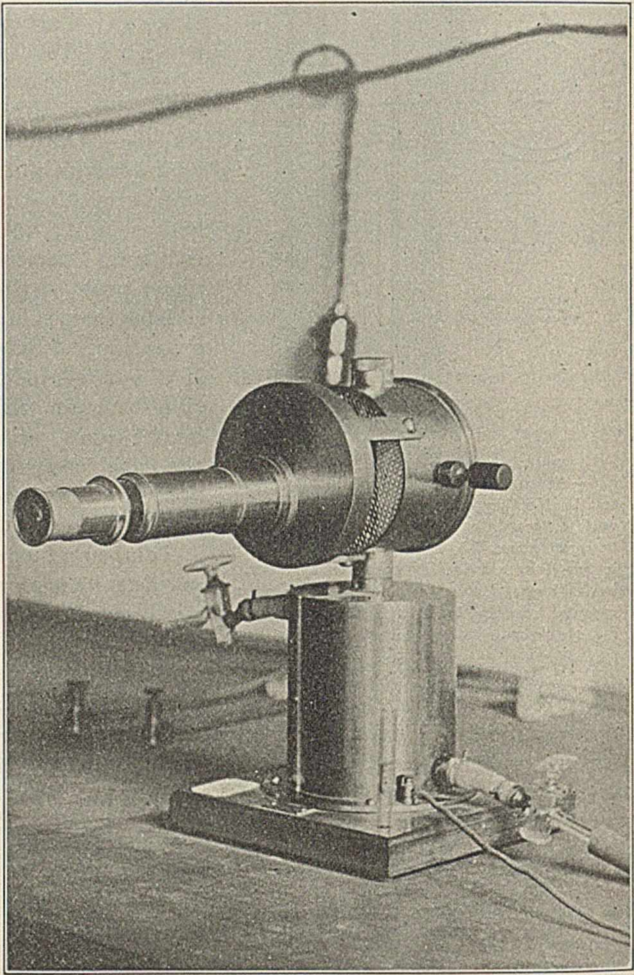

FIG. 1

It may also be mentioned that the failure of many attempts to extract radium profitably on a commercial scale may be attributed in most cases to the neg-

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[1] Published with permission of the Director of the Bureau of Mines.

[2] For further discussion see paper to follow.

[1] Lind and Whittemore, *J. Am. Chem. Soc.*, **36** (1914), 2066.

lect or the inability of the operator to make an accurate quantitative determination of radium in the various products obtained at each step of the process. Consequently the radium has often been lost or the whole operation conducted blindly without hope of success. Photographic methods, for example, are wholly unsuitable for this or any quantitative measurement; and even radiation methods using the α-ray electroscope for solids, though presenting great convenience of operation, must be subject always to control by the emanation method.

CONSTRUCTION OF THE ELECTROSCOPE

The detachable electroscope is shown in Figs. 1 and 3, and the detached emanation chamber in Fig. 2. The latter is a gas-tight brass cylinder 4 in. in height and $3^1/_2$ in. in diameter with a volume of about one-half a liter. The brass wall of the cylinder is about $^1/_{16}$ in. thick, except the bottom plate, which is about $^1/_8$ in. thick. The bottom plate projects $^1/_2$ in. outside the cylinder and is screwed to a wooden base 6 × 6 in. This projection also carries a binding post for grounding the instrument. The vertical cylinder projects into the base into which it is carefully soldered so as to make a gas-tight joint.

On account of the difficulty of obtaining gas-tight brass stop-cocks, glass ones have been used and are connected to the plain brass outlet tubes *o* (Fig. 3) from the cylinder by means of heavy rubber tubing wired on and with the ends covered with piscein glue. These outlet tubes are $^1/_4$ in. internal diameter and placed $^1/_2$ in. from the top and bottom on opposite sides of the cylinder.

The electrode (*e*) is a brass cylinder $^1/_2$ in. in diameter, projecting downward in the vertical axis of the cylinder to within $^1/_2$ in. of the bottom and clearing the top by the same distance. The electrode is suspended by a small brass rod $^1/_8$ in. in diameter which screws into the top of the electrode, passes upward through the insulating material (*d*) and terminates in a small conical cap (*c*) serving to make metallic contact with the leaf system above.

The best insulating material for an instrument of this type has been found to be a high-grade sealing wax, such as "bankers' specie." It has the advantage over sulfur of furnishing at the same time a gas-tight connection and a good electrical insulation, and is, of course, much less expensive than amber. The sealing wax insulation is bridged across the bottom of a cylindrical neck $^3/_8$ in. internal diameter and 1 in. high above the top of the cylinder. It is desirable to have the minimum layer of wax which will give the necessary strength. A layer $^1/_4$ in. deep should be ample. The additional height of the neck merely furnishes a friction support for the upper part of the instrument. The electrode and insulation can be removed by unscrewing the whole collar, which is threaded into the upper brass plate of the cylinder $^3/_{16}$ in. thick. The collar screws down on a thin lead or rubber washer to insure gas-tightness. The removal of the collar and electrode enables one to melt the wax into place with great ease and also to place the electrode in position without disturbing the soldered joint at the bottom of the emanation chamber.

A friction cap (see Fig. 2) fitting snugly down over the neck and the projecting electrode stem protects the insulation from contamination when detached from the upper part of the instrument.

The leaf system and telescope are carried by the upper part of the instrument (Fig. 1) and have the advantage over some instruments of being fixed in a perfectly rigid position with respect to each other.

The horizontal cylinder *b* (Fig. 3) containing the leaf system is $1^1/_4$ in. deep and $3^1/_4$ in. in diameter; the ends are closed by sheet mica held in place by steel wire rings which fit in grooves in the edge of the cylinder in the same way that an automobile tire is held in place. This system has proved most convenient and far preferable to the use of screws. Inside the mica plates and in close contact with them, fine iron wire gauze serves to conduct off any stray electrical charge. Circular openings in the gauze $1^1/_2$ in. in diameter furnish a clear field of vision opposite the leaf system.

The leaf system (*f*) is supported from the top of the cylinder where it is held in place by the sealing wax insulation set in a milled-head cap (*g*) which screws into a vertical collar on the cylinder $^1/_4$ in. in height. The cap is hollowed out inside to contain the insulating wax from which a flat brass rod (*f*) $^1/_4$ in. broad, about $^1/_{16}$ in. thick, and $2^1/_4$ in. long projects downward, terminating below in a light brass spring (*s*) to make a slight contact with the conical top of the electrode of the ionization chamber.

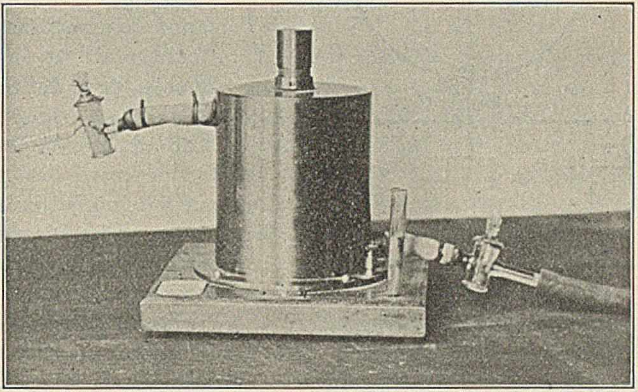

FIG. 2

This spring should touch the electrode lightly or it will throw the leaf system out of position. The aluminum leaf itself, about 2 in. in length, is attached to a small offset at the top of the brass rod by a moisture contact. The whole leaf system may be removed by unscrewing the cap without disturbing the rest of the instrument. In case the cap does not screw down tightly into the desired position, it may be advisable to put a drop of solder across the joint between screw head and collar to prevent accidental displacement of the leaf.

The charging device (*k*) consists of a brass rod threaded horizontally through the side of the case in a hard rubber insulation (*n*), sloping first upward inside the case at an angle of 45° and then horizontally, so as to make contact with the brass rod of the leaf system while charging, or by turning to be grounded against the wire grating of the outer case.

A collar $^3/_4$ in. long below the bottom of the cylinder makes a fairly snug contact fit over the collar on top of the discharge chamber and serves as support. It is also desirable to have some kind of wooden frame to hold the upper half of the instrument when detached from the base.

Opposite the aluminum leaf is a vertical brass plate (not shown in diagram) parallel to the leaf which may be pushed in almost to touch the latter and thus protect it from mechanical disturbance during transportation. Whenever the instrument is in use this protector should be withdrawn against the outer case, turning it crosswise, if necessary, to remove it as far as possible from the leaf.

Instead of supporting the telescope on an upright fixed to the same wooden base as the rest of the electroscope, it appeared preferable to fasten it firmly to the case carrying the leaf system. Three arms such as the one shown in Fig. 1, carrying a solid brass vertical plate, are firmly screwed on to the case of the leaf system. The telescope fits tightly into a heavy horizontal collar which is screwed into the front plate thickened by one or two plates fastened to the brass front plate to increase the depth of the screw thread. The telescope may be fit very firmly into place and soldered after focusing, or the collar may be split and carry a tightening screw for readjustment. The telescope used is a Bausch and Lomb type with a 32 mm. objective and a No. 5 eyepiece, carrying a micrometer scale serving to measure the rate of discharge of the leaf. The eyepiece fits very firmly into its case so as to rotate with difficulty after the micrometer scale has been set parallel to the leaf.

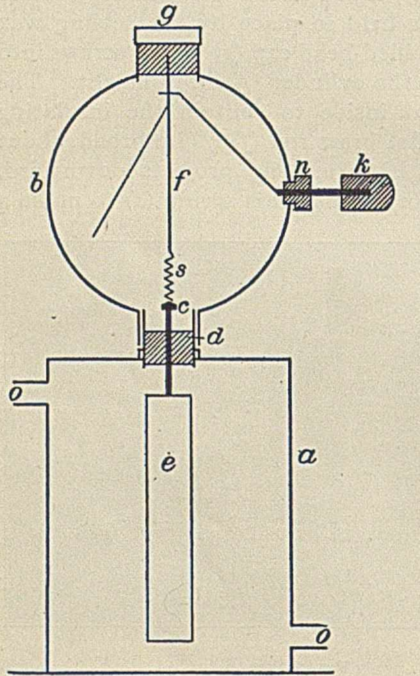

Fig. 3—Cross Section of Electroscope with Detachable Ionization Chamber

Whenever possible it is desirable to have a charging battery by means of which a charge can be maintained for some time on the instrument. Otherwise one can charge with amber or hard rubber (with an ordinary rubber comb for example).

The glass tube (see Figs. 1 and 2) fixed into the wooden base of the instrument about 1$^1/_2$ in. from the cylinder, serves to hold a small sealed tube of radium salt used in controlling the calibration of the instrument. A suitable quantity of radium (about 1 mg. of element, in a sealed tube) furnishes a constant source of penetrating radiation which may be conveniently employed to control the calibration by measuring the rate of discharge when this tube is placed in the glass tube fixed into the base, and by making comparison with the discharge obtained in the same way at the time the calibration with emanation was originally made. Such a measurement can be made in a few minutes and saves a great deal of time in avoiding the repetition of the calibration with emanation, in case no marked change is found to have taken place in the rate of discharge, which is usually the case.

USE OF THE ELECTROSCOPE IN THE EMANATION METHOD

The principle underlying the use of the emanation electroscope is that, in a given discharge chamber containing at two different times different quantities of radium emanation, the ionization and consequent rate of discharge will in each case be proportional to the quantity of emanation present. If in one case this quantity is known, the unknown quantity can be determined by a direct comparison of the two rates of discharge. The principle seems very simple and with the observation of a few essential precautions is really so in application.

Owing to the rapid decomposition of radium emanation into the series of elements, Radium A, B, and C, which deposit as a solid "active layer" on the walls of the chamber, and contribute very materially to the activity, it is necessary to wait three hours after the introduction of the emanation for the active deposit to have rached a *maximum*. This maximum is maintained with little change between the third and fourth hours and hence the measurement of the rate of discharge may be made during this period.

It is also to be noted, however, that these active decomposition products of radium emanation carry a positive electrical charge when formed and hence the position at which they are deposited in the chamber will be somewhat dependent upon the electrical field to which they are exposed during deposition, and in turn the ionization and rate of discharge will be influenced. It would seem simple to allow the deposition of the active layer always to take place with no electrical field, but the difficulty here is, that as soon as the field is made for measuring the rate of discharge, a shift in the position of newly formed RaA takes place so rapidly that even in the few minutes necessary for measurement, the rate of discharge may change considerably, either increasing or decreasing according to whether as the new position of RaA is more or less favorable to ionization. To overcome this difficulty one practice is to keep the electroscope charged during the entire three hours of activation, but this may be quite inconvenient if different instruments are being used on the same charging line, and it has been found more satisfactory in this laboratory to charge *for fifteen minutes* before the measurement. This allows any shift of RaA to be practically completed and that of RaC (through RaB, an α-rayless product), not to have proceeded to any considerable degree.

The measurement itself consists in determining with a stop-watch the time elapsing during the passage of the leaf over a certain part of the scale, always reading between the same scale divisions. Two or three closely agreeing measurements suffice, but if the deviations are greater than 1 per cent, an average of ten measurements should be taken. The discharge is then reckoned in terms of scale divisions per second, from which is subtracted the "natural leak" of the instrument which should be determined before the introduction of emanation. Even with a double contact of wax insulation, the natural leak should maintain a low value of about 0.003–0.005 divisions per second.

Another source of error, which seems especially pronounced in using sealing wax as insulation, is found in the so-called "electrical soak" of the insulator, meaning that a certain time is necessary for the insulator to become fully charged. Unless sufficient time is allowed (not less than 15 minutes) for this process to complete itself, the rate of discharge will be erratic.

The procedure in the use of the electroscope is then as follows:

1—Set up electroscope as shown in Fig. 1, and charge for 15 minutes from a battery with just sufficient voltage to hold the leaf on the part of the scale to be used later.

2—Observe the natural leak during 15 minutes.

3—Carry out the calibration control by means of penetrating rays if radium is available for this purpose.

4—Detach the top and evacuate the lower chamber to the desired vacuum.

5—Pass the emanation-air mixture through a sulfuric acid drying tube into the evacuated chamber and restore normal pressure.

6—Allow the emanation to stand in the discharge chamber for three hours.

7—Charge for fifteen minutes as before.

8—Take three readings if agreements are good, or ten if deviations are greater than one per cent.

9—Clean out the emanation chamber by drawing dry, dust-free air through it for some time (over night if convenient).

10—Calculate the discharge and subtract the natural leak, expressing both in divisions per second.

11—The corrected discharge is compared with the calibration of the instrument to determine the quantity of radium under measurement.

CALIBRATION OF THE ELECTROSCOPE

The calibration of the electroscope is carried out in exactly the same way as in ordinary measurement, except that a known quantity of emanation is introduced. This known quantity may be obtained in two ways:

(1) From a standard solution of some radium salt by passing air through it until its emanation is all transformed into the electroscope. This practice has two disadvantages, the necessity of having and taking care of such a standard solution and the uncertainty attaching to the quantity of radium emanation removed from it, owing to the great tendency of radium in such small quantity to be precipitated out in part or be occluded in the walls of the vessel during prolonged standing. In short, the practice of employing standard radium solutions, though quite general, is not to be recommended, and has been pronounced unsatisfactory at the Radium Institute[1] in Vienna. (2) The preferable practice is to use high-grade analyzed pitchblende, dissolving a suitable quantity for each standardization, and calculating the quantity of radium from the uranium analysis. The quantity of radium emanation obtained on dissolving will not correspond exactly to the radium content because a small fraction (2 to 5 per cent) of the gas diffuses from the ore; this fraction, termed the "emanating power," must be determined by sealing a quantity of the ore in a tube for a month or more, and drawing off the emanation into an electroscope by the passage of air. The emanating power thus determined in the standard sample is used as a subtractive correction. Quantities of radium emanation are convenient which will produce a discharge of the order of 1 to 2 scale divisions per second.

EXAMPLE

Given a standard pitchblende containing 60 per cent uranium metal and having an emanating power of 3 per cent. If the Ra/U ratio is 3.33×10^{-7}, one milligram of pitchblende contains 2×10^{-10} g. of radium, but since only 97 per cent of this radium can give off emanation, one milligram of pitchblende on dissolving will furnish emanation equivalent to 1.94×10^{-10} g. of radium. For the electroscope herein described use 20 to 40 mg. of high-grade pitchblende.

Contamination of the discharge chamber may come about through the gradual accumulation of active deposit on the inner walls, which results in the increase of the natural leak of the instrument. For this reason more emanation than necessary for a measurement should never be introduced. The removal of emanation from the chamber should take place at once after the completion of the measurement, and to avoid the introduction of any emanation that may be present in the laboratory air, it is better to draw air from the outside, passing it through a train of cotton batting to remove dust and through sulfuric acid to remove moisture. Should the discharge chamber become contaminated in spite of all precautions, the chamber should be opened and the walls thoroughly washed with dilute (1 to 3) nitric acid, and then with distilled water and finally dried. Repeat this operation until the natural leak is sufficiently reduced. Contamination of the insulation itself usually necessitates its complete removal.

In measurements of great accuracy it is desirable to calibrate each discharge chamber separately, but by taking greater precaution in the construction and position of the electrode each chamber could be made to have the same electrical capacity and hence one calibration would serve for all. It seems quite practicable to reproduce chambers which shall have the same calibration value within two per cent.

The convertible electroscope may also be used with other forms of discharge chamber than that used for emanation. For example, it may be used in water analysis by attaching to a water chamber of the fontacto-

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[1] 48th Communication, p. 5, by Stefan Meyer, *Sitzb. Vienna Acad.*, **122**, *Abt. IIa*, June, 1913.

meter type, or may be attached to an open α-ray chamber such as is used for the cursory examination of ores, or to any other desired form of discharge chamber.

Bureau of Mines Experiment Station
Foster Building, Denver, Colorado

HEAT TRANSMISSION CAPACITY OF A SILICA DISH

By W. K. Lewis

Received January 20, 1915

In coöperation with the Thermal Syndicate Company, an investigation[1] has been carried on in this laboratory into the heat transmission capacity of fused silica dishes as used in the concentration of corrosive liquids, such as sulfuric and phosphoric acids, zinc chloride, etc. The only source of energy employed was the cooling of hot combustion gases, formed by burning Boston City gas in an ordinary gas crucible furnace, arranged for this work as shown in Fig. I. It is here desired to make a report of the results to date.

The temperature under the dish was controlled by regulation of the gas and air supply, the flame being at all times non-luminous. This temperature was measured at various points under the dish by movable thermo-couples as indicated in the diagram. The setting of the dish was such that the surface exposed was 66 sq. in. Solutions of different concentrations were evaporated, the boiling points ranging from 100° C. for water up to 240° C. for strong zinc chloride. Each solution was kept constant in amount and boiling point by running in water at exactly the rate at which it was evaporated; the measurement of this rate of feed of make-up water gave the heat absorption of the solution, the heat consumption per unit weight of water evaporated being equal to the total heat of the steam at the temperature and pressure evolved, less the heat of the liquid fed in. These quantities were taken from the steam tables. Each run was continued a sufficient length of time to eliminate any appreciable error due to uncertainty as to the constancy of the amount of boiling liquid in the dish.

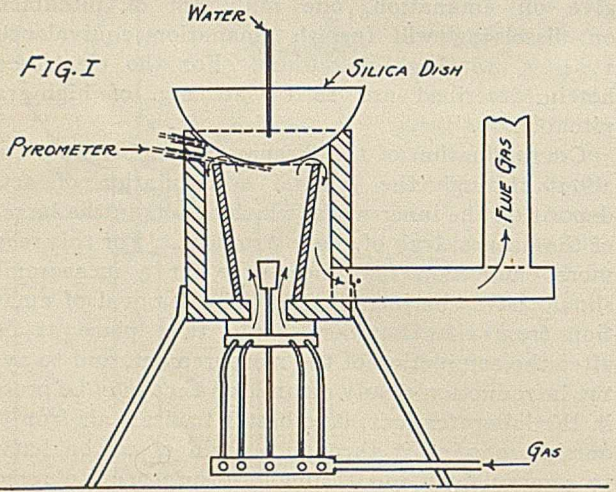
FIG. I

The heat supply coming from the cooling of hot gases, there must evidently be a drop in the temperature of the gases under the dish. Measurements made as stated, with the thermo-couple, proved this to be approximately a straight line function from the center out as far as the dish was exposed to the gases. This is shown for a typical run in Fig. II. The total drop in temperature from the center to the exposed edge increased as the temperature under the center was raised, as is depicted in Fig. III. The total heat absorbed by the boiling liquid in the case of water itself is shown as a function of the average temperature[1] under the dish in Fig. IV.

Mere inspection of this last plot shows that the heat transfer rises much more rapidly than the first power of the temperature difference, and that in consequence the phenomena must involve more than simple conduction. To appreciate the significance of this curve in any way an analysis of the factors involved is essential. A hot body can give up heat to a cold one in only three ways—by conduction, by convection, and by radiation. The hot gas, which is the source of energy in this case, is incapable of radiating energy in appreciable amounts, and must therefore give up its heat by conduction and convection only. The work of Langmuir[2] makes it probable that the transfer of heat from a hot gas to a solid is essentially a matter of conduction through a thin stationary film of gas on the surface of the solid, convection currents in the body of the gas outside this film being sufficient to transport the energy up to the outside surface of the stationary gas as rapidly as it is conducted through this film to the solid. Under the experimental conditions of this investigation it is probable, therefore, that the heat given up by the gas is proportional to the difference in temperature between the gas and the solid with which it is in contact, and furthermore that the proportionality factor, namely, the coefficient of heat transfer, may be considered as constant through the relatively narrow temperature range employed in this work.

On the other hand, the hot gases in this furnace were in contact not only with the surface of the dish which it was desired to heat, but with the surface of the furnace walls as well. These walls are therefore heated to a temperature approximating that of the gas itself, but at this high temperature they also lose heat rapidly. Even neglecting heat conducted away through these walls to the outside air, which on account of their thickness and low heat conductivity will be small, large amounts of heat will be given up by radiation to the cold surface of the dish. The only possible source of this heat is the energy content of the hot gases, but in order for the walls to receive this heat from the gas the wall temperature must be lower than that of the gas and higher than that of the dish. There exists, therefore, a dynamic equilibrium, heat flowing by conduction from the gas to the fur-

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[1] Thesis by A. H. Spaulding, submitted in June, 1914, in partial fulfilment of the requirements for the degree of S.B. from the Massachusetts Institute of Technology. All experimental data in this article are taken from this thesis.

[1] Obtained in a way to be described later.

[2] *Phys. Rev.*, April, 1912.

nace walls, and by radiation an equal amount passing from the walls to the dish, the temperature of all the elements remaining constant. The thermo-element, or rather its encasing porcelain tube, is subject to approximately the same influence as the wall, and will therefore record, not the temperature of the gas, but that of the solid wall. Indeed there is known no accurate method of measuring the temperature of a hot gas which is interchanging heat with a solid with which it is in contact, since any solid introduced into the gas will, due to this radiation effect, have a temperature intermediate between that of the gas and the body with which it is interchanging heat. This temperature will be determined by the relative rates of conduction and radiation, the first being proportional to the temperature difference, and the second to the difference in the fourth powers of the temperatures.

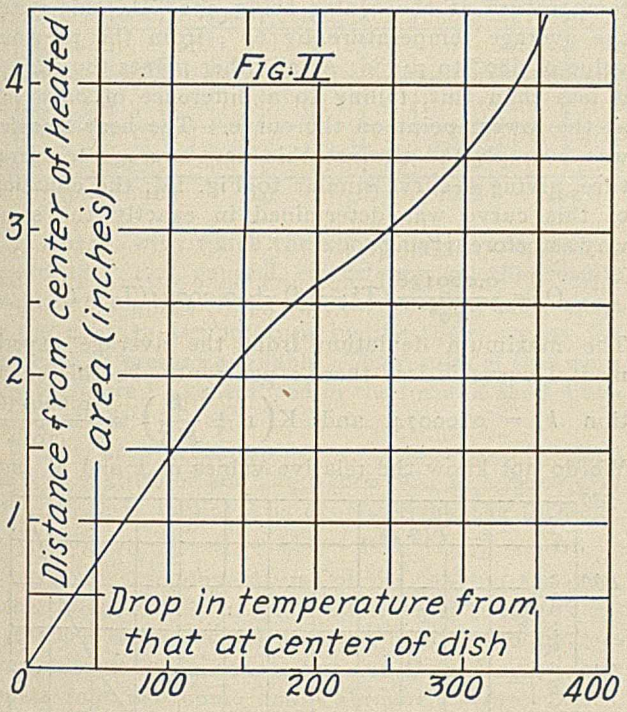
FIG. II

Call the temperature of the dish t, and, in view of the high heat conductivity of fused silica, assume this temperature equal to that of the boiling solution. Designate the temperature of the furnace walls by T, and the unknown temperature of the hot gas by θ. Call the heat absorbed by the dish, per unit area and time, Q, and the coefficients of heat transfer by radiation and conduction from the furnace walls and the gas to the dish K and k, respectively; and k' the conductivity coefficient from gas to furnace walls. Moreover for each unit area of the dish let there be an area of furnace wall equal to A. It is evident then that the following relationships may be expected to hold:

$$Q = K(T^4 - t^4) + k(\theta - t),$$

and

$$K(T^4 - t^4) = k'A(\theta - T).$$

From this second relationship,

$$\theta = T + \frac{K}{k'A}(T^4 - t^4).$$

Substituting this value of θ in the first equation,

$$Q = K\left(1 + \frac{k}{k'A}\right)(T^4 - t^4) + k(T - t).$$

In this equation it will be necessary to use an average value of T, since the temperatures show wide variations. The average value chosen is the temperature at the center of the dish less $^2/_3$ the total decrease in temperature from the center to the edge.[1] It is difficult to test the applicability of this formula directly, owing to its complexity, but if it be differentiated with respect to T, for the case of the water runs, where t was constant, there results

$$\frac{dQ}{dT} = 4K\left(1 + \frac{k}{k'A}\right)T^3 + k.$$

If, therefore, the slope of the curve of Fig. IV be plotted against the third power of the absolute temperature,

[1] This method of estimating the average temperature under the dish was derived as follows: As previously stated, the temperature drop from center to edge of the dish was experimentally found to be linear. Calling the radius of the setting R, the temperature at the center T, the drop in temperature between the center and the edge of the dish ΔT, and the temperature at any variable distance r, from the center T_r, this last quantity is determined by the equation

$$T = T - \frac{\Delta T}{R} r.$$

For the moment assume the heat transfer at any point proportional to the temperature difference at that point, and furthermore consider the curvature of the dish so slight that its exposed surface may be taken as a flat plate. Under these conditions the area exposed to the temperature T_r, at the radial distance, r, from the center of the setting, is $2\pi r dr$, and the heat transfer,

$$\frac{dQ}{\tau} = k(2\pi r dr)(T_r - t)$$

$$= k(2\pi r dr)\left(T - \frac{\Delta T}{R} r - t\right).$$

Integrating between the limits o and R, and inserting for the total area of the dish, $a = \pi R^2$, this gives

$$\frac{Q}{a\tau} = k[(T - {}^2/_3\Delta T) - t].$$

In other words, under these conditions the average temperature to be used in calculating heat transfer is the temperature at the center of the heated area, less two-thirds the total drop in temperature to the edges.

For the case of a spherical dish, as was employed in this work, in a setting such that the exposed surface subtends at the center of the sphere a radial angle of 2 α, the formula for the average temperature to be used in calculating heat transfer which is proportional to the temperature difference, a formula derived exactly similarly to the above becomes

$$T_{av} = T - \Delta T\left[\frac{\alpha/\sin\alpha - \cos\alpha}{2(1 - \cos\alpha)}\right].$$

That this formula simplifies to the above for the case of a spherical dish of infinite radius, *i. e.*, for a flat plate, can be shown by successive differentiation of numerator and denominator. Inserting the value of α for the dish employed, the temperature correction is found to be 0.687 times the total drop in temperature, rather than 0.667 times that drop as before.

The flow of heat from furnace walls to the dish is proportional, however, not to the difference in temperature but to the difference of the fourth powers of the temperatures. For the case of such radiant flow to a flat plate, the average temperature is given by the equation

$$T^4_{av} = T^4 - \frac{8}{3}T^3\Delta T + 3T^2(\Delta T)^2 - \frac{8T}{5}(\Delta T)^3 + \left(\frac{\Delta T}{3}\right)^4.$$

This equation is derived in exactly the same way as the preceding ones. This formula gives an average temperature slightly higher than the two-thirds rule. Thus for $T = 823$, $\Delta T = 225$, and $T - {}^2/_3\,\Delta T = 673$, while this last formula gives $T_{av} = 679$. For the higher temperature, $T = 1223$, $\Delta T = 410$, and $T - {}^2/_3\,\Delta T = 949$, the radiation formula gives 964. These differences are within the experimental error. Having shown for the previous case that the spherical shape does not appreciably affect the correction term, the complicated expressions for radiant flow into the sphere have not been derived, but in all instances the temperature under the center of the dish, less two-thirds the drop to the edges, has been taken as an average.

a straight line should result. This has been done in Fig. V, and from this line the constants k and $K\left(1 + \frac{k}{k'A}\right)$ obtained, giving in gram calories per sq. cm. per second,

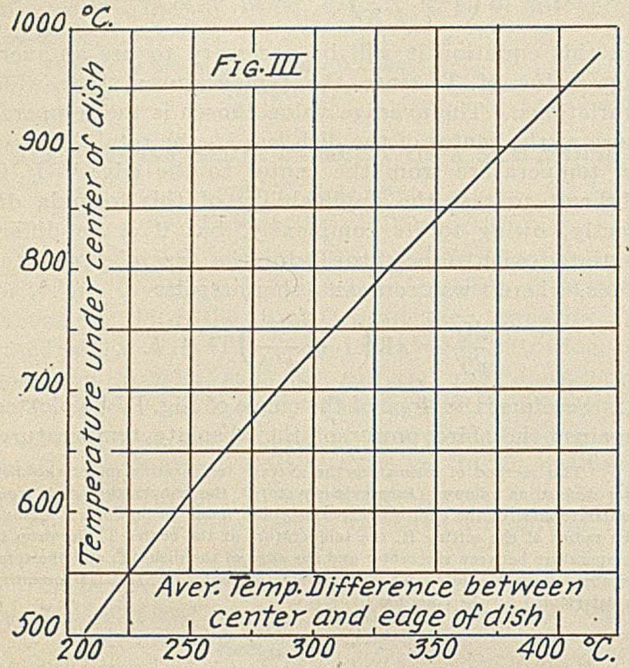
Fig. III

$$Q = \frac{0.000197}{10^8}(T^4 - t^4) + 0.000563(T - t).$$

This equation reproduces the average experimental curve of Fig. IV within 1 per cent. It also reproduces the data on all solutions of zinc chloride and sulfuric acid well within the experimental error (about 10 per cent).

There is no data at hand for the determination of the relative values of the constants k and k', but from the similar nature of the surfaces it is probably allowable to call them equal.[1] Owing to the configuration of the furnace walls employed it is also difficult to decide exactly how much of their surface is capable of heat interchange with the dish by radiation, but the constant A has been carefully estimated for this case as 4.8. This gives for the radiation constant, K, from fire brick to fused silica, the value 0.000163.

Since the value of K for black body radiation is only 0.000128,[2] this high result proves that there is somewhere an error in the work. To eliminate all possibility of an influence of the gas flame itself upon the heat transmission, the burner was moved from below the furnace to one side and the hot gases led to the setting through a horizontal flue. The two arrangements are shown in Figs. VI and VII. Within the experimental error, no change in performance was found, so the discrepancy must be sought elsewhere.

Inasmuch as the results indicate a higher radiation effect than can correspond to the temperatures, it is natural to suspect that the true average temperatures are higher than the values assumed. The estimation of the average temperature by subtraction of two-thirds the drop in temperature from center to edge from the value at the center is based on the assumption that all parts of the surface of the furnace are equally effective in radiation. In consequence of the configuration of this setting it is evident that those parts of the furnace walls in the center radiate more directly upon the dish, and therefore give up more heat to it, than those at the outside of the furnace. This would mean that, in averaging the temperatures under the dish, those at the center should be given more weight than those near the circumference. This assumption has been tested by using as the average temperature under the dish the arithmetical mean of the temperatures at center and edge; at the highest point on the experimental curve, the temperature at the center being 950° C., this raises the average temperature by 67°, from the previous value of 680° to 747°. At all other points the change is less than this, falling to a difference of only 29° at the lowest point on the curve. The heat transfer was now plotted against this new average temperature, giving a curve similar to Fig. IV; the equation of this curve was determined in exactly the same way as before, giving

$$Q = \frac{0.000136}{10^8}(T^4 - t^4) + 0.00074(T - t).$$

The maximum deviation from the average experimental curve is less than 2 per cent. In this equation $k = 0.00074$, and $K\left(1 + \frac{k}{k'A}\right) = \frac{0.000136}{10^8}$. We do not know the relative values of k and k', but, as already stated, A has been estimated as 4.8. Two assumptions will now be made: first, that $k = k' = 0.00074$, on which basis $K = 0.000113$; and second that $k' = 0.75\ k = 0.000555$, giving $K = 0.000106$; the second asumption is probably nearer the truth.

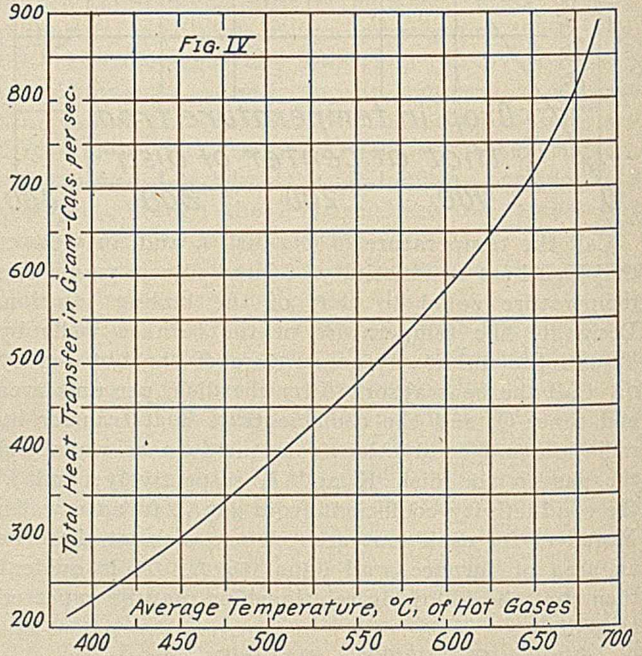
Fig. IV

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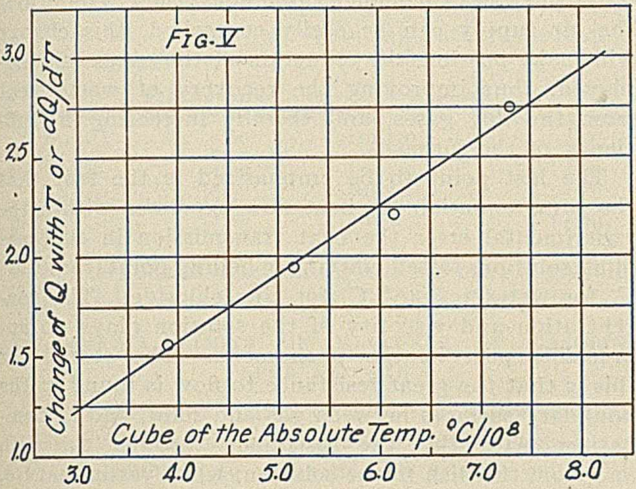
[1] Since the gases flow parallel to the furnace walls, but impinge upon the dish, k' will tend to be less than k. On this account we shall also consider the assumed approximation, $k' = 0.75\ k$.

[2] Kurlbaum, W. A., **65** (1898), 746.

Regarding the radiation coefficient, the very fact that the surface is the interior of an enclosed space leads one to expect a high value. The only comparable numerical determination would seem to be that of Wamsler,[1] who found nearly identical values for various inorganic compounds such as metallic oxides, and indeed for all substances investigated other than polished metals. He found for lime mortar a coefficient of 0.000112, with which the above figures are in close agreement. The general consistency of the results calculated on the basis of the arithmetical mean as the average temperature justify their use as the best data at present available. The results of this work may therefore be generalized in the form of the following equations:



I—The heat given up by a furnace gas, between the temperature of 400° and 1000° C., to a silica dish upon which it impinges is expressed by the formula

$$Q = k(\theta - t).$$

θ and t are the temperatures of the gas and the dish, respectively; if Q is in gram calories per square centimeter per second, while temperatures are in degrees centigrade, $k = 0.00074$, but for Q in B. t. u. per square foot per hour, and Fahrenheit temperatures, $k = 5.5$. Furthermore, it is probable that the same formula gives the heat interchange between gas and any unglazed ceramic material, but that for parallel flow of the gas past the surface the coefficients should be approximately 0.00056 and 4.1, respectively.

II—The heat received by radiation per unit area and time by the cold surface of a silica dish from hot firebrick walls entirely surrounding it is given by the equation

$$Q = K(T^4 - t^4),$$

in which T and t are the absolute temperatures of walls and dish. For Q in gram calories per square centimeter per second, with Kelvin temperatures, $K = 0.000106$, while in B. t. u. per square foot per hour, with absolute Fahrenheit degrees, $K = 0.134$. This expression is also probably valid for heat interchange by radiation between all unglazed ceramic materials.

III—The temperature, T, of the walls entirely surrounding a cold surface which is receiving heat from a hot gas as the only original source of energy, the walls losing heat in no other way than by radiation to this cold surface, is given by the equation

$$K(T^4 - t^4) = kA(\theta - T),$$

the symbols having the significance given above, and A being the ratio of the hot furnace wall surface to the cold surface absorbing the heat.

IV—The total heat absorbed from a hot gas by a cold surface in a furnace setting is:

$$Q = K(T^4 - t^4) + k(\theta - t)$$
$$= K\left(1 + \frac{k}{k'A}\right)(T^4 - t^4) + k(T - t).$$

Q cannot be expressed directly in terms of θ, but T is found from the equation

$$K(T^4 - t^4) = k'A(\theta - T),$$

best by graphical methods in the case of a large number of problems.

While the utility of this data in the design not only of silica dish evaporators, but in that of most fuel-fired furnaces as well, is evident on its face, three important points have come up in the progress of this work which are not brought out in the preceding discussion. In the first place it can be seen from the last equation quoted above that the greater the area of the furnace walls, the more nearly their temperature approaches that of the gas, and therefore the greater the radiation to the cold surface. Since the heat received by the cold surface directly from the gas by conduction is dependent only on the temperature of the gas, this increased radiation is clear gain in useful heat transmission-capacity of the system. The furnace design should therefore provide for the greatest possible area of furnace wall, so placed as to get effective contact with the moving gas, and at the same time capable of radiating as directly as may be to the heat-absorbing surface.

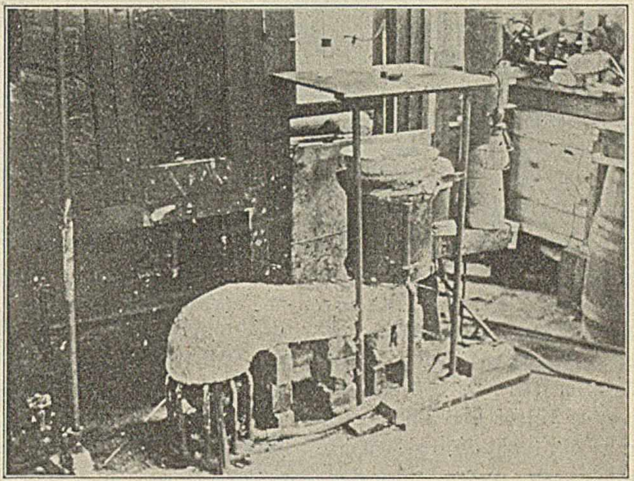


Fig. VI

This last object will often be difficult of attainment, but if the interior furnace structure be of material of high heat conductivity, heat absorbed on any surface exposed to the gas will be conducted to surfaces

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[1] Wamsler, "Mitteilungen über Forschungsarbeiten," Heft 98, 1911.

radiating directly to the cold body, and thus efficiently transmitted to the point desired. The flue space should therefore be filled with an open checkerwork of refractory of high heat conductivity, so designed that the gases will pass freely through the mass and come in effective contact with it, on surfaces as rough as possible, and furthermore so placed that the resistance to flow from absorbing surface to radiating surface will be a minimum.

In the second place, these results suggest an effective method of avoiding one of the serious difficulties in the operation of silica dish evaporators, using counter current flow of hot gases and acid, in the concentration of sulfuric acid. As ordinarily operated, those dishes directly over the fire are so strongly heated both by the hot gases and to an even greater extent by the direct radiation from the fuel bed itself that bumping and excessive breakage result. The temperature of the fuel bed can be lowered by carrying a thick fire and using insufficient air, producing mainly carbon monoxide by the combustion. If necessary, steam may be injected below the grate to further lower the temperature by the heat absorption of the water gas reaction. The combustible gas thus produced will give up its sensible heat to the lowest dishes in the series, but will not be excessively hot. At various points along the flue, air may now be admitted to complete the combustion. Under operating conditions previously employed this would cut down the evaporative capacity of the system, due to the resistance to flow of heat from gas to dish, but by increasing the heat absorption area of refractory in the flue, this will be avoided, as the heat absorbed from the gas by conduction will be transmitted to the dish in the most efficient manner possible, namely by radiation. Furthermore, this will enable the operator to maintain at every point in the flue, and not merely over the fire alone, the highest temperature the dishes can stand without danger, and thus distinctly increase total evaporative capacity. Not only this, but inasmuch as under these conditions the air supply can be easily controlled, this change will make possible the reduction of the excess air employed, thus improving the recovery of waste heat from the flue gases, and thereby increasing the efficiency of the furnace.

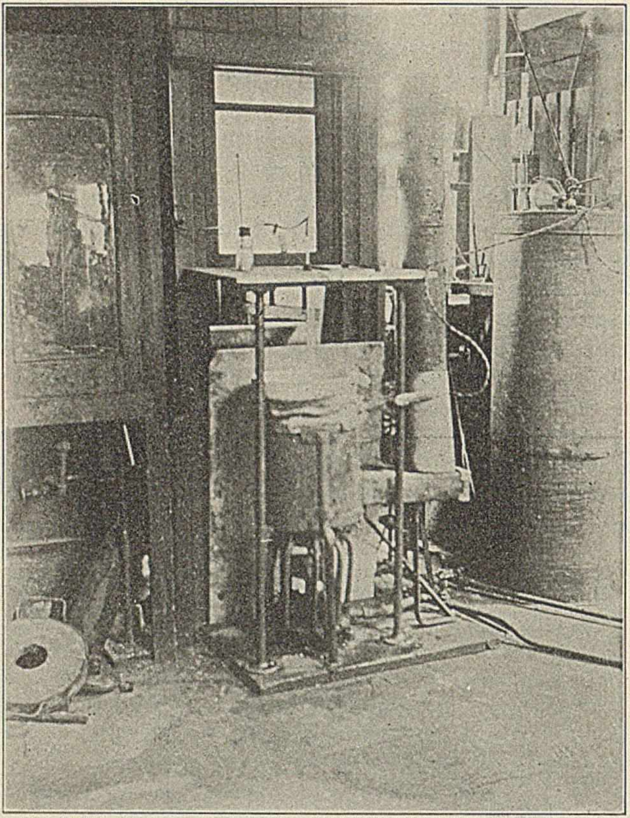

Fig. VII

The last point to be emphasized is the fact that the same equation for heat flow expresses within the experimental error the heat transmission in the case of all solutions tested, varying in boiling point from 100° C. for water to 240° C. for zinc chloride. The concentration and viscosity of the solution plays no appreciable part in the phenomena. The reason for this is that the great resistance to flow is found at the boundary surfaces between gas and solid, and in comparison with this the resistance through the dish and from the dish to the solution, whatever its nature, is negligible. It seems therefore justifiable to use this data for the concentration of any liquid in apparatus of the type employed.

SUMMARY

The heat transmission capacity of a silica dish heated in a gas furnace has been experimentally determined, and it is shown that this capacity can be expressed as consisting of the sum of two terms, the first a conduction term proportional to the temperature difference, and the second a radiation term proportional to the difference of the fourth powers of the temperatures. The coefficients of these two terms have been estimated, and expressed in forms directly applicable to the solution of problems in design. The utility of the results in the study of furnaces in general has been pointed out, and suggestions as to desirable modifications in furnace construction and operation have been made. On the other hand, these results are merely a report of progress to date, and further work is under way in which it is being attempted to more accurately control the surface areas involved, to measure the true surface temperatures by means of an optical pyrometer, to estimate the true gas temperatures by carefully controlled air supply and calculation from the known heats of combustion and specific heats, and also by determination of total heat content, and to study the influence of velocity upon the results.

Research Laboratory of Applied Chemistry
Massachusetts Institute of Technology, Boston

THE INFLAMMABLE LIMITS OF MIXTURES OF GASOLINE VAPOR AND AIR[1]

By George A. Burrell and Hugh T. Boyd

Received December 15, 1914

In this report are shown experiments having to do with limits of complete inflammation in mixtures of

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[1] Published by permission of the Director of the Bureau of Mines.

gasoline vapor and air. The limits were determined in connection with coöperative work between the Bureau of Mines and the City of Pittsburgh on the prevention of explosions in sewers. Gasoline is so widely used in internal combustion motors and for other purposes that the limits are of interest to users of gasoline generally. Some of the gasoline used was a refinery distillate of 73° specific gravity, Baumé scale. The fractionation analysis as made by Dr. L. W. Dean, of the petroleum laboratory, Bureau of Mines, follows:

Fractionation Analysis of Gasoline

Temp. ° C.	Per cent by weight	Temp. ° C.	Per cent by weight
50	0.90	110–120	7.30
50– 60	9.00	120–130	4.90
60– 70	14.50	130–140	3.20
70– 80	14.40	Residue	2.70
80– 90	13.80		
90–100	12.90	Total	94.50
100–110	10.90	Loss	5.50

The methods of determining the per cent of gasoline vapor in mixtures are those published in This Journal.[1]

INFLAMMABLE LIMITS OF MIXTURES OF GASOLINE VAPOR AND AIR

In preparing mixtures of gasoline vapor and air for the inflammability experiments, the air was shaken with the gasoline to saturation in a 2400 cc. bottle and then enough of the stock mixture withdrawn from the bottle and diluted with air to form a desired mixture. The latter was always analyzed prior to exploding it. No precaution was taken to remove water vapor.

The mixtures were first tested in a Hempel explosion pipette of 100 cc. capacity, using mercury as the confining fluid. Two platinum wires entered near the top of the pipette, across which a spark was made to jump by means of an induction coil driven by five dry cells. Inflammation was deemed complete when, upon ignition of the mixture, flame filled the vessel as far as could be judged by the eye.

The Low Limit of Inflammability of Mixtures of Gasoline Vapor and Air; Igniting Spark at Top of the Hempel Pipette

No. of test	Percentage of gasoline vapor	Remarks
1	1.8	No visible result
2	1.9	No visible result
3	1.9	No visible result
4	1.9	No visible result
5	1.9	No visible result
6	2.0	Complete inflammation
7	2.0	Complete inflammation
8	2.0	Complete inflammation
9	2.1	Complete inflammation
10	2.1	Complete inflammation
11	2.2	Complete inflammation
12	2.2	Complete inflammation
14	3.2	Complete inflammation

According to the above results complete inflammation occurred when the mixtures contained between 1.9 and 2.0 per cent of gasoline vapor. Mixtures containing less gasoline vapor than the above, of course, underwent some slight burning next the spark, but there was no appreciable propagation of flame in them.

In order to obtain data regarding the influence of the position of the igniting spark on the limits of inflammability, experiments were next conducted under the same conditions as the foregoing, except the igniting spark was placed at the bottom of the explosion vessel.

The Low Limit of Inflammability of Mixtures of Gasoline Vapor and Air; Igniting Spark at Bottom of the Hempel Pipette

Trial No.	Percentage of gasoline	Remarks
1	2.15	Complete inflammation
2	2.00	Complete inflammation
3	1.94	Complete inflammation
4	1.78	Complete inflammation
5	1.73	Complete inflammation
6	1.62	Complete inflammation
7	1.50	No inflammation

All of these mixtures of 73° Baumé gasoline were analyzed before and after explosion.

Some flame occurred near the spark in the mixture analyzing 1.50 per cent, but only about 0.3 per cent of CO_2 was formed.

This method, then, gives in the Hempel explosion pipette, firing from below, a low limit between 1.5 and 1.6 per cent as against 1.9–2.0 when fired from above. It also gives a good check on the low limit obtained in the 2800 cc. bottle—1.4–1.5 per cent. There is a difference of only 0.1 per cent. This would tend to show that under the same conditions the initial impulse has almost no effect upon the low limits of complete propagation of flame, as practically the same results were obtained by a very small spark from an induction coil, and a large flash produced by drawing apart two heavy copper wires carrying 220 volts and 6 amperes current.

The Upper Limit of Complete Inflammation of Mixtures of Gasoline Vapor and Air, Using the Hempel Pipette; Spark Ignition at Top

Test No.	Percentage of gasoline	Remarks
1	3.5	Complete inflammation
2	4.8	Complete inflammation
3	5.0	Complete inflammation
4	5.2	Complete inflammation
5	5.3	Incomplete inflammation
6	5.4	Incomplete inflammation
7	5.9	Incomplete inflammation
8	6.0	Incomplete inflammation
9	6.1	Incomplete inflammation
10	6.1	Incomplete inflammation

According to the above tests the upper limit lies between 5.2 and 5.3 per cent of gasoline vapor. With more than 5.3 per cent there was some burning above the spark, for instance at 5.4 per cent the flame completely filled the small space (about 3 cc. capacity) above the spark but did not extend below it.

Experiments were next tried, using a vessel of larger capacity than the 100 cc. Hempel pipette, namely, one having a capacity of 2800 cc. This vessel was 30 cm. high and 12 cm. in diameter. Two copper wires met near the bottom of the jar, through which an electric current of 6 amperes and 220 volts could be passed. A flash was produced by drawing these wires apart when current was flowing.

The Low Limit of Complete Inflammation, Using a 2800 cc. Vessel Ignition from the Bottom

Test No.	Percentage gasoline vapor	Remarks
1	1.4	Incomplete inflammation
2	1.5	Complete inflammation
3	1.5	Complete inflammation
4	2.3	Complete inflammation
5	2.5	Complete inflammation
6	2.8	Complete inflammation

According to the above results, the low limit of complete inflammation lies between 1.4 and 1.5 per cent of gasoline vapor. With 1.4 per cent of gasoline vapor a tongue of flame about 1 inch at the base, tapering to a cone, extended one-half through the vessel.

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[1] G. A. Burrell and I. W. Robertson, "The Determination of Gasoline Vapor in Air," This Journal, 7 (1915), 112.

The following data show the high limit as determined in the 2800 cc. vessel, ignition from the bottom upwards:

High Limit of Complete Combustion, Using a 2800 cc. Vessel

Test No.	Percentage of gasoline vapor	Remarks
1	6.0	Complete inflammation
2	6.4	Incomplete inflammation
3	6.5	Incomplete inflammation
4	6.6	Incomplete inflammation

According to the above results, the high limit of complete inflammation lies between 6.0 and 6.4 per cent of gasoline vapor.

In commenting upon the difference obtained by the two methods of experimentation, it might be added that the Bureau of Mines and others have found that lower limits are obtained when ignition is effected from the bottom upwards. In the latter case the heated convection currents apparently rise faster than the flame does and transmit heat to the unburned gases prior to their ignition by the flame. As a consequence they receive more heat than when ignition is effected from the top and the mixture inflames with smaller percentages of gas present. Another point brought out by different experimenters is that in small vessels the cooling influence of the walls exerts a marked effect in fixing the limits. For instance, tubes may be of so small bore and hence the cooling influence of the walls so great that flame is not transmitted at all in them. Again, sparks may be so minute as not to ignite the most inflammable mixtures. In such a case the temperature of the spark may be quite above the ignition temperature of the gases, but its duration so short that the heat is dissipated before the gases can be raised to their ignition temperature.

INFLAMMABLE LIMITS OF VAPOR FROM CLEANERS' NAPHTHA

Further experiments were made to determine whether or not the inflammable limits of gasoline-air mixtures differed for gasoline of different grades, *i. e.*, whether the low limit as determined for gasoline having a specific gravity of 73° Baumé was different from the low limit of a gasoline having a specific gravity of, say, 59–60° Baumé. The gasoline used in the following experiments was 59–60° Baumé cleaners' naphtha. The 2800 cc. explosion vessel described in previous tests was used.

Low Limit of Complete Inflammation in 2800 cc. Vessel of Mixtures of Air and Gasoline Vapor of 59–60° Baumé Specific Gravity

Trial No.	Percentage of gasoline vapor	Remarks
1	2.4	Complete inflammation
2	2.3	Complete inflammation
3	2.1	Complete inflammation
4	2.0	Complete inflammation
5	1.8	Complete inflammation
6	1.7	Complete inflammation
7	1.5	Complete inflammation
8	1.5	Complete inflammation
9	1.5	Complete inflammation
10	1.4	Incomplete inflammation
11	1.4	Incomplete inflammation

According to the above results, complete inflammation, as observed by the eye, took place in a mixture containing 1.50 per cent of gasoline vapor. When a mixture analyzing 1.4 per cent was ignited, inflammation was incomplete, the flame lacking 6 cm. of extending to the top of the explosion vessel.

It was found impossible to obtain a mixture containing too much gasoline vapor to explode at the temperature of the laboratory: 20° C. The highest mixture obtainable, 4.6 per cent of gasoline vapor, completely inflamed. In other words, the vapor pressure of this particular naphtha at 20° C. is $740 \times 0.046 = 33$ mm. of mercury. It would have been possible, of course, by maintaining higher temperatures all through the experiment, to obtain mixtures of higher gasoline-vapor content.

EFFECT OF INCREASING THE INITIAL TEMPERATURE ON THE EXPLOSIVE LIMITS

It is interesting to consider the effect of high temperature and pressure, to which mixtures of gasoline vapor and air are subjected in the cylinders of internal-combustion engines. A pressure of about 70.0 pounds per square inch is reached before ignition. The temperature resulting is high because on compression to about 90.0 pounds per square inch pre-ignition sometimes occurs.

The Bureau of Mines found in experimenting with mixtures of methane and air[1] that when the initial temperature was 500° C., the low limit of complete inflammation was about 3.75 per cent. At ordinary temperature under the particular experimental condition adopted, the low limit was 5.50 per cent. Initial pressures up to 5 atmospheres at ordinary temperatures made no difference in the limits.

In the case of gasoline vapor—air mixtures—it was also found that increasing the initial temperature before ignition lowered the low limit very appreciably. Experiments were conducted with an apparatus substantially the same as that used in the methane-air experiments.[1]

The following table shows the shifting of the low limit as the initial temperature was increased. The gasoline was of 73° Baumé gravity, the same as that with which the first experiments were made.

Shifting of the Low Limit of Inflammation of Mixtures of Gasoline Vapor and Air with Increase of Initial Temperature—Ignition from Bottom

Temperature ° C.	Values between which the limits lie Percentage of gasoline vapor	Analyses of mixtures after explosion Percentages of gasoline vapor
23	1.50–1.62	Complete combustion with 1.50 per cent
200	1.42–1.50	Complete combustion with 1.51 per cent
300	1.22–1.28	Complete combustion with 1.28 per cent
400	1.02–1.22	Complete combustion at 1.22 per cent

The above table shows that with increasing temperature the lower limit was shifted until, with an initial temperature of 400° C., the limit is between 1.02 and 1.22 per cent of gasoline vapor. A mixture containing 1.00 per cent of gasoline vapor did not explode when it was heated to 500° C. just prior to ignition, but when it was allowed to stand for $^1/_2$ hour at this temperature without sparking it completely burned. At just what time during the $^1/_2$ hour interval combustion was complete was not determined.

The lowering of the low limit as the initial temperature is increased is due to the fact that the higher the initial temperature the less heat will be required to raise the temperature of a given mass of the gas to the ignition temperature and consequently the smaller

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[1] G. A. Burrell and I. W. Robertson, "The Influence of Temperatures and Pressure on the Explosibility of Methane-Air Mixtures," This Journal, 7 (1915), 417.

is the heat of combustion and the percentage of gasoline vapor required to furnish this quantity of heat.

SUMMARY

Using a 100 cc. Hempel explosion pipette and igniting the mixtures from the top, there was obtained as the lower limit of complete inflammation a value lying between 1.9 and 2.0 per cent of gasoline vapor. The upper limit under these conditions was found to be between 5.2 and 5.3 per cent of gasoline vapor. The gasoline used had a specific gravity of 73° Baumé. Under the same conditions, except ignition of the mixtures from the bottom, there was obtained a value lying between 1.5 and 1.6 per cent of gasoline vapor as the low limit. With the same grade of gasoline, using a 2800 cc. vessel, and with ignition from the bottom, by means of an electric flask produced by pulling two wires apart through which a current of 7 amperes at 220 volts was flowing, there was obtained a value lying between 1.4 and 1.5 per cent of gasoline vapor. The high limit under these conditions lay between 6.0 and 6.4 per cent of gasoline vapor. Appreciably different limits were not obtained with vapor from cleaners' naphtha.

When the initial temperature is increased before igniting the mixtures the low limit is gradually decreased until, with an initial temperature of 400° C., the low limit lies between 1.02 and 1.22 per cent of gasoline vapor.

Chemical Laboratory, Bureau of Mines, Pittsburgh

THE INFLUENCE OF TEMPERATURE AND PRESSURE ON THE EXPLOSIBILITY OF METHANE-AIR MIXTURES[1]

By G. A. Burrell and I. W. Robertson

Received December 15, 1914

In this paper are shown the results of experiments made to determine the effect of temperature and pressure on methane-air mixtures in changing the low limit of complete propagation of flame in mixtures. Temperatures up to 500° C. and pressures of 5.0 atmospheres above atmospheric pressure were employed.

The apparatus is shown in Fig. 1. *A* is the explosion pipette. It had a capacity of 100 cc. Platinum wires were fused into the upper part. A spark from an induction coil, driven by 4.0 dry cells, was used to ignite the gas mixtures. An electrically heated oven, *D*, surrounded the explosion pipette *A*. The temperatures were measured by means of a platinum-rhodium thermo-couple. Transparent mica plates were used to close the upper end of the oven in order to observe the effects of sparking the mixtures. At *B* is shown a reserve pipette of 200 cc. capacity fastened to the explosion pipette by means of pressure rubber tubing with mercury as the confining fluid.

The apparatus was made ready for use by raising the leveling bottle *C*, thereby completely filling the pipettes *A* and *B* with mercury. The leveling bottle was then lowered until all of the mercury had fallen from *A*, leaving a vacuum therein. The stop-cock between the two pipettes was then closed. The required gas mixture was then drawn into *B* through the free end of the stop-cock and the oven heated to the required temperature, whereupon the gas mixture was introduced into *A* and sparked after two seconds had elapsed. The flame produced, if any, was observed and the products of combustion analyzed.

Preliminary experiments were performed with a thermo-couple inserted in the explosion vessel *A*, to determine the time it took the gas after it was introduced into the evacuated pipette to reach the temperature of the oven. It was found that this took place in less than two seconds after the introduction of the gas.

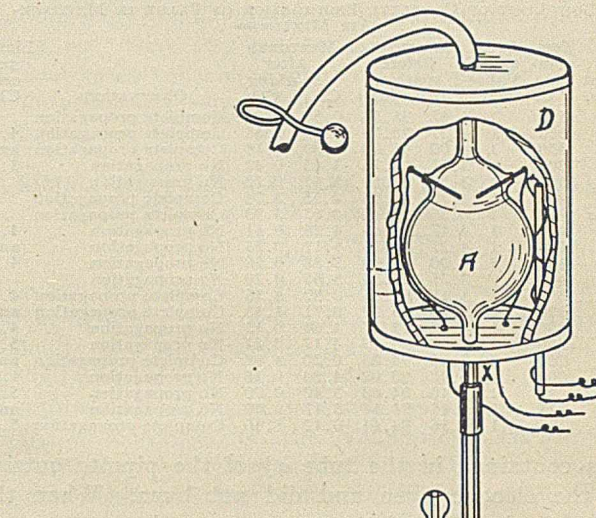

Fig. 1—Apparatus for Determining the Influence of Temperature and Pressure on the Explosibility of Methane-Air Mixtures

Methane was prepared from the natural gas used at Pittsburgh by fractional distillation at low temperatures. The natural gas was liquefied at the temperature of liquid air and as much gas pumped from it with a mercury pump as possible. The distillate was reliquefied and pumped again. A trace of nitrogen and pure methane to the extent of about 85.0 per cent of the original volume of the natural gas was obtained in this manner.

The results of the experiments are shown in Table I.

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[1] Published with permission of the Director of the Bureau of Mines.

Experiments 1 to 5 show the displacement of the lower limit of complete propagation with the initial temperature at 500° C. and the initial pressure at 1 atmosphere. As far as the eye could judge, there was a complete filling of the explosion vessel with flame when mixtures containing 4.00 to 4.47 per cent methane were sparked. However, a measurable amount of methane remained unburned, probably due principally to the fact that a small amount of gas was contained in the tube *xy* of the pipette outside of the electric oven and did not burn. When the methane in the mixture was dropped to 3.75 and 3.50 per cent, no propagation was observed, although some methane was burned, as was shown by the carbon dioxide found upon analysis.

TABLE I—EFFECT OF INCREASING THE INITIAL TEMPERATURE ON THE LOW LIMIT OF COMPLETE PROPAGATION OF FLAME IN METHANE-AIR MIXTURES

Test No.	Temperature ° C.	Pressures. Atmospheres	ANALYSIS OF MIXTURES Before sparking.		After sparking.		Observations	Limits per cent CH_4
			CH_4	Air	CH_4	CO_2		
1	500	1	4.47	95.53	0.58	4.08	Complete propagation	
2	500	1	4.27	95.73	0.64	3.85	Complete propagation	4.00
3	500	1	4.00	96.00	0.89	3.14	Complete propagation	and
4	500	1	3.75	96.25	3.45	0.42	No propagation	3.75
5	500	1	3.50	96.50	3.42	0.18	No propagation	
6	400	1	4.75	95.25	0.75	3.74	Complete propagation	
6*a*	400	1	4.55	95.45	0.65	3.93	Complete propagation	
7	400	1	4.47	95.53	4.26	0.41	No propagation	4.55
8	400	1	4.27	95.73	4.12	0.23	No propagation	and
9	400	1	4.00	96.00	3.88	0.20	No propagation	4.77
10	400	1	3.75	96.25	3.65	0.20	No propagation	
11	300	1	5.15	94.85	0.82	4.36	Complete propagation	4.88
12	300	1	4.98	95.02	0.71	4.13	Complete propagation	and
13	300	1	4.75	95.25	4.64	0.13	No propagation	4.75
14	300	1	4.27	95.73	4.17	0.21	No propagation	5.15
15	200	1	5.15	94.85	0.20	4.98	Complete propagation	and
16	200	1	4.98	95.02	4.84	0.18	No propagation	4.98
17	25	1	5.40	94.60	5.40	0.00	No propagation	5.46
18	25	1	5.46	94.54	5.47	0.00	No propagation	and
19	25	1	5.56	94.44	0.12	5.46	Complete propagation	5.56

According to these results, the low limit of complete propagation is between 3.75 and 4.00 per cent when the initial temperature is 500° C. and the initial pressure 1 atmosphere. At 400° C. and at atmospheric pressure a mixture containing 4.55 per cent methane completely propagated flame, as far as could be judged by the eye, although 0.75 per cent methane remained unburned. When the methane content was lowered to 4.47 per cent propagation could not be observed. The same was true of mixtures containing 4.27, 4.00, and 3.75 per cent methane.

Experiments 17, 18 and 19 were performed to obtain the low limit of complete propagation of methane-air mixtures under ordinary conditions of temperature and pressure. This value lies, it will be noted, between 5.46 and 5.56 per cent methane. Undoubtedly a small amount of carbon dioxide was formed in the case of Experiments 17 and 18, but not enough to detect by the method of analysis used. In each test an analysis was made of the mixtures before and after sparking. The sum of the carbon dioxide and methane should equal the methane present before sparking. The analyses agreed quite well. A curve representing the results of the experiments is shown at Fig. 2.

The variation of the limits of explosibility with temperature and pressure may be explained on purely thermal grounds.

If one heats an explosive mixture of methane and air, the number of collisions between the molecules increases with rising temperature and the speed of reaction increases until finally a violent reaction and appearance of flame follows. The temperature at which this kind of a reaction takes place is called the ignition temperature. The ignition temperature of methane-air mixtures was found to be between 650° and 750° C. by Dixon and Coward.[1] A slow combustion effect is possible, however, below the ignition temperature, depending on the nature of the source of ignition and length of time the gas is heated. But in order that flame may be propagated throughout the gas mixture, the heat of reaction of a layer of gas near the igniter must be sufficient and its rate rapid enough to raise the temperature of the adjacent layer to the ignition temperature. Obviously the higher the initial temperature the less heat will be required to raise the temperature of a given mass of the gas to the ignition temperature, and consequently the smaller is the heat of combustion and the percentage of methane required to furnish this quantity of heat.

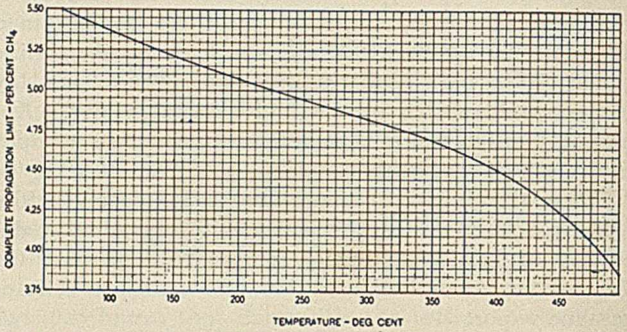

FIG. 2—EFFECT OF INCREASING THE INITIAL TEMPERATURE ON THE LOW LIMIT OF COMPLETE PROPAGATION OF FLAME IN METHANE-AIR MIXTURES

SLOW COMBUSTION OF METHANE-AIR MIXTURES AT HIGH TEMPERATURES WITHOUT SPARKING

A few experiments were performed to show the extent of burning when various mixtures of methane and air were subjected to high temperatures without sparking.

TABLE II—RESULTS OF EXPOSURE OF METHANE-AIR MIXTURES TO HIGH TEMPERATURES WITHOUT SPARKING

Temp. ° C.	Pressure Atmos.	Analysis before ignition		Analysis after ignition		Exposed Min.
		CH_4	Air	CH_4	CO_2	
500	1	4.27	95.73	4.21	0.10	1/2
500	1	4.27	95.73	3.89	0.40	30
500	1	4.60	95.40	3.74	0.90	30

The results, given in Table II, show that no appreciable combustion effect occurred in experiments previously cited between the time the gas mixtures were introduced into the pipette and the time they were sparked. In the experiments previously described, not longer than 2 seconds was required for the mixtures to attain the temperature of the oven after introduction into the exhausted pipette. It will be observed that as much as one-half minute exposure to a temperature of 500° C. resulted in only a small amount of carbon dioxide.

EFFECT OF INCREASING THE INITIAL PRESSURE ON THE EXPLOSIBILITY OF METHANE-AIR MIXTURES

Some experiments were made with the apparatus shown in Fig. 1 to determine the effect of initial pres-

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[1] H. B. Dixon and H. F. Coward, "The Ignition Temperature of Gases," *Chem. News*, **99** (March 19, 1909), 139.

sures higher than ordinary on the explosibility of methane-air mixtures. The first experiments were made with pressures up to five atmospheres, by raising the level bottle of the apparatus high enough to put the gas under this pressure. It was found that increased pressure up to five atmospheres had no effect in changing the low limit of complete propagation. In other words, the value, about 5.50 per cent methane, is true at five atmospheres pressure.

SUMMARY

When the initial temperature of methane air mixtures is 500° C., the low limit of complete propagation of flame of the mixtures is between 3.75 and 4.00 per cent methane. As the initial temperature is lowered from 500° C., the low limit is raised until at ordinary temperatures it is about 5.5 per cent methane. Differences in the initial temperature of as much as 200° C. higher, shift the low limit only from 5.50 per cent to between 4.98 and 5.15 per cent methane.

The results are important in that they show that pressure and temperature conditions may vary over rather a wide range without affecting the explosibility of methane-air mixtures. Inconsistent results that have been obtained in the laboratory by different investigators on the limits of inflammation of methane-air mixtures cannot be explained on the basis of slight variations in temperatures and pressures. They are better charged to the nature of the source of ignition, method of ignition, size and shape of the containing vessel, and in some cases, inaccuracies in mixing and analyzing the gases.

Since the low limit of complete inflammation for methane-air mixtures is not changed at pressures as great as five atmospheres, it can be stated that even in the deepest coal mines the low limit is not altered from the limit at ordinary temperatures.

Chemical Laboratory, Bureau of Mines
Pittsburgh

THE VARIATION IN COMPOSITION OF NATURAL GAS FROM DIFFERENT SANDS IN THE SAME FIELD[1]

By G. A. Burrell and G. G. Oberfell

Received December 15, 1914

In working on the composition of natural gases from different parts of the country, the authors have found that natural gases from different sands in the same field may differ appreciably in composition. Invariably the gas from the shallower sand has contained less of the heavier paraffin hydrocarbons than that from the deeper sands. The most striking variation yet encountered has had to do with natural gases from two different sands in a gas field near Trafford City, Westmoreland County, Pa. and not far from Pittsburgh. The compositions of these gases follow:

Gas from	Murraysville sand			Elizabeth sand			
Depth of sand....	1700 ft.			2295 ft.			
Rock pressure.....	190 lbs. per sq. in.			1000 lbs. per sq. in.			
Constituents	CO_2	CH_4	N_2	CO_2	CH_4	C_2H_6	N_2
Percentages.......	Trace	98.8	1.2	Trace	94.0	5.2	0.8

It will be noted that from the shallow sand there was collected a sample of almost pure methane, while in the deeper sand there is contained in addition to methane an appreciable proportion of the higher members of the paraffin series of hydrocarbons. If one were to assume a common source of origin for the natural gases in the two sands, then by some process of separation the gas in the upper sand has been freed of its ethane and higher paraffins.

It should be added that the paraffins were analyzed by burning them in oxygen, not by fractional distillation; hence in the case of the gas from the deep sand, only the two predominating paraffins are shown. Undoubtedly small proportions of propane, the butanes, etc., were also present, as in the case of other natural gases containing methane and ethane.

Chemical Laboratory, Bureau of Mines
Pittsburgh

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[1] Published by permission of the Director of the Bureau of Mines.

A SIMPLIFIED FERROUS SULFATE METHOD FOR THE DETERMINATION OF VANADIUM IN STEEL

By George T. Dougherty

Received October 17, 1914

In the application of Johnson's[1] or similar methods for the determination of vanadium in steel, considerable difficulty is often experienced in producing a colorless or "old rose" shade with ferrous sulfate in the solution containing an excess of permanganate after the preliminary oxidation of the vanadium. To obviate this difficulty the following method has been developed, in which this oxidation of the vanadium is effected by a sufficient quantity of nitric acid alone or with ammonium persulfate.

METHOD—Treat 2 to 4 g. of the drillings in a 500 cc. Erlenmeyer flask, with 60 cc. of water and 10 cc. concentrated sulfuric acid. After heating the solution nearly to boiling, until the reaction is complete, add 40 cc. of nitric acid (sp. gr. 1.20) and boil thoroughly for 10 minutes to oxidize the iron and vanadium and to expel the last traces of nitrous fumes. Cool the solution, add 60 cc. of cold sulfuric acid (1:2) and dilute in a 600 cc. beaker to 450 cc. Add 3 cc. of a freshly prepared 1 per cent solution of potassium ferricyanide, and titrate rather rapidly, with constant stirring, with 0.05 *N* ferrous ammonium sulfate, to the appearance of the first dark blue color. The end point can best be observed by looking through the side of the beaker toward the bottom of the beaker placed directly before a window. Deduction of a blank of 0.4 cc. of the ferrous solution has been found necessary, and is independent of the weight of the sample, the presence of chromium, and of the carbon content up to 0.5 per cent C.

For steels with over 0.50 per cent C, the blanks are higher; and, moreover, with 4 g. samples of such steels, the end point is rendered indistinct by a turbidity which appears toward the end of the titration. This difficulty may be avoided by adding to the solution immediately after the boiling with nitric acid as above, 60 cc. of 1:2 sulfuric acid and 5 to 8 g. of ammonium persulfate (which in the absence of silver nitrate will not oxidize the Cr and Mn), and continuing to boil for 15 minutes, so that all nitrous oxides and hydrogen peroxide are expelled. (Before this second boiling, wash down with hot water loose specks of the per-

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[1] C. M. Johnson, "Analysis of Special Steels."

sulfate which stick to the glass.) Cool, dilute and titrate as above. After such treatment the blank is 0.35 (instead of 0.4 cc.) for steels with under 0.5 per cent C, and 0.5 cc. for 0.60 to 0.70 C, and 0.6 cc. for 0.90 to 1.25 C steels. The blanks are the same with or without the persulfate treatment for steels of over 0.50 per cent carbon.

The ferrous ammonium sulfate solution may be standardized against 0.1 N permanganate, the strength of which has been determined with sodium oxalate. The iron value of the permanganate multiplied by 0.917 gives the vanadium value.

By this method the following results were obtained, the chromium in expts. 9, 10, 13 and 14 being added as $K_2Cr_2O_7$ before the solution of the steel.

The following steels were employed:

A—U. S. Bureau of Standards Sample No. 24, containing 0.15 per cent V, 0.35 per cent C, and a trace of Cr.

B—U. S. Bureau of Standards Sample No. 30, containing 0.21 per cent V, 0.37 per cent C, and 1.35 per cent Cr.

C—A steel casting containing 0.215 per cent V, 0.30 per cent C, and no Cr.

D—A plain steel containing 0.85 per cent C.

E—A plain steel containing 1.25 per cent C.

TABLE I—VANADIUM DETERMINATIONS BY SIMPLIFIED METHOD

Expt.	Sample	Weight of sample Grams	Persulfate added Grams	Vanadium found Gram
1	A	2	0	0.148
2	A	4	0	0.146
3	B	2	0	0.206
4	B	4	0	0.208
5	C	2	0	0.216
6	C	4	0	0.216
7	C D	2 2	0	0.222
8	C E	2 2	0	0.210
9	C D 1.3% Cr	2 2	0	0.210
10	C E 1.3% Cr	2 2	0	0.200
11	C D	2 2	7	0.216
12	C E	2 2	7	0.216
13	C D 1.3% Cr	2 2	7	0.216
14	C E 1.3% Cr	2 2	7	0.210

From these results it is apparent that in general for such materials, the method is accurate to 0.01 per cent vanadium.

If chromium also is to be determined, it is determined in a separate portion of the sample, using any of the usual volumetric methods.

AMERICAN STEEL FOUNDRIES, CHICAGO

THE EFFECT OF CERTAIN ORGANIC COMPOUNDS ON WHEAT PLANTS IN THE SOIL—PRELIMINARY PAPER

By FRED W. UPSON AND A. R. POWELL

Received March 20, 1915

In recent years our knowledge of the chemical nature of soil organic matter has been greatly extended through the work of a number of investigators, chief among whom are Jodidi and the several workers in soil fertility investigations of the United States Bureau of Soils. A very complete historical account of the work on soil organic matter and of the older views regarding it has been presented by Schreiner and Shorey[1] and by Jodidi.[2] Through the work of these investigators and their co-workers, we have come to regard the soil organic matter not as consisting of three of four compounds of rather indefinite properties, but as being made up of a large number of different organic compounds which result from plant and animal residues through the agency of the various chemical processes which are taking place in the soil. From various soils there have been isolated and identified up to the present time, more than half a hundred definite organic compounds. Among the various classes of organic compounds represented are acids, aldehydes, alcohols, amino acids, resins, esters, glycerides, hydrocarbons, sugars, amines and other nitrogenous compounds. The methods by which these compounds have been isolated and identified are somewhat involved and need not be considered here.

The toxic effect on wheat plants of the various organic compounds which have been isolated from various soils has been extensively studied by Schreiner[1] and his co-workers. With two exceptions,[2] the work by these investigators on the toxic effect of organic compounds has been determined by growing plants for short periods in distilled water cultures containing the various compounds. The organic compounds studied are either those which have been isolated from the soil or those which may result through the breaking down of plant and animal residues.

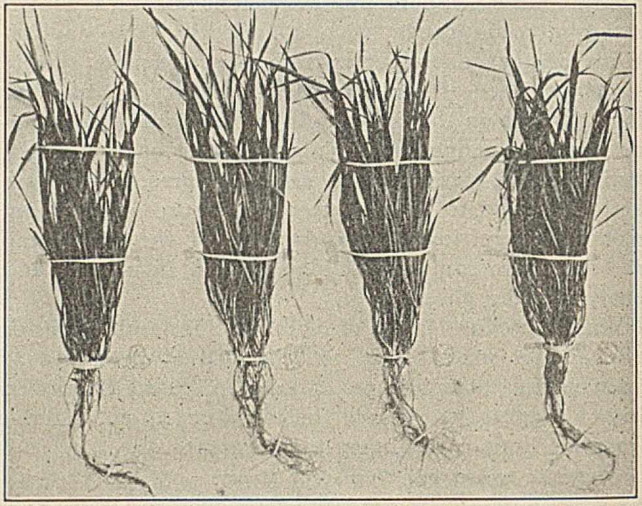

PLATE I

Many of the compounds studied have been shown to be more or less toxic to wheat plants in comparatively low concentrations, 10–200 parts per million of solution. Some few have been found beneficial to the growth of wheat plants in water solution. In many cases the addition of fertilizer salts to the culture solution has partially or completely overcome the toxic effects of the organic compounds.

While a knowledge of the effect of these compounds on the growth of wheat seedlings in water solution is of the greatest importance, nevertheless we should

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[1] *Bull.* **53**, Bur. of Soils, U. S. Dept. Agr., p. 21.

[2] *Biochem. Bull.* **3**, 17.

[1] A summary of the effect of various organic compounds on growth is given in *Bull.* **87**, Bur. of Soils, U. S. Dept. Agr., p. 70.

[2] Schreiner and Skinner have studied the effect of cumarin (*Bull.* **77**, Bur. Soils, p. 16) and of salicylic aldehyde, U. S. Dept. Agr. (*Bull.* **108**, 5, 12), on wheat plants in the soil.

not assume from results obtained in this manner that these compounds will exhibit the same behavior toward plants growing in the soil. Conditions are much more complex in the soil. Adsorption and other surface effects, aeration, the effect of chemical compounds and the action of microörganisms are all factors which are of little importance in the water culture, but which play a much more prominent rôle in the soil.

Extensive work on the behavior of these organic compounds toward plants in the soil, is necessary before we are able to draw final conclusions in regard to the relation of these substances to soil fertility.

EXPERIMENTAL PART

The present paper deals with the behavior of vanillin, salicylic aldehyde, cumarin, quinone and dihydroxystearic acid toward wheat plants in the soil.

Vanillin is of special interest because it exists in many plants in the form of a glucoside. Vanillin or substances which give rise to it have been reported in oats,[1] asparagus shoots[2] and other plants. Quite[3] recently it has been isolated from ungerminated wheat seeds and from seedlings five days old. It has recently also been isolated from Florida soils.[4]

Vanillin has been shown by Schreiner, Reed and Skinner[5] to be toxic to wheat seedlings grown in distilled water solution, 500 parts per million being sufficient to cause death in nine days. It was noticeably toxic in much lower concentrations. Schreiner and Skinner[6] have shown also that vanillin is much less toxic in water solution in the presence of fertilizer salts.

EXPERIMENT 1—The soil used in this experiment came from a meadow which has long been in blue grass. It is a black silt loam of excellent texture and rich in organic matter. Approximately 1800 g. of dry soil were mixed with the required amounts of vanillin, potted and brought to the proper moisture content with distilled water. After standing 24 hours, ten wheatseeds were planted in each pot. Complete germination was secured in each. After the plants were well sprouted each pot was thinned to five plants. The experiment lasted from October 20 to November 28th (39 days). At the end of this time the pots were opened, the soil very carefully removed from the roots and the green and dry weights of the whole plant determined. The results are shown in Table I, A.

TABLE I—RESULTS WITH VANILLIN

		A			B			C		
No.	TREATMENT	Green weight	Dry weight	Relative growth	Green weight	Dry weight	Relative growth	Green weight	Dry weight	Relative growth
1	Soil untreated	19.2	2.21	100	48.1	7.58	100	51.0	6.4	100
2	Same + 250 p. p. m. vanillin	19.2	2.20	100	51.5	7.43	107	51.8	6.39	101
3	Same + 500 p. p. m. vanillin	18.8	2.09	98	47.7	7.20	99	58.2	7.13	114
4	Same + 1000 p. p. m. vanillin	18.6	2.16	97	48.4	7.46	101	50.1	6.57	98

The roots were not visibly injured in any way even in the highest concentration of vanillin. A photograph serves to show this more clearly. Plate I shows the plants from Experiment 1: Nos. 1, 2, 3 and 4 show the plants from the untreated soil and from the soil containing 250, 500 and 1000 parts per million vanillin respectively.

EXPERIMENT 2—This is a duplicate of the first experiment except that the plants grew till December 23rd (64 days). The results are shown under B in Table I.

EXPERIMENT 3—This experiment was carried out in the same manner as Experiments 1 and 2 except that the vanillin was added to the soil in water solution. This experiment ran from October 30th to December 29th (60 days). The results are given under C in Table I.

EXPERIMENT 4—Another experiment was carried out using soil from a field which has been under cultivation for about thirty years. It is a silt loam of excellent texture, but much less fertile than the soil used in the previous experiments. The plants grew from November 30th to February 3rd. Three plants were grown in each pot, the green weights of the tops only being recorded (Table II).

TABLE II—RESULTS WITH VANILLIN

TREATMENT	No.	Green weight	Relative growth	No.	Green weight	Relative growth
Soil untreated	1	6.5	100	4	6.69	100
Same + 500 p. p. m. vanillin	2	6.39	97	5	6.59	99
Same + 1000 p. p. m. vanillin	3	5.9	90	6	6.49	97

These experiments show that vanillin is not appreciably toxic to wheat plants when present in the soil even in quantities as high as 1000 parts per million. Vanillin is therefore, to say the least, much less toxic in the soil than in water cultures. Even with the addition of fertilizer salts in the most favorable combinations, solutions containing only 50 parts per million of vanillin gave a relative growth of wheat plants[1] of 88.

Salicylic aldehyde has very recently been found in a soil by Schreiner and Skinner.[2] These investigators have also determined its effect on corn and wheat in distilled water cultures and also in the soil. They find that in distilled water, growth of wheat is reduced by the presence of 25 parts per million salicylic aldehyde, 69 per cent and that in concentrations of 50, 100 and 200 parts per million this substance produced death.[3] Much the same effect was produced on corn grown in nutrient solutions: 10 parts per million of the aldehyde gave a relative growth of 60 after 25 days, whereas 200 parts per million gave a relative growth of only 10.

The effect of salicylic aldehyde on wheat and corn in soil in pots was also determined.[4] Salicylic aldehyde in 50 parts per million gave a relative growth of wheat of 61, after 22 days and in concentrations of 100 and 200 parts per million caused death: 50 parts per million of the aldehyde reduced the growth of corn in soil 24 per cent and in quartz sand 60 per cent. These experiments were carried out in paraffined wire pots described in Circular 18 of the Bureau of Soils.

EXPERIMENTS WITH SALICYLIC ALDEHYDE

For these experiments the soil selected was the same as the one used in Experiment 4 with vanillin. Pots holding about 1800 g. of soil were employed. The aldehyde was dissolved in water and added to the soil in the proper proportions.

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[1] de Rawton, *Compt. rend.*, **125**, 797.

[2] von Lippman, *Ber.*, **18**, 1335.

[3] Sullivan, THIS JOURNAL, **6**, 920.

[4] Shorey, *J. Agr. Res.*, **1**, 357.

[5] Bur. Soils, U. S. Dept. Agr., *Bull.* **47**, 31.

[6] *Ibid.*, *Bull.* **77**, 20.

[1] Schreiner and Skinner, Bur. Soils, U. S. Dept. Agr., *Bull.* **77**, 21.

[2] U. S. Dept. Agr., *Bull.* **108**, 1 (1914).

[3] *Ibid.*, **108**, 3; Skinner, *Biochem. Bull.* **3**, 390; *J. Am. Soc. Agron.*, **6**, 108.

[4] U. S. Dept. Agr., *Bull.* **108**, 5.

EXPERIMENT 5—This experiment with salicylic aldehyde was carried out in the same manner as the vanillin experiments. Ten wheat seeds were planted in each pot and the plants thinned to five after they were well sprouted. The experiment ran from November 22nd to January 2nd. Section A of Table III shows the weights of the tops only.

Table III—Results with Salicylic Aldehyde

		A			B		
No.	Treatment	Green wt. G.	Dry wt. G.	Relative growth	Green wt. G.	Dry wt. G.	Relative growth
1	Soil untreated	6.7	.85	100	12.7	2.51	100
2	Same + 10 p. p. m. salicylic aldehyde	6.8	.89	102	12.1	2.29	95
3	Same + 25 p. p. m. salicylic aldehyde	6.2	.77	93	11.8	2.30	93
4	Same + 50 p. p. m. salicylic aldehyde	5.7	.73	85	12.2	2.42	96
5	Same + 100 p. p. m. salicylic aldehyde	6.2	.75	93	12.3	2.47	97

EXPERIMENT 6—This experiment is a duplicate of Experiment 5, except that it ran till January 28th. The results are shown under B in Table III.

EXPERIMENT 7—The same method was used as in the preceding experiments, except that higher concentrations of the aldehyde were used and the experiment ran from January 15th to March 6th. A of Table IV gives the results.

Table IV—Results with Salicylic Aldehyde

		A			B		
No.	Treatment	Green wt. G.	Dry wt. G.	Relative growth	Green wt. G.	Dry wt. G.	Relative growth
1	Soil untreated	8.5	1.6	100	4.5	.33	100
2	Same + 100 p. p. m. salicylic aldehyde	7.8	1.55	92	3.8	.25	84
3	Same + 200 p. p. m. salicylic aldehyde	8.4	1.73	99	3.3	.20	73
4	Same + 500 p. p. m. salicylic aldehyde	8.0	1.59	94	4.4	.34	98

EXPERIMENT 8—The effect of salicylic aldehyde on corn was also determined. The experiment ran from February 3rd to March 6th. Two plants were grown in each pot and the method was the same as the one used in the wheat experiments. The results are given under B in Table IV.

Our experiments indicate that salicylic aldehyde is much less toxic to wheat and corn plants in the soil than in water cultures. The toxic effect on wheat, even in a concentration of 500 parts per million, is practically negligible. This does not agree with the results of Schreiner and Skinner.[1] In order to determine whether this difference was due to the method or to the soil we repeated the experiment, using the paraffine wire pots according to the method of Schreiner and Skinner.[1]

EXPERIMENT 9—Wheat was grown for twenty-two days in paraffined pots. At the end of this time the tops only of the six plants from the check pot weighed 0.98 g. while those from the pot treated with 100 parts per million of the aldehyde weighed 1.09 g. The soil which we used was a silt loam of loose texture and fairly high in organic matter, while the one used by Schreiner and Skinner is described as "a heavy clay loam."

Our experiments show that the effect of salicylic aldehyde on the growth of wheat and corn is different for different soils. We are of the opinion that aeration and absorption are important factors in overcoming the effect of the aldehyde. It is probable that the explanation of our results is to be found in the fact that the soil used was of a looser texture and more absorptive than the one described by Schreiner and Skinner.

Preliminary experiments on the behavior of cumarin, quinone and dihydroxystearic acid toward wheat plants in the soil indicate that the effect is entirely different from the effect of these substances in water solutions. Quinone in concentrations below 500 parts per million in soil is beneficial to the growth of wheat. The other two substances are somewhat more toxic in the soil than is vanillin. A complete series of experiments with these compounds is in progress. Experiments are also in progress to determine the fate of these compounds and also of vanillin and salicylic aldehyde, in the soil.

CONCLUSIONS

The behavior of vanillin and of salicylic aldehyde toward wheat plants in the soil is shown to be quite different from the behavior of these substances in water cultures.

The behavior of salicylic aldehyde is shown to be different in different soils.

The necessity for more extended experiments of the nature of those here reported, has been demonstrated.

Laboratory of Agricultural Chemistry
University of Nebraska Experiment Station
Lincoln

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[1] *Loc. cit.*

THE ENGINEERING PROPERTIES OF SOILS

By R. O. E. Davis[1]

Received February 6, 1915

The engineering properties of soils are of interest to all peoples living under civilized conditions, and engineering questions concerning the soil are of importance next to that of productiveness. The construction and maintenance of drainage, irrigation or commercial canals, the proper foundations for architectural structures, the construction and operation with safety of mines and quarries, and the protection afforded by levees and embankments are all dependent directly in most cases and indirectly always on these engineering properties. Attention has not been given to the subject in proportion to its importance. Lately, however, engineers and engineering societies have evidenced a growing interest in the subject, as it is realized that while the engineering features of the superstructures have been worked out with much care and detail, the properties of the soil on which the foundation rests are very little understood.

The statement has been made that nothing is known of these properties. This, however, is rather misleading; the facts are that the properties that the engineer has to deal with are mainly the physical properties of the soil and these have been studied systematically for some years, mainly from the agricultural standpoint. So it is well to see in what way the two studies are related so that needless work may be avoided.

Approaching the problem from the engineering standpoint, the properties of the soil on which the engineer wishes information are the rigidity of the soil, its cohesiveness, its penetrability, and its porosity. These are the properties that determine the weight which the soil will support under structural conditions, the height to which a retaining wall of soil will stand without additional support, the resistance

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[1] Scientist in Soil Laboratory Investigations, Bureau of Soils, U. S. Dept. of Agriculture.

offered to the driving of piles or similar operations, and the rates at which water is lost from irrigation ditches and canals. These same physical properties of the soil determine the resistance of a soil to erosion by wind or water, regulate the rate of water movement as a supply to the plant, determine the resistance offered by the soil to tillage operations and to the expansion or growth of plant roots. While important to know these properties in engineering operations, the studies carried on from an agricultural viewpoint have resulted in generalizations that must be regarded if the engineering investigations are not to result in much unnecessary duplication.

PHYSICAL NATURE OF SOIL

Soil is made up of solid particles mostly mineral in character, a varying amount of water within the interspaces of the soil and generally gases occupying part of the interspace. The relative proportions of these constituents are constantly changing, but the actual amount of solid material remains more or less constant. Even this, however, is not actually true; the movement of wind or water over the surface causes a translocation of the solid soil-material, and the movement of water within the soil is constantly causing the removal or deposition of the solid phase of the soil A more serious change in the soil as a result of the changing moisture content will be referred to later. It is sufficient to state here that the soil is constantly changing in actual composition, and the properties are also changing; that is, the soil problem is not static but dynamic.[1] If we consider more in detail the physical properties we shall see in what manner this is true.

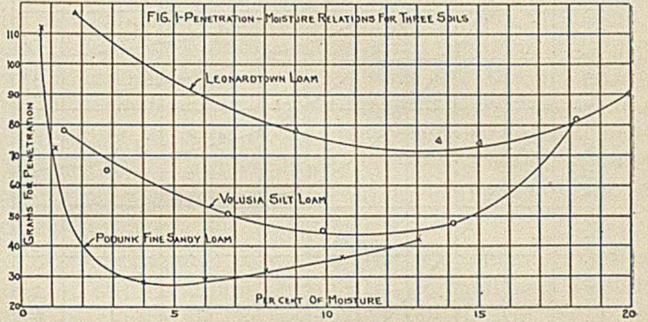
SOIL TEXTURE

The texture of soil is the factor upon which many of the physical properties are dependent. The soil texture is determined by the mechanical composition and by the crumbing of the soil. Mechanical composition refers to the relative amounts of different sized particles composing the soil. A soil made up mostly of sand or larger sized particles has larger interstices than a soil composed of smaller particles, under conditions in which crumbing does not take place. Accompanying the presence of the smaller grades the phenomenon of crumbing occurs. This is the grouping of the small silt and clay particles into larger aggregates, the result of which is a more open and porous soil. The actual amount of interspace is not increased greatly but the size of the spaces is materially enlarged. This is closely related to the moisture content as will be shown later.

The amount of water which a soil may contain is measured by the pore space. In the case of heavy clay soils, where the amount of pore space is great, the capacity for absorbing water is very large. The rate at which water will move through a soil depends upon the size of the pore spaces which is directly dependent on the size of the soil particles or kernels.

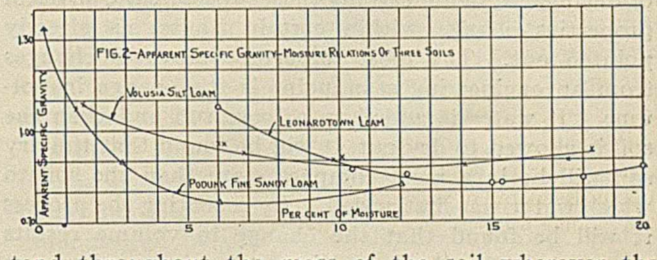
MINERALOGICAL COMPOSITION

The mineralogical composition of the soil has an effect upon the engineering properties of the soil that is both chemical and physical. The chemical factor is the ease with which the minerals are broken down or changed chemically, due to the weathering conditions, or the action of soil water and soil atmosphere. These are exactly the same conditions that are important from an agricultural standpoint. The physical factor is due to the particular shape or condition of surface of the soil minerals connected with various mineral compositions. This question is one of vital importance in the erosion of soil. The presence, for example, of much micaceous material in the soil is presumed to cause the particles to move over each other more easily than when these are absent. This is also vitally important to the engineer in selecting foundations or building embankments.



MOISTURE CONTENT

While the textual relations of the soil and its mineralogical composition are important in studying the physical properties, probably the most important single factor in determining the physical condition of the soil is the moisture content. It is not stating the case too strongly to say that the soil is constantly changing and that these changes are mainly due to the soil moisture. There are surface changes taking place due to the action of wind, and these changes are large; but the changes resulting from water extend throughout the mass of the soil wherever the rainfall is sufficient, and the aggregate of these changes is very large.



Experiments have shown[1] that the magnitude of any physical measurement of the soil changes with a change in moisture content. The degree of the change varies with the mechanical composition of the soil, the variation in soils of fine texture being more gradual with changing moisture content, than that in soils of a coarser texture. However, the change in dimen-

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[1] This has been emphasized by Cameron in several articles, especially in the article, "The Dynamic Viewpoint of Soils," THIS JOURNAL, 1 (1909), 806.

[1] Cameron and Gallagher, *Bull.* 50, Bureau of Soils, Dept. of Agric. (1908).

sion of any physical property of a soil varies with the moisture content, reaching a maximum or minimum value at a definite moisture content for any specific soil. As examples, the volume or the penetrability of a soil changes with a change in moisture content.

Figs. 1 and 2 show the curves[1] for the apparent specific gravity and the penetrability of several soils, in which these values vary with the change of moisture content. From the penetration curves it will be noted that the penetration reaches a minimum value with Podunk fine sandy loam at about 6 per cent moisture, with Volusia silt loam at 13 per cent and with Leonardtown loam at 15 per cent. The apparent specific gravity is at its minimum value at 6 per cent moisture for Podunk fine sandy loam, at 12 per cent for Volusia soil and at 14 per cent for the Leonardtown loam.

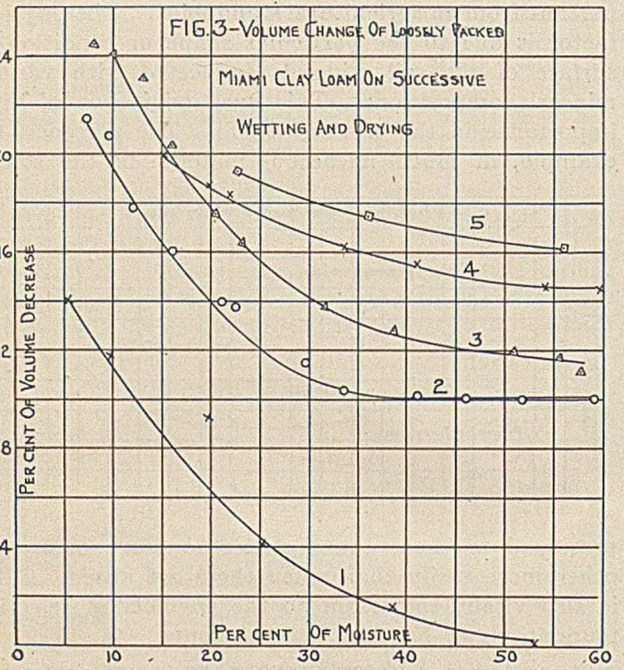
FIG. 3—Volume Change Of Loosely Packed Miami Clay Loam On Successive Wetting And Drying

Since the soil as a whole is always either being wet or drying out, in undergoing these processes the physical properties change within certain limits, as already pointed out. The most important of these changes from an engineering standpoint is the change in volume. If water is added to a loose soil and then the soil is allowed to dry out, it will be found that the dry soil will be in a more compact state than the soil to which water was first added. By repeating the process it will be found that the change in volume results always in the soil occupying more volume when wet than when dry. However, the change in volume becomes smaller each time, approaching a limiting curve for the volume changes. Those changes are shown in Fig. 3 for a clay loam soil. The curves in Fig. 3 show the percentage volume decrease of a loosely packed soil on successive wetting and drying. The curves are numbered in the order of the wetting. There is a decrease of 14 per cent in volume on the first drying, but when re-wetted the volume shows an increase of only 4 per cent. This is followed by a shrinkage of nearly 12 per cent. The change becomes less with each cycle, approaching limiting values.

On the other hand, if the soil is compacted as much as it is possible to do by mechanical means and then wetted, the volume will increase; but on drying out, while shrinkage takes place, the dry volume will be larger than the volume of the originally compacted soil. Again the changes in volume show a hysteresis effect approaching a limiting curve, as shown in Fig. 4. In this case the soil was first compacted and then wetted. The compacted condition is taken as the zero volume. The first curve shows a decrease in volume on drying, but on rewetting there is an increase in volume over the previous condition of the soil with the same amount of moisture. The direction of change on wetting is indicated but the actual path followed is not shown. This, then, explains natural packing. Regardless of the condition of the soil, by several successive wettings and dryings the soil particles so arrange themselves that the changes in volume approach a limiting curve. This is the process that the soil follows under natural conditions, so that this process of "natural packing" produces a soil of a definite volume for a given moisture content. Whether we start with a loosely packed or a compacted soil, on continued wetting and drying there are changes in volume and a hysteresis effect until a state is reached in which the expansion on wetting is just equal to the contraction on drying. This is the state of natural packing. Within narrow limits the change of volume on contractions is not greatly dependent on the packing of the soil.

Still another property of the soil influenced by the moisture content is that of the rate of evaporation of the water contained therein. Measurements of the rate of evaporation for several soils show that there is a fairly rapid increase in the rate of evaporation from the dry condition up to the critical moisture content, and that the rate then becomes nearly constant. The change in the rate curve corresponds to the maximum or minimum of other physical properties. The curves reproduced in Fig. 5 show more

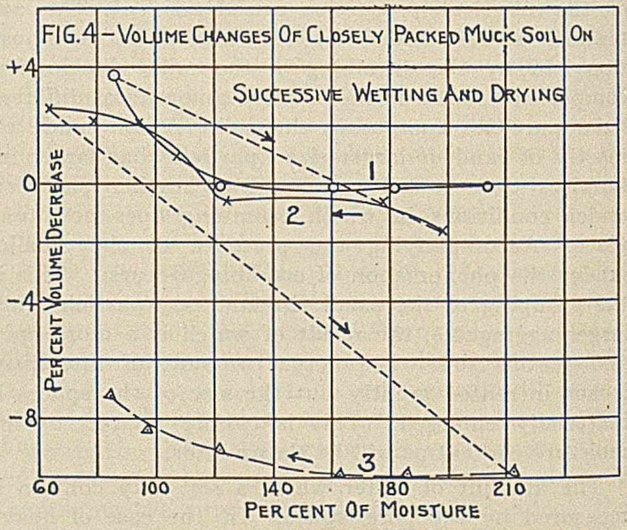
FIG. 4—Volume Changes Of Closely Packed Muck Soil On Successive Wetting And Drying

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[1] Reproduced from *Bulls.* **50** and **82**, Bureau of Soils, U. S. Dept. of Agric.

clearly how this change in rate of evaporation takes place.

From the consideration of the changes taking place in the soil it is evident that the conditions of the soil are not constant. The composition as well as the physical properties of the soil is constantly changing and these changes must be considered in any study of soil conditions. The largest and most important changes in the soil are wrought by a changing water content. The influence of these changes follow a definite law and with this understanding of the influence of moisture variation, it remains to investigate the amount of such changes due to specific soil conditions.

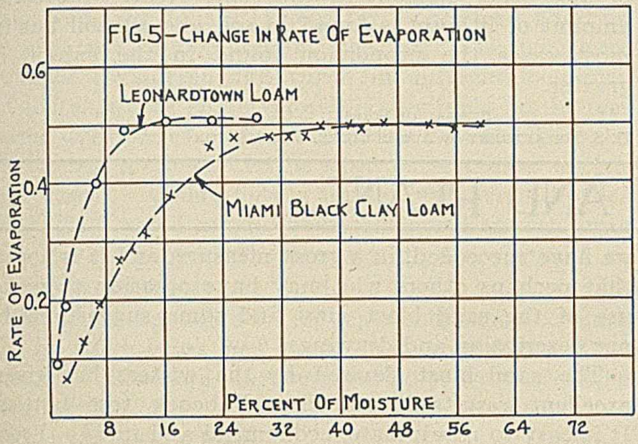
FIG. 5—CHANGE IN RATE OF EVAPORATION

SUMMARY

The engineering properties of the soil are the properties of interest from the physical standpoint and are identical with those physical properties of importance to agricultural operations.

The factors influencing the physical properties are mechanical composition, mineralogical composition and moisture content. All of these are constantly changing, but the greatest variation occurs in the moisture relations of the soil.

A study of the moisture relations has demonstrated the fact that all of the physical properties change with a changing moisture content and with any given soil there is a particular moisture content at which the properties either reach a maximum or minimum value; this moisture content is the critical moisture content of the soil.

The soil, if allowed to become wet and dry out several times, reaches a condition of compactness known as "natural packing." This compactness varies with the moisture content just as the other physical properties do.

The study of the engineering properties of the soil will consider the changes due to specific soil conditions, but must recognize the dynamic soil conditions.

BUREAU OF SOILS
U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON

LITHIUM IN SOILS

By L. A. STEINKOENIG

Received January 6, 1915

Lithium is very widely, though not abundantly, distributed in nature. It has been found in a large number of sedimentary rocks examined by A. Hilger,[1] in a great number of primary rocks, granites, syenites and gneisses, by L. Dieulafait,[1] and in many varieties of marble, calcareous rocks and English chalk by Kirchoff and Bunsen.[2]

Lithium is also very often found in mineral waters and salines. It has been found in the larger bodies of water: in the Dead Sea, by Dieulafait[3] and in the waters of the Mediterranean Sea, Red Sea, Indian Ocean, Chinese Sea, Atlantic Ocean, Antarctic Ocean and the Northern Ocean by the same author,[4] the concentration of lithium being great enough in the waters of the Mediterranean to make it easy to detect in the residue from one cubic centimeter of water.

Being so widely distributed in rocks one would expect to find lithium in the soil and plants supported by the soil. Beet[5] and tobacco plants take up considerable quantities of this element from the soil. Lithium was found in tomatoes, chick peas and Iris germinica by Passerine[6] and in a great number of plants growing exclusively in Austria by Tschermak.[7] Bunsen and Kirchoff found lithium in the ash of the wood of trees grown on a granite soil and in the ash of all kinds of cereals grown in the valley of the Rhine.

Lithium has also been found in the blood and muscles of man and ruminant animals by Kirchoff and Bunsen and in nearly all the organs of the human body by Herrmann.[8]

Lithium has been known to be present in soils, for a long time, but there are few quantitative estimates of this element. It was found present in all soils examined by Robinson.[9]

The lithium was obtained together with the sodium by the J. Lawrence Smith method and the excess of platinum used to precipitate the potash removed by treatment with hydrogen sulfide. The lithium and sodium salts remaining in solution are filtered and concentrated to small volume.

The lithium was determined by means of a Hilger wave length spectroscope using the line of 6708.2 wave length. The intensity and duration of the line, compared with that of a standard solution, served to measure the content of lithium. The method of comparing the spectra of unknown and standard was very similar to that of Truchot, with the use of platinum spiral and addition of sodium chloride to standards as described by Skinner and Collins.[10]

A blank determination showed small amounts of lithium in reagents but not enough to interfere with the determination. To determine whether appreciable amounts of lithium are volatilized during heating twice to drive off ammonium salts, standards were made by adding lithium, in amounts occurring in soils, to powdered quartz. No loss of lithium occurred

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[1] *Deut. Chem. Ges. Ber.*, **8**, 335.

[1] *Ann. chim. phys.*, [5] **16**, 377–391.

[2] *Chem. News*, **98**, 151–2.

[3] *Compt. rend.*, **94**, 1352–1354.

[4] *Ann. chim. phys.*, [5] **16**, 377–391.

[5] von Lippmann, *Ber.*, **30** (1897), 3037–3039.

[6] *Staz. Sper. Agrar.*, **20**, 471–476.

[7] *Zeit. Landw. Versuchs-Wesen. Oesterr.*, **2**, 560–572.

[8] *Pflüger's Archiv.*, **109** (1905), 26–50.

[9] *Bull.* **122**, Bureau of Soils, U. S. Dept. Agriculture, 1914.

[10] Skinner and Collins, *Bull.* **153**, Bur. of Chem., U. S. Department of Agr. (1912).

Soils Analyzed for Lithium	Per Cent Lithia Soil	Per Cent Lithia Subsoil
Soils of River and Flood Plains Province		
Cahaba Fine Sandy Loam, Clay County, Ga	0.002	0.004
Cahaba Very Fine Sandy Loam, Minden, La	0.001	0.002
Soils of Glacial and Loessial Province		
Memphis Silt Loam, Grenada Co., Miss	0.002	0.002
Memphis Silt Loam, Smooth Phase, Grenada Co., Miss	0.001	0.002
Carrington Loam, Lawville, Wis	0.002	...
Gloucester Stony Loam, 3 mi. E. Marlboro, N. H.	0.003	...
Volusia Silt Loam, 3$^1/_2$ mi. S. W. Naples, N. Y.	0.003	...
Soils of Coastal Plains Series		
Ruston Fine Sandy Loam, Minden, La	0.002	0.003
Susquehanna Clay, Clark Co., Miss	0.008	0.007
Susquehanna Fine Sandy Loam, Smith Co., Texas	0.003	0.003
Orangeburg Sand, Terrel Co., Ga	0.002	0.003
Norfolk Fine Sandy Loam, 3 mi. S. W. Murphy, Colquit Co., Ga	0.003	0.003
Susquehanna Fine Sandy Loam, Colquit Co., Ga	0.002	0.003
Portsmouth Fine Sandy Loam, Colquit Co., Ga	0.003	0.004
Tifton Fine Sandy Loam, Bellville, Ga	0.002	0.004
Soils of the Limestone Valley and Upland Province		
Hagerstown Loam, 1 mi. N. W. Conshohocken, Pa	0.010	...
Soils of Great Plains Province		
Oswego Silt Loam, 2 mi. N. W. Manhattan, Kan	0.003	...
Colorado Sands, Greeley, Col	0.002	...
Soils of Piedmont Plateau Province		
Louisa Loam, Trevilians, Va	0.003	...

during the analysis of these standards. Approximately the same amount of sodium chloride as the soil samples contained was added to the standards.

The soils were taken from six different areas. The results of the analyses are given in the accompanying table.

Lithium, although occurring in small amounts, was found present in all soils examined and in many cases in larger amounts than rubidium[1] is usually found. The content of lithium does not seem to follow that of any other element in the soil. Nearly the same amount of lithium is found in soil and subsoil but in most cases the proportion found in the subsoil is greater.

Bureau of Soils
U. S. Department of Agriculture, Washington

LABORATORY AND PLANT

SAND BLAST FOR MARKING GLASSWARE

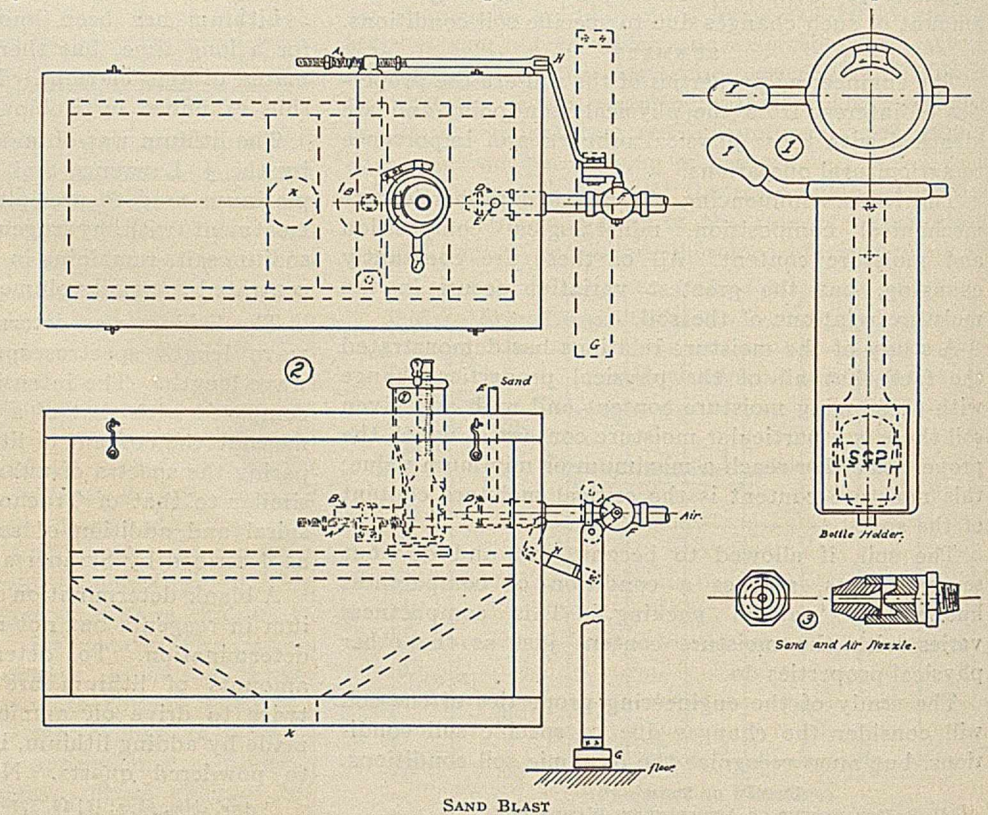
By George Spitzer and L. S. Trachsel

Received March 19, 1915

Sometime ago it became necessary for the senior writer to devise a means for marking glassware. The main objects desired were rapidity, economy and durability. Where large quantities of glassware are to be marked rapidity is very essential. The method of using an emery wheel or emery paper answers the purpose quite well where only "spot etching" is required and the glassware is sufficiently strong to withstand the pressure of the rapidly moving emery wheel or emery paper. When lettering is to be done other methods are resorted to, and the so-called diamond ink or hydrofluoric acid method is sometimes used. Before employing either hydrofluoric acid or diamond ink for effective etching it is necessary that the glassware be warmed and free from grease or dirt. The rubber stamps used for applying the etching agent clog up with the paste, making frequent cleaning necessary and also making the whole operation very slow and sometimes unsatisfactory. In addition the etching done by the hydrofluoric acid is fine-grained and soon becomes very faint if the glassware is handled to any great extent. This is true when grease or greasy substances come in contact with the etching.

To overcome these difficulties an effort was made to devise a sand blast, embodying the features necessary for rapid work, economy in various relations and one that would give durable markings. In this we believe we have succeeded, in a great measure, and it is hoped that perhaps others who may have occasion to make use of the sand blast may find some suggestions in our description and drawings.

The sand blast devised by the writers has given excellent results in marking Babcock test bottles. It is easy to manipulate, economical and rapid. From the drawing it will be seen that the manipulation is very simple; the bottle to be marked is placed in a cylindrical receptacle (bottle holder), the bell-crank presses the bottle against the stencil, the air cock is opened and the sand forced against the stencil. At the same time the cylinder is rotated by the hand sufficiently to expose the letters to the blast; when the turn is made the foot-lever is released which cuts off



Sand Blast

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[1] *Bull.* **122**, Bureau of Soils, U. S. Dept. Agriculture, 1914.

the air blast, also prevents the sand from escaping, and the glassware is then withdrawn. From the construction of the apparatus very little sand is blown out during the marking, even though high pressure is used.

Where large quantities of bottles are to be marked the cost of marking becomes an important factor from the financial point of view, not only for time consumed, but also with reference to cost of the material. During the past year over twenty thousand (20,000) bottles have been marked at a cost of less than ten cents for sand and two dollars ($2.00) for stencils, in addition to the cost of compressing the air. The last item is to be considered and varies in different locations. In places where steam power is available, as in factories, creameries etc., the expense is scarcely to be considered after the initial cost of installing an air compressor. Where only a limited number of bottles are to be marked a hand compressor will answer quite well; for rapid work the pressure need not exceed 20 to 25 lbs. per sq. in.

It has been possible for an experienced man to mark six to eight gross per hour, in a very satisfactory manner. The sand blast requires no previous cleaning of glassware, as is frequently the case when marking with hydrofluoric acid.

DESCRIPTION OF DRAWINGS

Fig. 1 is a brass receptacle of such dimensions as will accommodate the bottle to be etched or marked. This receptacle has a guide opposite the opening containing the stencil. The stencil is held in front of the piece of glassware to be marked, by two clamps.

Fig. 2 shows plans of and elevations of the air-tight box which encloses all the etching mechanism. The spring (A) through the medium of the roller (B) forces the guide and the bottle against the stencil. This rotation is obtained by pressing the foot-lever (G) and is communicated through the bell-crank and rod (H). The spring (A) is adjusted to obtain the proper pressure of the bottle or piece of glassware against the stencil. The sand is blown from the nozzle (D) and forced against the stencil. The receptacle is rotated by means of the handle (I) sufficiently to bring each letter of the stencil normal to the blast of sand. The sand enters the nozzle (D) through the opening (E) by gravity. The compressed air enters through the valve (F), which is controlled by the foot-lever (G), this one lever operating the valve (F) and spring (A) simultaneously. The sand entrance to the nozzle is so located that no sand escapes when the air pressure is removed. All the motions necessary to mark each piece of glassware are controlled by the foot-lever simultaneously, except the rotation of the receptacle, the speed of which depends upon the depth to which the glassware is to be marked. All the sand blown into the box escapes through the opening (K) into a container. The sand is returned to the sand box supplying the sand to the nozzle. This sand box is placed two or three feet above the apparatus and the sand is carried by means of rubber tubing or small glass pipe to the opening (E) of the nozzle.

The fundamental design of this apparatus can be made use of in marking various kinds of glassware. Stencils can be easily made containing a greater number of letters or rows of letters. Stencils having plain openings may be used in etching laboratory glassware, beakers, necks of flasks, etc., or for "spot" etching.

PURDUE UNIVERSITY, LAFAYETTE, INDIANA

A MODERN HYDRATED LIME PLANT

By RICHARD K. MEADE

Received March 23, 1915

One of the newest hydrated lime plants is that of the Dutchess County Lime Company, at Dover Plains, N. Y. This plant was completed in the fall and has now been in operation for about four months. This company, however, has been in existence for several years, operating two small kilns about two miles from the town of Dover Plains, hauling their lime to the railroad with teams and bringing the coal and other supplies to the plant by the same means.

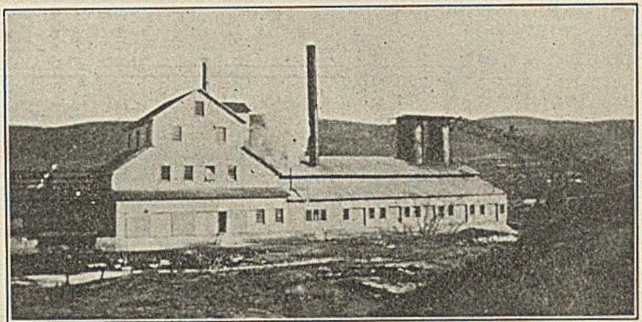


FIG. 1—PLANT OF THE DUTCHESS COUNTY LIME CO., DOVER PLAINS, N. Y.

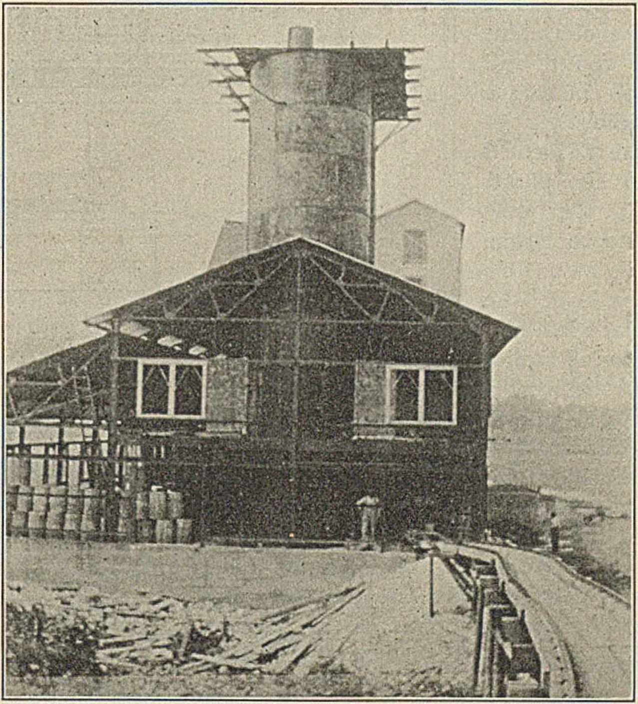


FIG. 2—LIME KILNS DURING CONSTRUCTION

The stone found on the property is a high-grade magnesian limestone of which the following analyses give a good idea.

ANALYSES OF LIMESTONE	From old quarry	From new quarry
Silica	0.74	0.88
Iron oxide and alumina	0.92	0.90
Lime	31.04	30.74
Magnesia	21.03	21.11
Loss on ignition	46.34	46.64

The lime has been sold for years in New York City, Albany, Poughkeepsie and other cities along the line of the New York Central R. R. and enjoys the reputation of being a very high-class building lime. About a year ago, the company decided to build a new plant consisting of both kilns and hydrating equipment and commissioned the writer to prepare plans and specifications for this plant. It was decided also to locate the plant on a part of the property adjacent to the railroad, where the same quality of stone as at the old plant is found and to extend a siding from the railroad to the plant. At the new site, the stone lies to the south of the plant in a hill, having quite a considerable elevation, while an ideal location for the mill was found on a level plateau immediately adjacent to the hill and easily reached from the railroad. Work was begun upon the plant last winter and completed in the late summer.

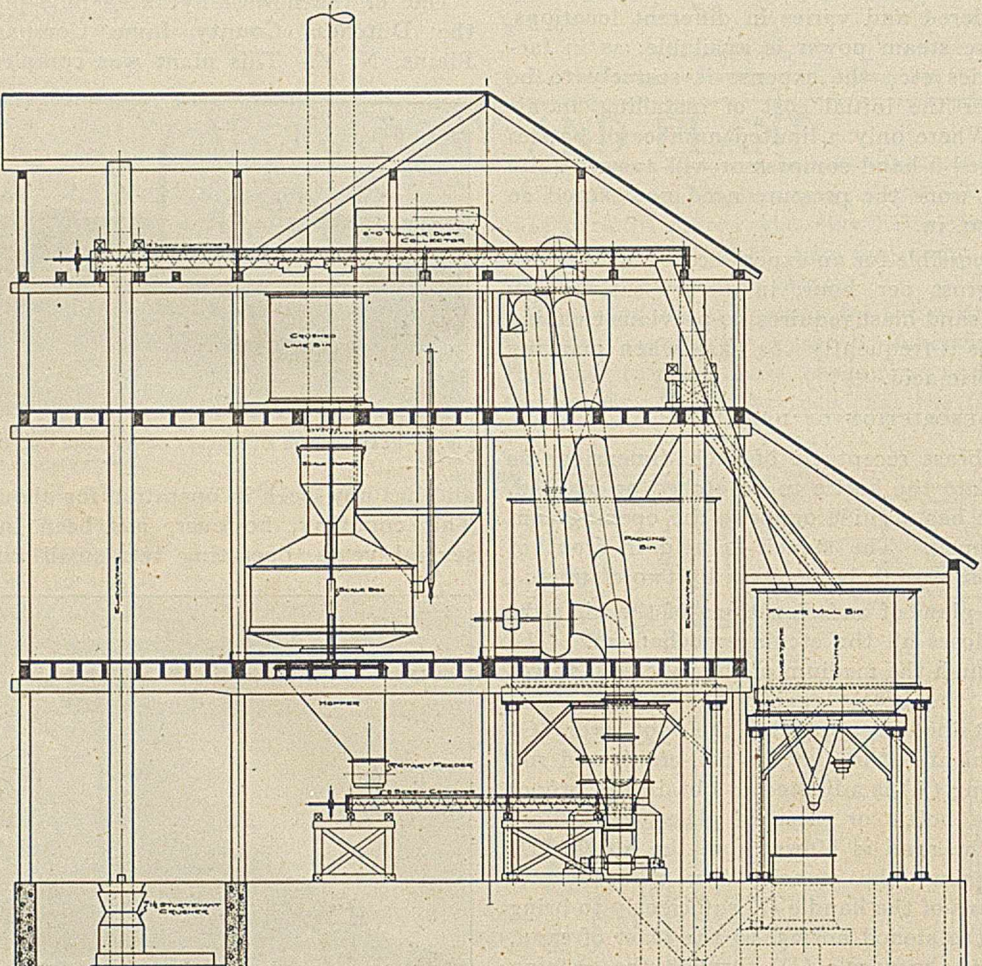


FIG. 3—SIDE ELEVATION, HYDRATING PLANT, DUTCHESS COUNTY LIME CO.

The general layout of the plant is shown in Fig. 1. The kilns are located at the end nearest the quarry; next comes the cooperage and barrelling department, then the boiler room and the hydrating plant in the order named and finally a storage for hydrated lime, which latter is not yet completed.

The kiln building is designed to receive five kilns, two of which are already in place. These kilns are of the general type found throughout Maryland and Southern Pennsylvania (Fig. 2). They have been modified, however, so as to obtain both increased output and economy over the latter. The kilns are equipped with two fire boxes, one on each side and a cooling cone below. They also have a storage for stone in the upper part of the kiln. The capacity of the kilns on the stone found at Dover Plains will average about 12 tons per day. The fuel ratio is about 1 of coal to 4 of lime.

Arrangements have been made to install a belt conveyor to carry the lime from the kilns to the hydrating plant but at the present time the lime will be wheeled from one to the other.

On entering the hydrating plant, the lime is first passed through a Sturtevant open-door crusher (see Figs. 3 and 4). This reduces the lime to such a size that it will all pass through a one-half inch screen, which is fine enough for hydrating purposes. From the crusher the lime is elevated to the third and top floor of the building into a large steel bin which holds about 20 tons of lime and is provided at the bottom with a spout and gate, the latter being opened and closed by a lever. Below the spout is located the weighing hopper and beneath this, the Clyde hydrator (Fig. 5), which rests on the second floor: the scale box and indicator to the water tank are also on this floor, so that all the operations of the hydrator are controlled at one point. The lime is weighed out in batches of 200 lbs. and dumped directly from the scale hopper into the hydrator. The water is measured in a tank beside the lime bin and is sprayed on the lime after the latter is introduced into the hydrator. The process of hydration lasts about 20 minutes, although it is probable that when the plant is pushed for capacity this time can be shortened to 15 minutes, as this lime hydrates very rapidly—particularly so for a magnesian lime.

After passing through the hydrator, the lime is dumped into a large steel bin or hopper, capable of holding comfortably the charge from the hydrator, and provided at the bottom with an automatic feeder which serves to regulate the supply of lime going from the hydrator to the pulverizer and is so adjusted as to empty the hopper before the new charge from the hydrator is ready to be dumped. The lime falls from the feeder into a screw conveyor which carries it to the pulverizer.

For treatment of the lime after passing through the hydrator, the Raymond system is used. The lime first goes to a No. 1 automatic Raymond pulverizer (Fig. 6), located on the ground floor; this mill is equipped with a throwout which separates from the hydrate any large pieces of core or unhydrated lime left in the product of the hydrator. From the pulverizer the fine product is sucked up by means of a No. 11 fan, and blown into a 7 ft. dust collector located above the packing bin, as shown in Fig. 3.

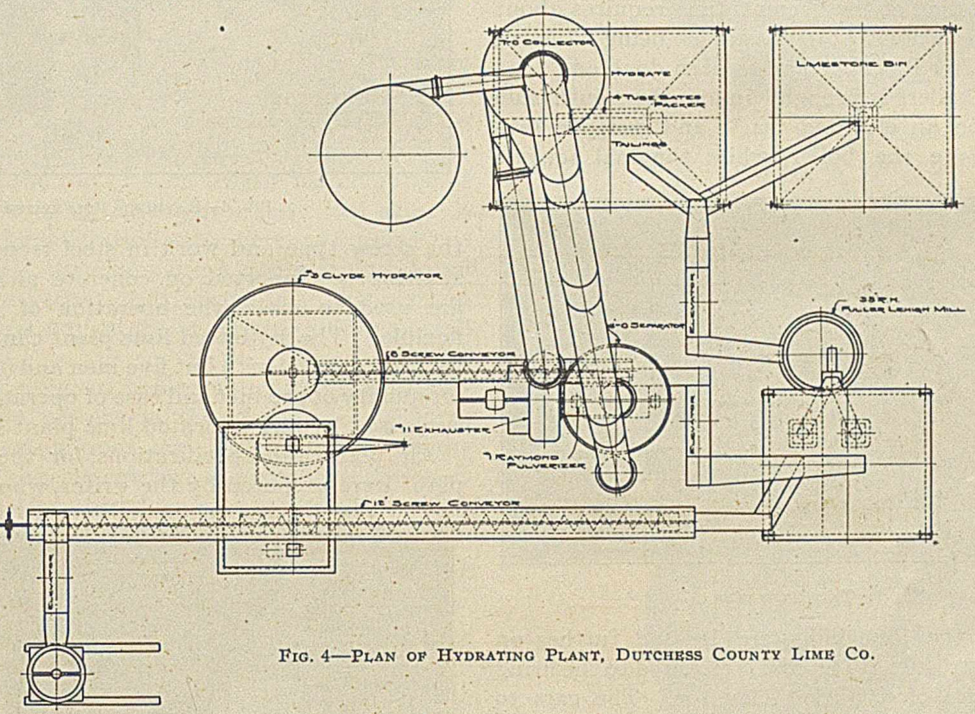


Fig. 4—Plan of Hydrating Plant, Dutchess County Lime Co.

It will be noticed that for the hydrating part of this plant only one elevator is used, namely that for carrying the lime from the crusher to the lime bin. This is a feature of all the plants which the writer has designed, thus greatly simplifying the installation.

In connection with the cyclone dust collector there is also a tubular collector with 18 ft. tubes. This is designed to catch the dust in the exhaust from the Raymond system. The product obtained from this is so fine that all of it will pass a 100 mesh screen, and on account of this extreme fineness, it is suitable for the manufacture of grease and for other uses where a superfine hydrate free from grit is necessary.

Space has been left in the building, and all arrangements made for adding another hydrator and separating system whenever it is desired to double the capacity of the plant, which has been designed with this end in view.

From the dust collector, the hydrate, as we have said, falls into a bin above the packing machine. This latter is of steel plate supported on steel columns and holds 40 tons of hydrate. A novelty in its construction is a partition dividing it into two parts. By an arrangement of slides, hydrate may be packed from either side with the same packing machine. This feature is designed to allow two grades of hydrate to be manufactured at once, the uniform product being obtained from the Fuller mill as explained further on. The packing is done by the Bates packer and Bates valve bags are used (Fig. 7). This packer is now being equipped with a dust catching system which will remove practically all of the dust and will make the plant almost dustless. This system consists of a suction fan connected with a pipe running along behind the packing machine. Branches with openings extend to the tubes of the machine and the spill from the tubes is sucked away through the pipe. The dust is discharged into the dust collector of the Raymond system.

A feature of this plant is the equipment for pulverizing limestone. For this purpose a 36 in. Fuller mill is employed and with it almost any fineness desired can be obtained. Where the limestone is desired for agricultural purposes the mill is provided with a $^1/_4$ inch mesh woven wire screen. This gives a product sufficiently fine for farm requirements. At this fineness the mill will grind about 5 tons of the Dover Plains dolomite per hour. The limestone to be pulverized is passed through the same crusher used for the lime, goes up the same elevator and into a screw conveyor which carries it to a bin over the Fuller mill. As the capacity of the crusher is 8 to 10 tons per hour, this is amply large enough to take care of both the hydrator and the pulverized limestone department by hydrating first on lime and then on stone. The discharge from the Fuller mill is taken up by an elevator to another bin and it may be packed from this into bags by hand or it can be spouted directly from the discharge of this elevator into the cars.

There is also an elevator leading from the throwout of the Raymond mill. This takes the tailings from the latter up to the bin above the Fuller mill (which latter bin has a special compartment for these tailings) where they can be mixed with limestone and ground for agricultural purposes or they can be mixed with fresh hydrate ground and elevated into one of the compartments of the hydrate packing bin. The idea of this latter arrangement is to allow the making of a very fine hydrate by adjusting the Raymond mill to reject all but the finest hydrate. The coarse material so rejected is then ground in the Fuller mill and sold as second-grade or mason's hydrate. The two compartments in the packing bin are to allow the two grades of hydrate to be manufactured simultaneously.

Figs. 3 and 4 show the general arrangement of the hydrating plant.

Power for driving the plant is obtained from an Atlas-Corliss engine which can develop about 135 H. P. Steam for this is supplied from two water tube boilers which have a rated capacity of about 60 H. P. each. The machinery installed at the present time requires about 75 H. P., the additional power available being intended for the plant after its capacity has been doubled.

Coal for the boilers is brought in on the south side of the plant on an elevated track and dumped into a pocket opposite the boiler, while the coal pockets for supplying the lime kilns are located further on along the same trestle. The coal is elevated to the firing floor by the use of a bucket elevator. The cars to be loaded are brought in on the north side of the plant and the platform from the bagging machine is on a level with the car floor.

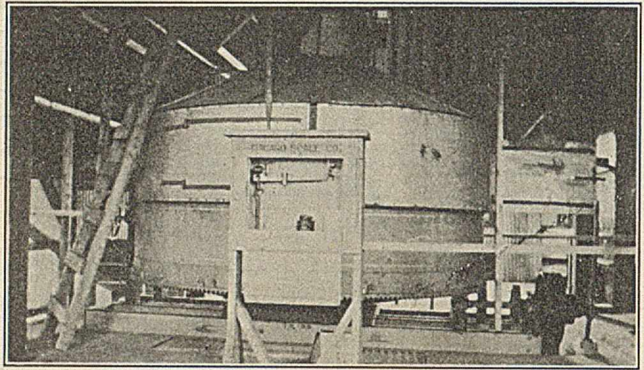


Fig. 5—The Hydrator

The kiln building is 60 ft. x 53 ft. and is of steel covered with corrugated iron. The firing floor is of concrete and steel and all of the ground floors throughout the buildings are concrete. The hydrator building is 60 ft. x 53 ft., of frame covered with galvanized iron and the construction throughout is of heavy mill-type. At the present time, a storehouse 53 ft. x 100 ft. is being built. This is of light steel construction and will be covered with galvanized iron. This storehouse is designed to hold hydrated lime in bags. It is the intention, however, very shortly to put in a steel tank storage in which the hydrate will be stored in bulk as manufactured and then conveyed back to the plant for packing, as desired for shipment.

The bins are all of steel and with the exception of the crushed lime bin are all supported on latticed columns. All the elevators are encased in steel and are of the chain bucket type. The conveyors are of the screw type and work in steel troughs. The main shafting is supported on concrete piers, and clutches are used to make the operation of the plant more flexible. The hydrated lime plant can be operated at its full capacity with but five men and it is believed that for quality of product and ease of operation it will not be surpassed by any hydrated lime plant in the country.

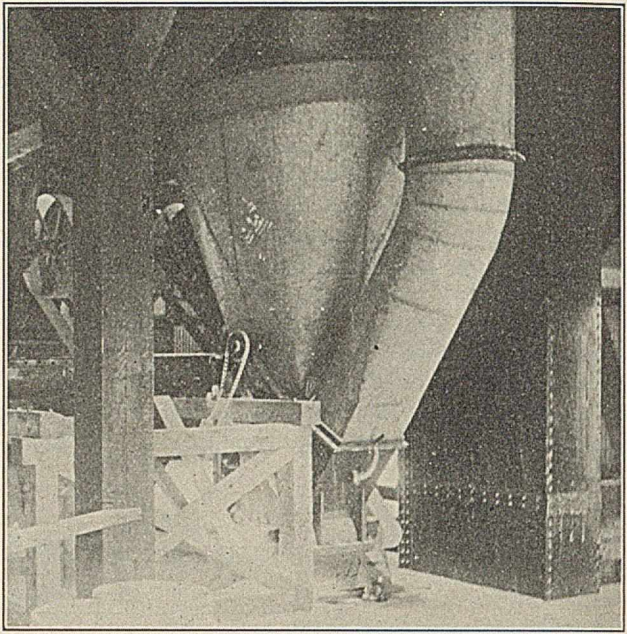


Fig. 6—Raymond Pulverizer

All plans and specifications for the hydrated lime plant were prepared by the writer, who also drew plans for the general arrangement of the entire plant, selected the mill site, prospected the store deposits, etc. The construction work was in charge of Mr. Ambrose Allen, superintendent of the plant.

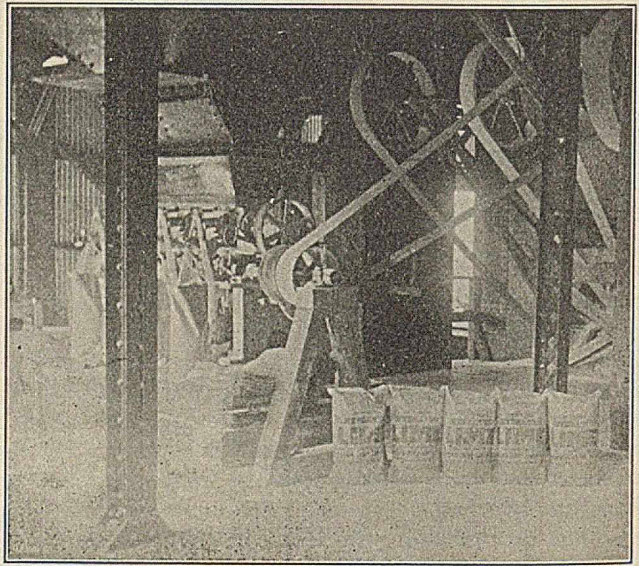


Fig. 7—Bates Valve Bag Packing Machine

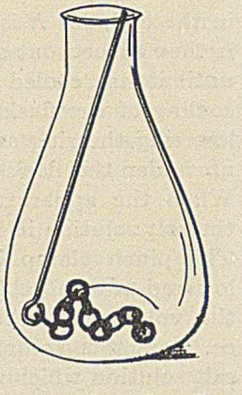
202 North Calvert Street
Baltimore, Md.

A NEW TYPE OF APPARATUS FOR THE REDUCTION OF IRON SOLUTIONS BY METALLIC ALUMINUM

By C. L. Schumann

Received January 12, 1915

The use of aluminum in the form of a sheet for the reduction of iron from the ferric to ferrous state was first recommended by W. H. Seamon.[1] Aluminum wire in the form of a spiral in a large test tube was worked out independently about the same time at the University of Michigan by Professor E. D. Campbell. Since that time the method has been widely used on account of its convenience and accuracy. A modification has been proposed with the view of eliminating the error resulting from the oxidation of the iron during the transfer from the reduction tube to the titrating flask.



The writer has found a very convenient form in an aluminum chain made from heavy aluminum wire attached to a glass rod of such length that it projects up into the neck of an Erlenmeyer flask (see sketch). The reduction and titration may be thus carried out in the same flask, the chain being easily removed and washed after the reduction is complete. This method has the additional advantage of requiring only a small depth of liquid.

The chain is weighed before and after use to correct for the iron present in the aluminum. A large number of determinations may be in progress at the same time, for experiment has shown that differences in time of reduction introduce no appreciable error.

University of Michigan, Ann Arbor

THE USE OF LIGHT FILTERS WITH THE TASSIN METALLOGRAPHIC APPARATUS

By Frederick H. Getman

Received January 23, 1915

In the course of certain investigations now in progress in this laboratory it became necessary to employ photomicrographic apparatus for the examination of metallic surfaces. In order to secure satisfactory illumination, the Tassin electric illuminator[2] was used in connection with a Bausch and Lomb microscope and photomicrographic camera. While more or less satisfactory results were obtained with ordinary isochromatic photographic plates it was found to be almost impossible to secure negatives showing much contrast and sharply defined detail.

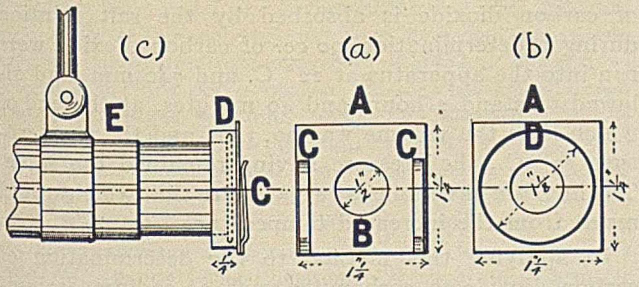


Fig. I

To overcome this defect a very simple accessory to the Tassin apparatus was devised as shown in Fig. I (*a*) and (*b*). Through the center of a sheet of brass, A ($^{1}/_{32}$ in. thick and $1^{1}/_{4}$ in. sq)., a $^{1}/_{2}$ in. hole, B, was bored. To one side of A was soldered a brass ring, D ($1^{1}/_{8}$ in. in diameter and $^{1}/_{4}$ in. deep), the center of the ring being concentric with the hole B. To the opposite side of A were fastened two spring clips, CC, $^{1}/_{8}$ in. wide and $^{7}/_{8}$ in. long. This device was then slipped over the lens in front of the vertical illuminator as shown in Fig. I (*c*), the ring D being split in order to hold A securely in place.

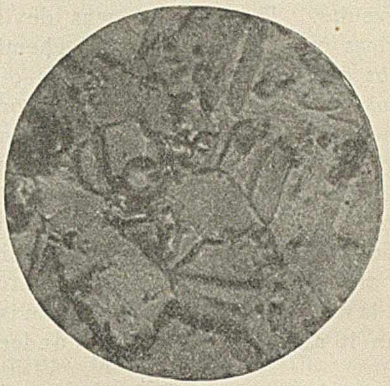


Fig. II—Taken with Ordinary Isochromatic Plate

After focusing on the ground glass screen in the usual manner, a Wratten and Wainwright gelatine light filter of the desired color was slipped under the spring clips CC, and the exposure made with a Wratten and Wainwright panchromatic plate, the time of exposure being determined by means of appropriate factors for each screen. The Wratten and Wainwright A, B and C screens gave a sufficient range of colors for all ordinary purposes, but if it is desired to obtain a record of the true color ratios of a heat-tinted specimen the K_3 screen should be used.

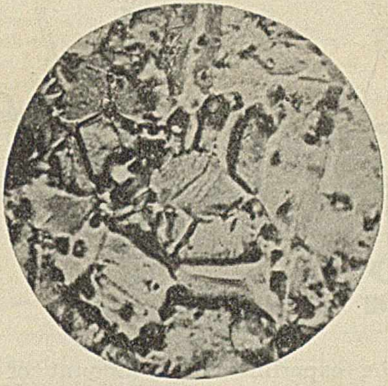


Fig. III—Taken with W. and W. Panchromatic Plate and B Filter

The accompanying photomicrographs (Figs. II and III) of a polished brass surface, etched with nitric acid, and magnified 200 times, may be taken as typical of the results obtained when the Wratten and Wainwright filters and plates are used in conjunction with the Tassin apparatus.

Chemical Laboratory, Bryn Mawr College
Bryn Mawr, Pa.

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[1] *West. Chem. Met.*, **4**, 105.

[2] Tassin, This Journal, **6** (1914), 95.

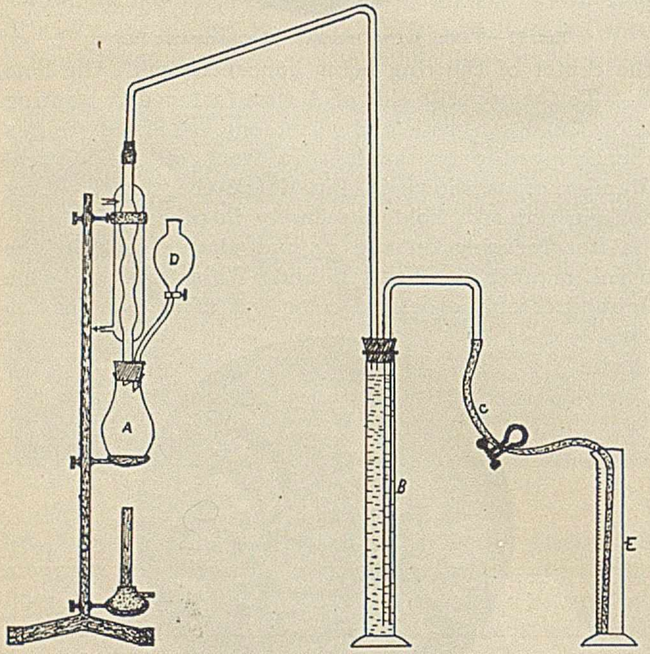
A METHOD FOR THE DETERMINATION OF CARBON DIOXIDE IN BAKING POWDER AND CARBONATES

By H. W. Brubaker

Received December 7, 1914

The following is the result of an attempt to devise a method for the determination of the available carbon dioxide in baking powders, which is simple in principle, requires an apparatus easy to construct, and manipulate, consumes little time and gives reasonably accurate results. The method was devised for the use of a class of girls in household chemistry. It is adapted not only to the determination of carbon dioxide in baking powder but also in carbonates, bicarbonates and minerals such as limestone and dolomite.

The principle of the method, in brief, is the liberation of the carbon dioxide, causing it to displace its own volume of a saturated solution of sodium chloride into a graduated cylinder and measurement of the volume of the solution displaced. A saturated solution of salt is used because carbon dioxide is not readily dissolved in it and tests show that under the conditions of the experiment the amount of absorption is so small that it may be neglected. A saturated solution of salt is also used, instead of water, in the decomposition of the baking powder. The principle of collecting carbon dioxide over a saturated solution of sodium chloride is used by Jago in determining the strength of yeast.



PROCEDURE

One gram of the baking powder is placed in the flask *A*. Water is circulated through the condenser for several minutes. The cylinder *B* is nearly full and the delivery tube *C* is full, to the open end, of a saturated solution of salt, the pinch clamp being closed. The stopcock in the funnel *D* is now closed and exactly 25 cc. of a saturated solution of salt placed in the funnel. The pinch clamp on the delivery tube is now opened and the salt solution run in from the funnel by opening the stopcock, care being taken not to admit any air. The carbon dioxide begins to be liberated at once and the salt solution is driven over into the graduated cylinder *E*. The decomposition of the baking powder is completed by heating with the gas burner until the solution has boiled for two or three minutes or until the rise of the salt solution in the cylinder *E* is seen to have stopped. The flame is then turned out and the apparatus allowed to stand until it has cooled to room temperature again. The cooling of the flask *A* can be hastened, if desired, by lowering the ring and bringing a beaker of cold water up under the flask until it is immersed in the water. When the apparatus has reached room temperature the salt solution in *E* and *B* is leveled up by raising *E*. The pinch clamp is then closed; the cylinder *E* is lowered to the table, the delivery tube removed and the volume of salt solution in *E* read. Subtract 25 cc. from this volume to compensate for the 25 cc. of salt solution which were run into the flask *A* to decompose the baking powder. Correct the remaining volume to 0° C. and 760 mm. pressure. As 5.1 cc. of carbon dioxide gas at 0° C. and 760 mm. pressure weigh 0.01 g., which is one per cent of 1.0 g., the per cent of carbon dioxide in the baking powder may be found by dividing the corrected volume by 5.1.

Note: In making the correction for aqueous tension I have used that for pure water which is two or three mm. too high in each case. The effect of the small error thus introduced into the results here recorded is to make them too low.

RESULTS

The purpose of the condenser in the apparatus is to prevent any water from distilling over into the cylinder *B* and thus diluting the salt solution. Table I shows some results obtained with various baking powders:

Table I—Analyses of Baking Powders for CO_2

Sample Baking powder	Vol. CO_2 Cc.	Temp. ° C.	Barometer Mm.	Per cent CO_2
Royal A 1	65.0	20	740	11.30
2	66.0	20	740	11.47
Royal B 1	66.4	21	742	11.43
Calumet A 1	78.3	22	740	13.47
2	77.9	23	740	13.34
Calumet B 1	82.0	29	745	13.69
K. C. 1	65.0	24	745	11.14
2	64.5	25	745	11.02

In order to ascertain whether an appreciable amount of carbon dioxide is absorbed by the salt solution during a determination, 90 cc. of carbon dioxide were run into the apparatus at 22° C. and 740 mm. and allowed to stand 2 hours and 40 minutes, at the end of which time the volume was 90.3 cc. and the temperature 23° C., the pressure having remained the same. The increase in volume is very close to that which would result from the increased temperature.

In applying this method to the determination of carbon dioxide in carbonates such as sodium carbonate and precipitated calcium carbonate the sample was decomposed by means of a dilute solution of hydrochloric acid which was saturated with sodium chloride. The absorption of carbon dioxide by the acid solution is appreciable and must be allowed for.

This is done by decomposing one sample with 10 cc. of the acid solution, then running a second determination, using 15 cc. of acid. The difference in the amounts of carbon dioxide obtained in the two cases being due to the absorption by 5 cc. of acid solution, the proper correction is made on either determination. When decomposing precipitated carbonates with hydrochloric acid no heating is necessary, hence the time consumed in each determination is very short, but two or three minutes being required for the liberation of the carbon dioxide. In running two samples of calcium carbonate in this way, the whole process, including the weighing of the samples, required only ten minutes.

Table II shows some of the results obtained on carbonates. In Determinations 1 and 2 heat was used. In Determination 3 no heat was used. The sample of sodium carbonate used in determinations 4 and 5 was found to contain 4.46 per cent of moisture. The theoretical amount of carbon dioxide in this sample is therefore 39.65 per cent. Some of this sodium carbonate was now dried and Determination 6 made upon the dry sample with the result shown. Allowing for the same absorption as in Determination 5, which is 2.97 cc., gives a total volume of 121.17 cc. under the above conditions of temperature and pressure which correspond to 41.38 per cent of carbon dioxide.

TABLE II—ANALYSIS OF CARBONATES FOR CO_2

Detn. No.	Sample	Wt. taken Gr.	Decomposed by cc. acid	Vol. CO_2 Cc.	Temp. ° C.	Bar. mm.	PER CENT CO_2 Found	PER CENT CO_2 Theoretical
1	$CaCO_3$	1/4	5	62.5	23	737	43.98	44.00
		1/4	10	61.0	25	737		
2	$CaCO_3$	1/4	3	64.0	24	739	43.88	44.00
		1/4	8	63.5	25	739		
3	$CaCO_3$	1/2	8	127.0	25	735	43.98	44.00
		1/2	13	124.65	25	735		
4	Na_2CO_3	1/2	7	116.0	25	734	39.95	39.65
		1/2	12	113.88	25	734		
5	Na_2CO_3	1/2	7	116.0	25	734	39.95	39.65
		1/2	12	113.88	25	734		
6	Dry Na_2CO_3	1/2	7	118.2	24	742	41.38	41.50
7	Limestone	1/2	10	111.5	25	744	38.18	38.45(*a*)
		1/2	15	113.5	28.3	742		

(*a*) By difference; see text.

Determination 7 was made on a sample of limestone. It was necessary to use heat to completely decompose the sample with the acid solution. I had no gravimetric determination of carbon dioxide in this limestone against which to check the result. However, according to the figures of another analyst, the limestone contains 12.28 per cent SiO_2, 1.15 per cent $Al_2O_3 + Fe_2O_3$, 46.74 per cent CaO and 1.38 per cent MgO, making a total of 61.55 per cent, which leaves for carbon dioxide 38.45 per cent. This makes no allowance for potassium and sodium which may be present in very small quantities. The result is undoubtedly a close approximation to the actual percentage of CO_2 present.

NOTE (Jan. 11, 1915): Since sending this paper for publication I have found a convenient way of obviating the necessity of making a correction for the absorption of carbon dioxide in those cases where the sample is decomposed by dilute acids. This makes it unnecessary therefore, to decompose more than one sample of the substance for one determination. The procedure is as follows: Just before making the determination pour 30 or 40 cc. of dilute hydrochloric acid (1 acid : 3 water) on 0.5 g. of precipitated calcium carbonate. When the effervescence has ceased, and the acid solution has become clear, pipette 10 cc. of this into the bulb of the separatory funnel and proceed with the determination. This method of saturating the acid with carbon dioxide requires but a moment and makes it unnecessary to correct for any absorption whether the sample is decomposed by heating or at room temperature. The following determination will illustrate the accuracy of this method of procedure:

Wt. of limestone taken	0.5 g.
Volume of salt solution displaced	138.18 cc.
Temperature, 22° C. Barometer	739 mm.
Volume corrected to 0° C. and 760 mm	112.3 cc.
Per cent CO_2 found	44.03
Theoretical per cent CO_2	44.00

DEPARTMENT OF CHEMISTRY
KANSAS STATE AGRICULTURAL COLLEGE
MANHATTAN

ADDRESSES

THE FIXATION OF ATMOSPHERIC NITROGEN[1]

By W. S. LANDIS

It is now some three years since I have occupied this side of the lecture table, and I can assure you this is a most delightful occasion to me, not only because I can here omit the tedious routine of taking an attendance record of my class, but also because it is my first opportunity to tell the chemical and engineering professions something about the interesting work I have been engaged in since giving up university teaching.

I am going to assume that you are all more or less familiar with the use of nitrogen in one or more of its various combinations, for to catalogue even a partial list of the most common commercial nitrogen compounds would read like a few pages out of Mr. Olsen's "Chemical Annual," or from the "Chemiker Kalender." I am not even going to bore you with statistics of consumption of the nitrogen compounds, because the very complex nature of these statistics would make them difficult of comprehension if merely read from prepared tables, and I believe our time can be better occupied along other more interesting lines intimately connected with our subject. I shall add only that in tonnage alone the nitrogen compounds stand well at the head of the list of the world's trade in heavy chemicals, nitrate of soda and sulfate of ammonia being produced in 1913 to the value of $200,000,000.

Not including atmospheric nitrogen, whose utilization is yet in its infancy, we are practically dependent for our supply of this valuable element upon the nitrate deposits of Chile, and its recovery as a by-product from our fuels. The Chilean deposits have been so frequently and fully described elsewhere that we can omit reference to the same here. The end of this source of supply is, however, in sight, and it will be only a few years until Chilean nitrate will pass into history along with our anthracite coal and the Saxon silver-lead ores.

The recovery of ammonia as a by-product from fuel is entirely different, since for many centuries to come, we shall have an ever-increasing source of this element in the coke oven and the gas producer, from which it is obtained in one of its most valuable forms of combination, ammonia. This source

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[1] Presented before the Washington Section of the A. C. S. on March 17, 1915, and before the Philadelphia Section of the A. C. S., March 18, 1915.

supply is, however, somewhat unsatisfactory, inasmuch as it is wholly a by-product of the coal distillation industry, a ton of coal yielding only 5 to 6 pounds of ammonia, and by-products as a source of primary supply have many limitations. This is well illustrated by the present status in Germany, from which country I have lately returned. There is in that country just now a considerable shortage of nitrogenous fertilizer because the Government has confiscated all stores of nitrate for military purposes (the fertilizer industry there consumes about 800,000 tons of nitrate per year). The coke ovens which we should expect would normally come to the rescue in such a crisis are, however, largely closed down because industrial Germany is at a standstill, and no one wants coke. Ammonium sulfate production is, therefore, correspondingly decreased just at a time when agriculture needs it most, and its lack is felt acutely. Since my return I have learned that the use of coal has been prohibited in Germany in order to force the use of coke, and thus increase the supply of ammonia and tar.

We come very near having the same conditions arising in this country, for were the farmer in position to take his normal fertilizer requirements there would be a great sulfate shortage, as our own industrial depression has closed down many of our coke ovens, and we would have no ready means of meeting even a normal demand for sulfate. We thus see the disadvantage of a by-product source of such an important element as nitrogen, and why inventors have been so actively engaged in finding a substitute for the Chilean nitrate and the coke-oven ammonia.

Naturally the inexhaustible store of atmospheric nitrogen has presented itself most prominently in this search for a new source, and it is upon the activities of the inventors in that field that I wish particularly to speak tonight.

Neglecting the many proposals which have merely wasted much paper and ink in describing impossible methods for the fixation of our atmospheric nitrogen, I shall devote my attention solely to the successful, and at the present time commercially developed efforts in this field. We can classify these successful attempts into three groups:

I—Direct synthesis of nitrogen and hydrogen to ammonia.
II—Combustion of nitrogen and oxygen in the electric arc.
III—Combination of nitrogen with metals or carbides.

The only commercial process today belonging to Group I is the so-called Haber Process. Dr. Bernthsen described this process at the Eighth International Congress of Applied Chemistry,[1] and exhibited a small working model of the apparatus. I am sorry that I can add but little to the technical information he there presented, but the owners of this process have maintained the greatest secrecy with respect to its commercial development, and but little is known regarding the details in the commercial world.

As you will recall, this process consists in passing a mixture of three volumes of hydrogen and one volume of nitrogen, at a pressure of upwards of 150 atmospheres, over a suitable catalyzer operating at a temperature of some 500 to 700° C. A single passage of this mixture through the apparatus causes a transformation of 2 to 6 per cent of the nitrogen to ammonia, which is recovered from the apparatus by condensation, and the rest of the uncombined gases are again returned to the cycle.

Too much honor cannot be shown the courageous chemists who have succeeded in placing this process on a commercial working basis. The difficulties seem almost insurmountable. The catalyzer, which has taken various forms and compounds, principally metals and carbides, poisons very readily, and hence extreme care must be taken in the purification of the gases. Purity which the average chemist would classify as C. P. finds no place in this industry, as that would lack almost as much of meeting the requirements of the process as would the use of crude chemicals in the analytical laboratory. It took years of work to find a suitable metallic container for the high pressure gas mixture, because of the permeability of most ordinary materials. However, most of these difficulties have been overcome, and I have been reliably informed that the Badische Plant at Oppan supplied its allotted quota of sulfate to the German Sulfate Sales Company last year, but I greatly doubt that they did it at a profit if it was made from synthetically produced ammonia, with sulfate prices as low as they were in the early part of 1914.

This process, as ordinarily understood, is not supposed to involve the use of any considerable quantity of electric power, which is not quite true, but does require a large amount of highly skilled labor, for the units are small and complicated. This particularly suits it to the Rhine location, but renders its value in the United States rather questionable. I personally cannot see a future for its operation under American conditions, particularly in view of the competition of the much cheaper Cyanamid process which furnishes the same end product—ammonia.

FIG. I—GENERAL VIEW OF FACTORIES, AMERICAN CYANAMID COMPANY

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[1] THIS JOURNAL, 4 (1912), 760.

At Oppan the Badische must dispose of large quantities of waste sulfuric acid and have at their disposal by-product hydrogen; hence local conditions favor this process above all others.

The second group of processes embraces those oxidizing the nitrogen of the atmosphere in the electric arc. It is well known that when air is heated to temperatures of above 1800° C. and rapidly cooled, the nitrogen oxidizes to NO and remains in that form. At this temperature, however, the reaction velocity is very low and commercial working requires that temperatures of above 3000° C. be used, at which temperature the reaction velocity becomes quite considerable.

Three types of apparatus are in commercial use for performing this reaction:

1—The drum furnace with disc arc—Birkeland-Eyde.

2—The long tube furnace with spiral arc—Schonherr.

3—The narrow furnace with fan-shaped arc—Pauling.

There are numerous other proposed types of apparatus which are claimed to be far superior to the above, as reference to patent literature in particular will show, but the above listed three furnaces are the only ones in actual every-day operation.

The products obtained by passing air through the arc of any of these furnaces consists of a highly heated gas containing from 1 to 2 volume per cent of nitric oxide. On cooling down to temperatures of approximately 600° C. this nitric oxide unites with free oxygen to form nitrogen peroxide, NO_2; on further cooling of this nitrogen peroxide to below 140° C. it polymerizes to N_2O_4. When brought into contact with water and oxygen, this reacts, forming a mixture of equal molecular parts of nitric and nitrous acids. By subjecting the nitrous acid to further action of the peroxide this is also changed to nitric acid with the liberation of nitric oxide, which again passes through the cycle. Thus by suitable cooling of the nitric oxide in the presence of air and water one ultimately attains a product which consists almost quantitatively of nitric acid, and actual operating results of the large furnace plants have shown a steady recovery of about 90 per cent of the nitrogen oxides in the form of nitric acid or nitrate salts, the remainder being received as nitrite or not absorbed.

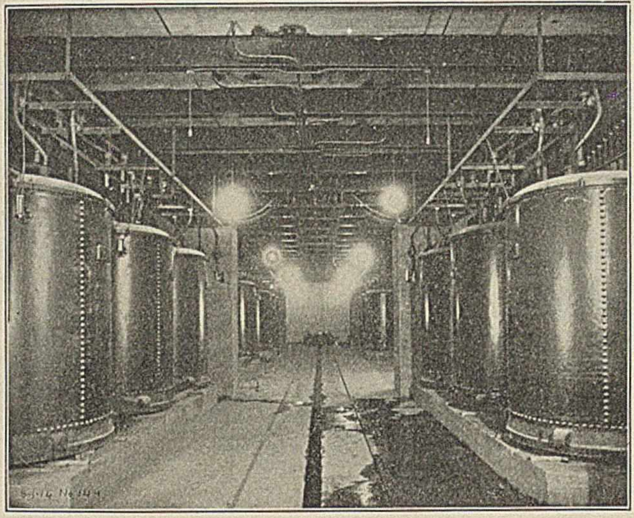


Fig. II—One of the Transformer Rooms

In general, the handling of the nitrose gases from the arc furnaces is now well standardized, and the design of a condensation plant is almost as well understood today as that of a sulfuric acid plant. After passing the various systems of cooling apparatus, consisting of steam boilers, evaporators, etc., the gases enter aluminum condensers where the temperature is reduced to approximately 100° C. They then enter a preliminary oxidation chamber so proportioned that they remain at least 1$^1/_2$ minutes, and the preliminary oxidation to peroxide takes place. The gases next pass into a series of four or five stoneware or granite towers where they are washed with water by a counter current system, remaining in the tower system for from 3 to 5 minutes. Of the nitrogen oxidized, 90 per cent is here condensed as nitric acid, the most concentrated acid being obtained in the first tower, and averaging from 30 to 35 per cent HNO_3. After passing these condensing towers the gases usually enter a final tower fed with caustic soda liquor, where a further 3 to 5 per cent of the oxidized nitrogen is recovered as sodium nitrite. The remaining 5 per cent passes out into the air unabsorbed.

As above mentioned, these towers deliver a 30 to 35 per cent nitric acid; this can be further concentrated to 50 per cent nitric acid, using the heat of the hot gases issuing from the arc furnace to perform the necessary evaporation. It is not possible to carry this evaporation much above 50 per cent for economical reasons, and where higher concentration of nitric acid is demanded special complicated concentration processes must be employed.

Dilute nitric acid, as obtained from the towers, finds little use in industrial processes, and it is difficult to transport. Most of the nitric acid plants, therefore, either concentrate it to 96 per cent acid by special means, or convert it into calcium nitrate for fertilizer use, or into ammonium nitrate for explosive purposes. In the latter case most of the ammonia used today in the nitric acid plants, operating on the arc system, is obtained from Cyanamid. It is quite probable that calcium nitrate will soon disappear from the fertilizer market, as it certainly cannot be sold at a profit in competition with Chilean nitrate or ammonium sulfate, even when the latter is made from Cyanamid.

As we shall see later, these arc processes require enormous quantities of cheap electric energy, and must be located near such power centers. We have no cheap power in the United States, and there is no immediate prospect of our having an arc process in continuous large scale operation within our borders. Our Western powers are far from markets and transportation of the nitric acid as such to the East is almost out of the question.

I should like to dwell more at length upon the details of recovery of 95 per cent of the available products from the gas issuing from the arc furnace, which contains at its maximum concentration only 2 volume per cent of the same. But my time is rapidly passing and I want to give you at least a glimpse of the third group of the nitrogen fixation processes, the one in which I myself am most actively connected.

This third group of processes embraces fixing nitrogen by metals or carbides, and has reached its highest development in the Cyanamid process, which last year produced throughout the world, in the fourteen factories at present in operation, some 300,000 tons of material, carrying over 20 per cent nitrogen.

The inventors of the Cyanamid process originally attempted the synthesis of cyanides by subjecting barium carbide to the action of nitrogen, which, as is well known, forms barium cyanide. On attempting to use the cheaper calcium carbide in place of barium carbide, Professors Frank and Caro found that instead of obtaining a cyanide they obtained a new material, which proved to be calcium cyanamide. It was found later that this material could be utilized directly in agriculture, and from this discovery has grown the enormous Cyanamid industry which has proven itself to be the cheapest method of fixing atmospheric nitrogen at present in existence.

Reference to the literature existing upon the manufacture of Cyanamid seems to lead one to suppose that it is a comparatively simple matter to carry out the reaction so frequently written:

$$CaC_2 + N_2 = CaCN_2 + C.$$

This might be true to a limited extent were this the only reaction that we chemists at Niagara have to contend with, but I can merely say to you that even this reaction itself is so complicated that while it is well known that it is a reversible one, no one has yet succeeded in correctly establishing its equilibrium constants. A laboratory study of this reaction has been carried out in this country by Professor Thompson, and abroad by Professor Haber, but neither of them has succeeded in mastering it, because of the peculiar difficulties that arise in a study of it.

Naturally, if the highly skilled chemical laboratories met with these difficulties, we can assume that practice runs against a few of them itself. But aside from the fundamental absorption reaction, as written above, there are a number of other complications that arise in this industry which we have to meet with in our every-day work, and which I shall call to your attention to show that the actual carrying out of the Cyanamid process requires something more than writing the reaction on a piece of paper.

The fertilizer industry, into which most of our material at present goes, is a rather peculiar one, and probably has more peculiar fads and precedents than almost any other highly developed industry in the country. Naturally, to sell them material one must take into account all of the peculiarities of the industry, and must satisfy them, a fact which further complicates the Cyanamid industry itself. As there may be fertilizer men present here tonight in the audience, I am not going to expose them to the engineering profession, but will dismiss mention of these peculiarities, and you can assume that inasmuch as Cyanamid is being produced and sold at the rate previously mentioned we have succeeded somewhat in meeting their fancies.

The first stage of the Cyanamid process involves the production of calcium carbide. To produce day after day a high-grade calcium carbide that meets the peculiar requirements of the cyanamid industry is quite an art in itself. There are no journeymen carbide workmen in our country, and we had to start out and develop our own furnaces and methods of operation. We had to seek sources of raw materials for this manufacture, which are quite different even from those which meet the requirements of the manufacture of lighting carbide, and we have to operate our furnaces in a certain peculiar way in order to combine these raw materials into a product of such structure and grade that we can make Cyanamid out of it successfully. You will recall that Moissan in his early work found that he could not nitrify certain kinds of carbide, showing that there are conditions existing in our carbide manufacture that are different from those in the manufacturing of lighting carbide.

Our next great problem is to grind this special grade of calcium carbide so that it passes a hundred mesh screen. Naturally this must be done without slaking the carbide, as hydrated lime does not make good Cyanamid. Now 100 mesh carbide dust, when exposed to the atmosphere on a damp day or thrown out on damp ground, is almost as explosive as low-grade dynamite, so that it is quite a problem to grind this carbide to the required degree of fineness and have a mill left at the end of the day's run.

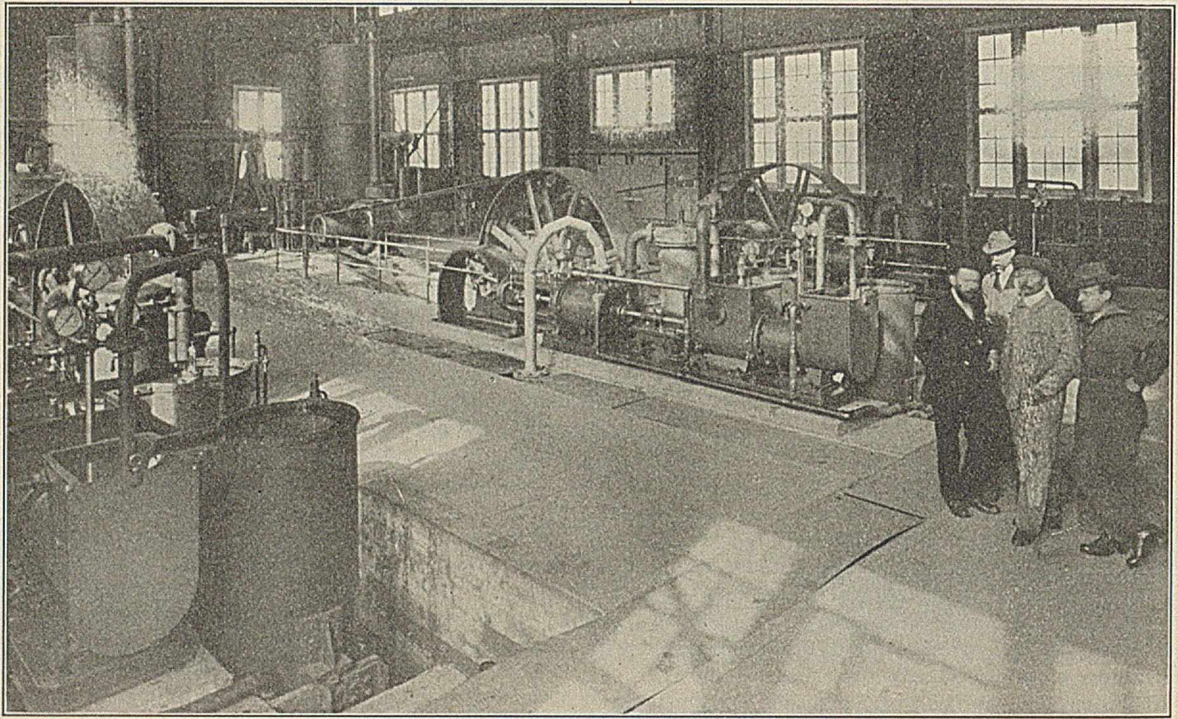


FIG. III—PART VIEW OF LIQUID AIR PLANT, AMERICAN CYANAMID COMPANY

Next comes the production of nitrogen. It is a comparatively simple matter for the chemist to make a few cubic centimeters of high-grade nitrogen in his laboratory, but if one were to call upon him for 2,000,000 cu. ft. of a practically pure nitrogen per day, such as we make at Niagara, he would probably have to do considerable research to find out just how this enormous quantity of such high-grade material could be made. In the early days of the Cyanamid process, when the Niagara plant started, liquid air machinery was in a rather backward state of development, and we were forced to make our nitrogen by passing air over copper. The original plant was later enlarged, and I am sorry that my pictures do not include it. It was a long step from the combustion tube of the chemical laboratory to our present plant, using retorts containing 5 tons of copper mass, but the problem has been successfully solved, and the new plant has been in operation with a minimum of trouble for some years. In the early days of the industry at Niagara we could draw upon natural gas for reducing our copper oxide, so as to re-vivify it, but this gas supply has since failed and we were forced to put up our own coal gas plant, shown in Fig. II. Even this coal gas plant is not a standard one, inasmuch as we are coking coal, not only for the production of gas, but also to furnish the coke for our carbide furnaces. We are running at temperatures in our retorts and obtaining qualities of coke and gas that the average city gas plant would not consider as possible of attainment, and it was only after considerable experiment that we ourselves demonstrated that our theories were correct in this respect and succeeded in finding gas engineers liberal-minded enough to incorporate our ideas into a working plant.

Eventually we had to install purification apparatus for taking out the impurities in the nitrogen, as it came from the copper retorts, and have equipped ourselves with soda towers for removal of carbon dioxide, refrigeration plants for drying, lime tanks for purification, etc., and have even developed this plant so highly that we have included a causticizing plant for recovery of our spent alkali.

After the development of the liquid air machinery, both in the way of capacity and reliability, the problem of producing pure nitrogen was much simplified, and our latest addition at Niagara includes what was probably the largest liquid air plant in the world at the time it was built, a year ago. This plant alone throws to waste almost thirty gallons of liquid air an hour, just to keep the apparatus flushed out and in good working order, not to speak of the thousands of cubic feet of rich oxygen-nitrogen mixture.

After one has overcome the difficulties in the production of a proper grade of nitrogen and of carbide, the next step is exposing these two to mutual reaction at a proper temperature, which is done in small individual ovens, holding from $^1/_2$ to $2^1/_2$ tons of carbide. The reaction itself is reversible, and particular precautions must be taken to keep it always running in the right direction until the carbide has all been nitrified. It would take several evenings to present the complex physical and chemical difficulties met in this phase of our work. The product removed from these ovens is a black, hard cake, which analyzes 22 per cent nitrogen and about 1 per cent un-nitrified carbide. This material, which we call Lime Nitrogen, is next finely ground and stored in silos. The carbon set free in the reaction previously indicated is in the form of graphite, and it is not an easy proposition to find a satisfactory mill that will grind this material fine and at the same time not blow itself up from liberated acetylene derived from the presence of any uncombined carbide, or wear itself out grinding the lime nitrogen-graphite mixture. Extreme precautions are taken in this part of our operation, both in the mills themselves and in the elevating and conveying apparatus connected with them to avoid dangerous explosions, and I can truthfully say that in the years I have been connected with the Company not a single injury has resulted from such explosions in our plant.

To prepare the lime nitrogen for agricultural purposes the finely ground material is partly hydrated to insure decomposition of the carbide it contains, and is then oiled to render it dustless, and stored in bulk, or packed immediately into sacks and shipped to the fertilizer mixer.

Calcium cyanamide tends to transform itself into a large number of organic compounds when subjected to the action of water, particularly at temperatures above normal, and, therefore, this hydration has proven an extremely complex problem, because we desire to avoid any such transformation, as agricultural experiments have shown that the calcium cyanamide in its unaltered form yields the best crop results.

But agricultural uses are not the only purposes to which the Cyanamid can be applied, as it is a very simple matter to convert the Cyanamid into ammonia by the exothermic reaction

$$CaCN_2 + 3H_2O = 2NH_3 + CaCO_3.$$

If lime nitrogen is mixed in a slurry with water and subjected to the action of heat and high pressure it is converted quantitatively into ammonia. In this country this use of Cyanamid was not developed on large scale outside our experimental laboratory until the beginning of this year, but while I was in Germany I saw in the yards of a big manufacturing concern some 60 autoclaves, each capable of converting 10 tons of Cyanamid per day into ammonia. This equipment was waiting railroad cars to move it out, and was in no sense experimental, because three similar plants have been in operation in Germany for at least three years. The cost of this transformation is hardly appreciable, and the purity of the product is quite high, requiring merely passing through a self-acting rectifying column for the removal of steam.

The ammonia so produced abroad is at present being converted into a high-grade sulfate and a pure nitrate, and we are at work now in this country on producing a new fertilizer material, "Ammo-Phos," consisting largely of ammonium phosphate; my experimental laboratory is at present working day and night trying to meet initial demands for this new material. Agricultural results during the past season have been so phenomenal that our friends will not await the completion of a large plant for meeting the requirements, but have insisted on our converting our laboratories into a miniature factory.

Our product contains over 13 per cent NH_3 and 45–50 per cent P_2O_5, or over 60 per cent plant food, the bulk of the remainder being chemically combined water, and when mixed with the high-grade potash salts available, will make a complete fertilizer some 6 times as concentrated as the average grade sold today.

It is also possible to transform Cyanamid into urea, and I have made in my experimental laboratory a great deal of pure salt in a comparatively easy and simple manner.

Similarly, Cyanamid can be converted into Dicyandiamid—by simple treatment with hot water. This material has been proposed for use as a deterrent in explosives, but I think it offers a much better field for transformation into the Guanidines.

Such transformations of Cyanamid abroad have received a great deal of attention, and there are numerous derivatives on the market. Just a few months ago I saw a sample of Creatine which had been made in a chemical laboratory from Cyanamid, and we feel that we are not very far from the synthetic production of foods when we can reach such a point in our chemical synthesis.

When a special grade of Cyanamid is melted down with a flux, such as common salt, it combines the free carbon present with the cyanamide radicle, forming cyanide. The resulting product of this fusion contains about 25 per cent of its full weight in equivalent potassium cyanide; this crude form of cyanide dissolves very readily in water and filters rapidly from the insoluble, after which the solution is ready for metal extraction, or other uses to which cyanide in its dissolved form can be put. Large scale experiments have been tried out in a number of the big cyanide plants scattered at various places throughout the world, and in every respect this material has shown an exactly equivalent value to the higher grade cyanides. The transformation of the cyanamide nitrogen into cyanide nitrogen is almost quantitative, and the fusion experiments can be carried out without difficulty and at a low cost. We have here, therefore, a crude form of cyanide which can be prepared very cheaply and which could be readily delivered to the consumer at a price approximately one-third under the present prices of the higher grade cyanide. Abroad this material has been made in large quantities and transformed into the pure cyanide, running approximately 127 per cent potassium cyanide equivalent, but we believe that with proper propaganda work our own cyanide users would find the low-grade material quite acceptable, provided it could be delivered to them at a cost sufficiently low to enable them to perform the extra dissolving and filtering operation which it involves over the use of the present high-grade alkali cyanides.

Cyanamid itself forms an excellent case-hardening material, and we have prepared a number of mixtures which are in steady use at our plant for performing this operation upon various machine parts which we are using. It works extremely rapidly at very low temperatures, but we have not yet succeeded in overcoming certain fads in large scale use of this material, and it has not met with any general introduction. We found that the case hardener is more concerned with the color of his hardening powders than he is with the actual work they perform, and as the colors and odors of our cyanamid products are rather fast we have not found it interesting to us to meet some of these peculiarities of the case-hardening trade. While abroad I saw these case-hardening materials being prepared by the hundreds of tons for use in the manufacture of armament and war materials, and the small factory engaged in their production has been swamped with orders ever since its inception.

The arc processes have shown themselves capable of producing nitric acid or nitrates. Cyanamid itself is an entirely different product, but it is quite easy to produce ammonia from it, and there has recently been evolved abroad a most successful method of oxidizing this ammonia to nitric acid, so that in case of competition with the Birkeland-Eyde process we are not entirely limited to the fixation of nitrogen, but can furnish this nitrogen in exactly the same form that the arc processes can, and at considerably less cost. Our raw materials are cheap—coke, limestone, air. We use only one-fifth the electrical power that the arc processes do per unit of nitrogen fixed in the form of Cyanamid, respectively ammonia, and by the addition of a very small percentage more power we can convert our Cyanamid into nitric acid. We require about the same quantity of labor to fix a unit of nitrogen in Cyanamid as the arc process does in nitric acid, but since there is only a small fraction more labor used to transform Cyanamid nitrogen into nitric acid we do not feel this is a great handicap when one considers our smaller power consumption. On the American continent where water power is so expensive and so scarce this difference readily off-sets the additional labor necessary to make nitric acid from Cyanamid. Further, our Cyanamid is easily transported and can be changed to ammonia or nitric acid at the end of its journey at the expenditure of a very small amount of steam and labor, so that we have the additional advantage in transportability of stable raw material, and subsequent conversion at the point of direct use. These commercial transformation units are small, and can be set up to supply even small amounts of ammonia or acid in a quite cheap and efficient plant. Practically all sulfuric acid plants in Germany have installed them since nitrate disappeared from trade.

There is no comparison between the initial investment required for a Cyanamid plant and for an arc plant, if one includes power development. The Cyanamid plant, per unit of nitrogen fixed, requires an investment of only about one-fourth that required by the arc process, and for a Cyanamid-ammonia plant about one-half that required by the Haber process. Even the combination of the Cyanamid-ammonia-nitric acid process requires an investment of only one-third to one-half that for the arc process. In each case we are assuming exactly the same quantity of fixed nitrogen in the forms above designated. Where electrical power is expensive, as in the United States, there is no question regarding the superiority of the Cyanamid process for the fixing of atmospheric nitrogen, particularly for fertilizer purposes, and we eventually hope that the future development of our nitric acid process will enable us to compete in every line of nitrogen compounds with all other competitive sources.

I have brought with me some moving pictures of our Niagara Plant, showing the arrangement of the whole and some details of the various units comprising it. It is manifestly impossible in a plant such as ours to obtain pictures of every operation, but I have brought the most representative views of the operation of fixing nitrogen. When one considers that we have at Niagara a 12 kiln lime plant, 25,000 H. P. of carbide furnaces, a liquid air plant which was the largest in the world a year ago, a gas plant of sufficient size to serve the average town of 25,000 inhabitants, a nitrogen retort plant, an ammonia refrigeration plant, a causticizing plant, a nitrification plant, a hydration plant, and innumerable crushers, mills, silos and feeding machinery, it is rather difficult to include them all in a few hundred feet of motion picture film.

CURRENT INDUSTRIAL NEWS

By M. L. HAMLIN

RECOVERY OF TOLUENE FROM GAS

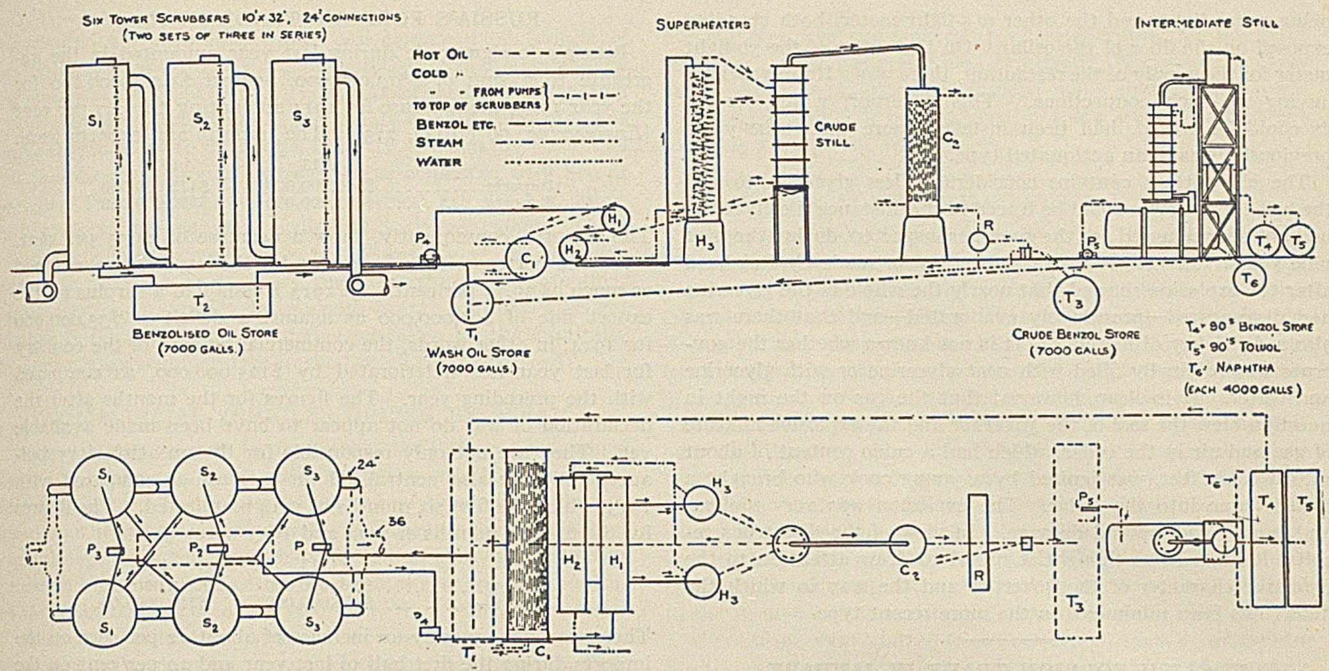
In the course of the proceedings at the conference on coal supplies held in Manchester in February, Mr. Macintosh Williams, who attended on behalf of the War Office Committee on the Supply of High Explosives, referred to the shortage of toluol and to the action taken by the committee with the object of obtaining the necessary quantity to meet requirements. He stated that satisfactory arrangements had been made with the tar distillers; the coke-oven manufacturers were approached, and did what they could. Subsequently an appeal was made to the larger gas undertakings to make arrangements to wash the toluol out of their gas, and, in case of need, replace it with benzol if this was necessary to preserve the illuminating and calorific power. They thought that if the wash oil employed for washing or scrubbing the gas was first pre-benzolized, it would take up only the toluol content of the gas and leave the benzol content to a certain extent intact. Birmingham had made experiments, and found that if the oil was pre-benzolized to the extent of 5 per cent, it was possible to extract nearly 80 per cent of the toluol content, and leave more than two-thirds of the benzol content still in the gas. If this were the case, it would materially assist the Government.

Dr. W. B. Davidson, the engineer-in-charge of the Nechells station of the Birmingham Gas Department, had drawn up a sketch of the plant which he thought might be adopted to effect the object in question. There is from twenty to forty times as much toluene in the gas made from a ton of coal as there is in the tar produced from this bulk of raw material; and probably at least 2 lbs. of pure toluene, making 4 lbs. of trinitrotoluene, can be readily recovered per 10,000 cubic feet of coal gas.

The stream of cooled debenzolized oil coming from the crude still is mixed with a small stream (about 5 per cent by volume) of benzol in tank T_1 and is then pumped at the required rate (about 1300 gallons per hour) by pump P_1 to the top of scrubbers S_3; then by pump P_2 from the bottom of S_3 to the top of S_2; and finally by pump P_3 from the bottom of S_2 to the top of S_1.

The oil now benzolized runs from the bottom of S_1 to the store-tank T_2, whence it is pumped by P_4 in a continuous stream through the heater H_1, where heat interchange takes place between the cold oil and the hot oil leaving the crude still; then through the exhaust steam heater H_2; then through the superheater H_3 (containing a closed high-pressure steam-coil) to the crude still, where it meets a current of high temperature steam, which deprives it of its crude benzol.

The hot debenzolized oil is drawn off and caused to flow first through H_1, and afterwards through a water condenser, C_1, to the store-tank T_1. The crude benzol vapors and steam are condensed in the water condenser C_2. The condensate flows to a receiver, R, whence it passes through a separator, the crude benzol being stored in the tank T_3.



Elevation and Plan of Plant for the Extraction of Toluol from Coal Gas—Capable of Dealing with 800 Tons of Coal or 10,000,000 Cu. Ft. of Gas per Day

A charge of about 1600 gallons of crude benzol is pumped by P_5 daily into the intermediate still where it is distilled by steam with the production of commercial benzol, commercial toluol and residual xylol and heavier oils. The commercial benzol is mixed with the wash oil, together with an additional quantity corresponding to the amount of toluol, etc., permanently removed from the gas. The commercial toluol is redistilled in a second still for the production of pure toluol.

If the wash oil contains much naphthalene, it may be necessary to return the xylol to the gas, to prevent naphthalene stoppages in the district services.

Gas oil will probably prove the most suitable oil for washing purposes, as it is generally ready to hand, contains no naphthalene and readily absorbs crude benzol.

COST OF HYDROGEN GAS

In the course of the report of the British Comptroller and Auditor-General upon the Army Services appropriation account for the year ended March 31st last, which has been issued as a White Paper, it is stated, in connection with expenditure at the Royal Aircraft Factory, that the cost of hydrogen gas showed an increase from $4.60 per 1000 cu. ft. in 1912–13 to $5.25 in 1913–14 [*J. Gas Lighting*, 129 (1915), 442]. The output during the latter year was 2,023,607 cu. ft. as compared with 3,493,296 cu. ft. in 1912–13.

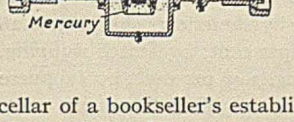
GAS PROGRESS IN TURIN

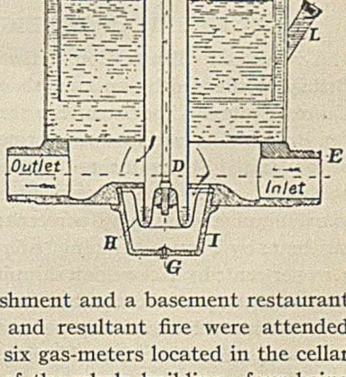
Notwithstanding the cost of coal and the outbreak of war, the Societa Anonima dei Consumatori di Gas-Luce, of Turin, Italy, states in its last annual report that gas affairs in that city are not only satisfactory but progressive. During the twelve months covered by the report, 21,750,465 cubic meters of gas were sold, which was an increase of over 500,000 cubic meters on the sales of the previous year. Gas-meters, likewise, have gone up in number—from 45,000 to 47,000. In spite of keen electricity competition, the board of directors are convinced the future offers splendid prospects—especially in respect of the use of gas for heating purposes.

Early in 1913 the price of coal was $5.75, c. i. f. at Savona. Later it rose to $6.12, while during 1914, it dropped first to $5.40 then to $5.00. The Company was fortunate enough, at the outbreak of war, to have their coal stores well stocked —even considerably above their contractual obligations with the municipality of Turin. All the coke is readily sold; so much so that efforts are being made to use, in the producers, coke dust mixed with tar, and coke dust briquettes made on the gas-works. Old scrubbers have been replaced by modern vertical centrifugal washing apparatus, and old benches of retorts have given place to new.

EXPLOSION FROM A DEFECTIVE GAS SERVICE GOVERNOR

A communication by Mr. Reinhard, manager of the Leipzig Gas Company was published in the *Journal für Gasbeleuchtung* of Jan. 30th, describing an explosion that occurred in a spacious cellar of a bookseller's establishment and a basement restaurant adjoining it. The explosion and resultant fire were attended with loss of life. There were six gas-meters located in the cellar for supplies to various parts of the whole building—four being 50-light meters in an open cupboard, one of the remaining two





being a 200-light, and the other a 5-light meter, both standing exposed on the floor of the cellar. On the outlet of the 50-light meter for the supply of the restaurant, there was a Hahn governor having $1^1/_2$-inch connections. This governor, which, as far as could be traced, had been installed more than nine years previously, was of an antiquated type.

The old pattern contains considerably less glycerine to seal the bell and so far as could be traced in this instance the glycerine had not been renewed nor the governor inspected, during the past nine years. Investigations on this governor made by Reinhard after the explosion showed that nearly the whole of the glycerine had disappeared—presumably evaporated—and that there was also a deficiency of mercury. It is not known whether the governor was originally filled with neat glycerine or with glycerine and water. It is clear, however, that the gas on the night in question blew the seal of the governor and the explosive mixture of gas and air in the cellar, which had a cubic content of about 11,650 cubic feet, was ignited by a young cook who brought a naked flame into the cellar. The explosion was very violent, and caused wide-spread damage. In view of the disastrous results, Reinhard has thought it useful to draw attention to the defective character of the governor and the way in which the defect has been minimized in the more recent type.

ENGLISH FOREIGN TRADE IN JANUARY

The English foreign trade of last January is compared with that of January, 1913, in the following table made from data published in *Z. angew. Chem.*, 28 (1915), III, 83:

IMPORTS	Value	Per cent change compared with Jan., 1913
Wheat	$ 2,160,000	+56.6
Wheat flour	4,710,000	+56.8
Barley	1,270,000	—21.7
Oats	1,300,000	—46.5
Corn	10,110,000	+226.9
Raw cotton	31,500,000	—36.2
Cotton manufactures	2,480,000	—45.3
Flax	1,599,000	—27.7
Raw hides	3,430,000	+81.6
Iron and steel	2,820,000	—52.3
Raw jute	2,620,000	—63.7
Lard	3,050,000	—8.4
Leather	8,590,000	+127.5
Preserved meats	3,330,000	+173.5
Saltpeter	380,000	+26.5
Petroleum	4,310,000	—19.9
Rice	2,080,000	+145.1
Raw sugar	12,000,000	+229.3
Refined sugar	6,800,000	+22.3
Tea	9,300,000	+73.7
Tobacco	3,420,000	—24.1
Raw wool	22,300,000	+7.7
EXPORTS		
Coal and coke	$11,000,000	—39.9
Cotton yarn	3,350,000	—49.7
Cotton cloth	23,950,000	—49
Other cotton manufactures	3,440,000	—48.8
Iron and steel	13,000,000	—45
Jute products	661,000	—51.8
Linen yarn	170,000	—67
Linen cloth	1,999,000	—34.4
Machinery	8,090,000	—50.8
Raw wool	712,000	—94.6
Woolen yarn	405,000	—81.5
Woolen cloth	4,350,000	—47.9

AMERICAN FOREIGN COMMERCE

A remarkable illustration of the maritime supremacy of Great Britain is afforded by an analysis of the foreign commerce of the United States in the American fiscal year 1914. Vessels flying the British flag carried 53.45 per cent of the imports and exports of the United States during that period according to *Engineering*, 99 (1915), 308. The corresponding proportion carried by German shipping was 13.79 per cent; by American shipping, 9.26 per cent; by French shipping, 4.64 per cent; by Dutch shipping, 4.10 per cent; by Norwegian shipping, 3.49 per cent; by Japanese shipping, 2.14 per cent; by Italian shipping, 1.94 per cent; by Austrian shipping, 1.57 per cent; by Belgian shipping, 1.27 per cent; and by all other shipping, 4.35 per cent. The analysis extending in the fiscal year 1914 to American imports and exports represented an aggregate value of $3,785,469,000.

RUSSIA'S FOREIGN TRADE IN 1914

Russia's foreign trade during last year amounted in the aggregate to a sum of $813,000,000, against $1,213,000,000 for the year 1913, the decrease for 1914 amounting to 32.7 per cent [*Engineering*, 99 (1915), 273]. The imports and exports were:

	1913	1914
Imports	$560,000,000	$423,000,000
Exports	$652,000,000	$390,000,000

The imports, consequently, show a decrease of 24.55 per cent, while the corresponding figures under the exports are reduced as much as 39.73 per cent. In 1913 Russia had a surplus on the export side of $92,000,000 as against a deficit of $33,000,000 for 1914; in other words, the commercial balance of the country for last year has deteriorated by $125,000,000, as compared with the preceding year. The figures for the months after the declaration of war do not appear to have been made available yet. They are not only responsible for the unsatisfactory balance, but have also neutralized the increase as compared with 1913, which the first six months of 1914 manifested. The figures for the first six months of 1914 and 1913 were:

	1913	1914
Imports	$259,000,000	$312,000,000
Exports	$260,000,000	$310,000,000

There was consequently an increase of about 22 per cent on the imports during the first half of last year and 20 per cent on the exports, as compared with the corresponding figures for the previous year. The value of the ruble is taken as $0.46. [1 ruble = 51.5 cents according to latest Treasury Department Circular.]

SWEDISH FOREIGN TRADE IN 1914

In 1914 Sweden's foreign trade amounted to 146,300,000 kroner, or 8.7 per cent less than in 1913 [*Z. angew. Chem.*, 28 (1915), III, 106], imports decreasing 77,100,000 kroner, or 9.1 per cent, and exports decreasing 69,200,000 kroner or 8.45 per cent. The decrease in the imports of raw material amounted to 33,200,000 kroner; of the exports, iron showed the greatest falling off. [1 kroner = $0.268.]

THE GRÄNGESBERG IRON-ORE DEPOSITS, SWEDEN

A Swedish expert has recently investigated the Grängesberg iron-ore deposits, and pronounced their content to be much larger than was formerly believed. Only a few years ago the aggregate capacity of these deposits was put at some 60,000,000 tons, and the area within which they were found at 72,800 square meters. Now, however, the quantity, as regards only the phosphoric ore, is reckoned to be three or four times as much [*Engineering*, 99 (1915), 255]. The surveying and examination work undertaken at Grängesberg is the greatest of its kind ever undertaken in Sweden, and it has been going on ever since 1906. The examination has revealed the presence of 180,000,000 tons pure ore, and it is now proposed to extend the boring to 1000 meters. Approximately an aggregate of 250,000,000 tons pure phosphoric ore may be reckoned upon. With the present production of about 840,000 tons annually, the deposits are calculated to last some 200 to 300 years. Further investigations are expected to reveal the presence of additional iron-ore deposits in this mining district.

MANUFACTURE OF EXPLOSIVES IN NATAL

It is reported that Messrs. Kynochs, Ltd., will shortly cause great extensions to be made to their dynamite factory at Umbogintwini. This manufacture will mean a very large consumption of wattle wood.—E. G. ANDERSON.

SCOTCH OIL TRADE

The *Oil and Color Trades Journal*, 47, No. 855, states that not for many years have the Scotch oil companies experienced such a brisk demand or as good prices for all their products as is being experienced at the present time. All classes of oil, sulfate of ammonia, and paraffin wax are being dispatched as soon as they are manufactured, and there are no stocks on hand. The shutting out of German competition in the sulfate of ammonia trade has brought prosperity to the Scotch industry. When the war broke out the price was around $50 per ton as compared with $70 at present. Paraffin wax has also risen about $45 per ton, lubricating oils $5 per ton, and burning oil $0.02 per gallon. These constitute almost record prices in the history of the industry during the past 10 or 15 years, and everything points to their being continued during the current year. Another excellent feature is the large amount of fuel oil taken by the admiralty at a price very remunerative to the Scotch companies.—A.

COMMERCIAL VEHICLES DRIVEN BY STEAM

Some time ago a new form of steam omnibus was sanctioned for use in London, in which solid fuel in the form of ordinary gas coke was used. The results have been so encouraging that no less an authority than Professor Vivian Lewes has predicted that everything points to steam challenging the supremacy of petrol or petrol substitutes for commercial motor traction. According to the *Mechanical World*, 47, No. 1471, the virtue of the steam vehicle using solid fuel is the cheapness in cost of running. Experimental working has shown the cost of fuel, where the stops are not frequent, to work out at 2 cents per 17 ton-miles, which is about half the cost with petrol, even when the latter is purchased in large quantities at 20 cents per gallon.

The uncertainty as to the price of petrol is undoubtedly the cause of many traders holding back from substituting mechanical for animal haulage, and there is some force in the argument that coke, being a home production, is not likely to be affected as to price in the same way as oil.—A.

CHLORINE IN COAL

Mr. A. de Waele in a paper before the English Society of Public Analysts gave particulars of a case of abnormal corrosion of the tube of an economizer, and traced the corrosion to the presence of chlorine in the coal used. The average chlorine content of the coal obtained from the Midland coals of the brine district was 0.22 per cent.—A.

BRITISH-MADE TUNGSTEN

Before the war all the tungsten powder used in the manufacture of high-class steels for shell steel, armor, and cutting tools used in engineering works and armament factories, was imported from Germany, and a serious condition arose when the supplies were cut off. A British firm has now been established to capture the industry, the combine company representing all the great steel firms of Sheffield, and also Armstrong, Whitworth & Company. Such good progress has been made that supplies on a commercial scale will be produced in a few weeks' time at the company's factory at Widnes.—A.

NEW SOUTH WALES STEEL WORKS

With reference to the completion of the Broken Hill Steel Proprietary Company's works at Newcastle, N. S. W., it appears from the Bulletin of January 14th, of the South Australian Official Intelligence Bureau at Adelaide, quoted by the British *Board of Trade Journal*, that the South Australian Government has already accepted a tender from the company for the supply of 2000 tons of 60-lb. steel rails and 140 tons of fish-plates. The rails will be manufactured on the basic open-hearth method, and the Sandberg process applied. The acceptance of the tender means that for the first time in the history of the South Australian Railways, rails of Australian manufacture will be used. In connection with the utilization of some of the large iron-ore deposits in South Australia, it is interesting to note that a shipment of 2800 tons of ironstone was recently dispatched to the Broken Hill Proprietary Company's iron and steel works. The ironstone was obtained from Iron Knob, some 41 miles from Port Augusta, where the largest deposit in that State is situated. This is contained in two great ore bodies known as the Iron Knob and Iron Monarch, the latter being the larger of the two. The ore from the Iron Knob has, during the last 12 years, been used by the Proprietary Company for fluxing purposes at its smelting works at Port Pirie, and its average content of metallic iron has been found to be over 68.5 per cent. The extent of the deposits has not yet been actually determined, but on the assumption that the average depth of ore is no more than 100 ft., it has been calculated that over 21,000,000 tons of ore are available.

SEGER CONES

Seger cones were at one time solely manufactured by the Prussian Government at the Royal Porcelain Works at Charlottenburg, and were imported into Great Britain in considerable quantities for use by pottery manufacturers in standardizing the fire of ovens and kilns. It is reported that Dr. Mellor, principal of the Pottery Section at the North Staffordshire College, has brought to a successful finish experiments directed towards carrying on the manufacture of these cones in England. The governors of the college have authorized the manufacture and the laboratories and are already turning out Seger cones at the rate of 1000 per day.—A.

SCIENTIFIC SOCIETIES

FIFTIETH MEETING AMERICAN CHEMICAL SOCIETY NEW ORLEANS, MARCH 31 TO APRIL 3, 1915

PROGRAM OF PAPERS

GENERAL PUBLIC MEETINGS, APRIL 1

Addresses of Welcome. Mr. Martin Behrman, Mayor of New Orleans, and President Robert Sharp, Tulane University.

Response. Charles Holmes Herty, President of the American Chemical Society. (See *this issue*, p. 371.)

Opening Address. The Industrial Resources and Opportunities of the South. Arthur D. Little. (See *this issue*, p. 373.)

Symposium on the Contributions of the Chemist to American Industries. Division of Industrial Chemists and Chemical Engineers. (See below and also *April issue*, pp. 273–304.)

The Stassfurt Potash Industry. (Slides and Moving Pictures.) H. A. Huston.

Evening Address. The Chemist's Contribution to the Industrial Development of the United States—A Record of Achievement. Bernhard C. Hesse. (See *April issue*, p. 293.)

AGRICULTURAL AND FOOD CHEMISTRY DIVISION

Floyd W. Robinson, *Chairman* Glen F. Mason, *Secretary*

1. **The Importance of Checking Foreign Organisms in Breadmaking.** Robert Wahl.
2. **On the Composition and Properties of an Oil from the Seeds of Martynia Louisiana.** E. H. S. Bailey and W. S. Long.
3. **Action of Milk on Colloids.** Edward Gudeman, Ph.D.
4. **The Relation of Index of Refraction, Specific Gravity and Solids in Tomatoes and Tomato Pulp.** W. D. Bigelow.
5. **The Influence of one Feedingstuff upon the Digestibility of Another.** H. S. Grindley, W. J. Carmichael and C. I. Newlin.
6. **Chemical Investigations at the Texas Experiment Station.** G. S. Fraps.
7. **Individuality of Pigs as to the Completeness with which they Digest their Feed.** W. J. Carmichael, C. I. Newlin and H. S. Grindley.
8. **The Influence of Litters on the Fermentation of Manure.** W. E. Tottingham.
9. **Bread: Weight of an Akron (Ohio) Loaf.** Chas. P. Fox.
10. **Tamarind Syrup.** W. C. Taber.

11. **A Survey of the Frozen Egg Industry of Chicago.** David Klein.

12. **Fertilizers for Field Crops in the Southwest of Alabama.** (Lantern). F. W. Zerban.

FERTILIZER CHEMISTRY DIVISION

J. E. Breckenridge, *Chairman* F. B. Carpenter, *Secretary*

1. **The Availability of Organic Nitrogen.** J. E. Breckenridge.

2. **Results of Some Co-operative Work on Determination of Sulfur in Pyrites. Some Observations on Details of Manipulation, Sources of Error, and on Barium Sulfate as Precipitated under Different Conditions.** H. C. Moore.

3. **The Activity and Availability of Insoluble Nitrogen in Fertilizers Determined by Chemical and Vegetation Tests.** F. R. Pember and B. L. Hartwell.

4. **The Determination of Potash in Fertilizers.** B. B. Ross.

5. **Effect of Lime and Limestone upon Acid Phosphate.** G. S. Fraps.

6. **Report of Committee on Research and Methods of Analysis.**

7. **Report of Committee on Fertilizer Legislation.**

BIOLOGICAL CHEMISTRY DIVISION

Carl L. Alsberg, *Chairman* I. K. Phelps, *Secretary*

1. **The Control of Cottonseed Products.** C. L. Alsberg.

2. **Emetine, the Specific Remedy of Pyorrhoea Alveolaris.** C. C. Bass.

3. **Saw Palmetto, a Biochemical Study.** Charles Mann.

4. **Volatile Oils of Some Species of Solidago.** Emerson R. Miller and J. M. Moseley.

5. **Volatile Oils of Several Species of Eupatorium.** E. R. Miller.

6. **The Volatile Oil of Achillea millefollium L.** E. R. Miller.

7. **Some Volatile Oils from the Genus Pycnanthemum.** E. R. Miller.

8. **Artificial Photo Synthesis by Chlorophyl.** W. J. V. Osterhout.

9. **The Role of Chlorine in Plant Nutrition.** W. E. Tottingham.

10. **Nitrification Studies.** G. S. Fraps.

11. **The Form of Nitrogen in Nitrogenous Materials as an Index to Nitrifiability.** C. B. Lipman.

12. **The Formation of Creatinine by Bacteria.** M. X. Sullivan.

13. **The Amount of Creatinine in Plants.** M. X. Sullivan.

14. **Toilet Papers, a Source of Infection.** Edward Gudeman.

15. **A Simple Colorimetric Method for the Determination of Free Reducing Sugars and Total Carbohydrate in Miscellaneous Food Products.** Adolph Bernhard.

16. **The Reducing Action of Certain Carbohydrates on Distillation.** J. P. Atkinson.

17. **A Precipitant for Ammonia.** Sara S. Graves.

18. **Phenols and Phenol Derivatives in Urine.** W. Denis.

19. **On the Physiological Activity of Combined Hydrochloric Acid.** J. H. Long.

20. **On Combinations of Proteins with Halogen Acids.** J. H. Long.

21. **On the Rate of Evaporation of Ether from Oils and its Application in Oil-Ether Colonic Anesthesia.** Charles Baskerville.

22. **The Free Amid Nitrogen and the Free Amino-acids Nitrogen of Feedingstuffs.** H. S. Grindley and E. C. Eckstein.

23. **Quantitative Determination of the Amino-acids of the Mixed Proteins of Feedingstuffs.** H. S. Grindley, W. E. Joseph and M. E. Slater.

24. **Nitrogen Distribution According to the Van Slyke Method in Soils and Their "Humic Acids."** R. S. Potter and R. S. Snyder.

25. **Amino Acid Nitrogen in Soils Variously Treated.** R. S. Potter and R. S. Snyder.

26. **A Study of Urinary Mucin.** Max Kahn.

27. **On Cystine.** M. Kahn and F. G. Goodridge.

28. **Biochemical Studies of Mercaptan.** F. G. Goodridge.

29. **Metabolism Studies of Multiple Myeloma with Bence-Jones Albumose.** M. Kahn and Francis Huber.

30. **Study of the Mineral Metabolism of Diabetics.** M. Kahn and S. Schneider.

31. **Mineral Metabolism of Two Cases of Haemophilia.** A. F. Hess and M. Kahn.

32. **A Study of the Ethereal Sulfates of the Urine in Various Diseases.** Jacob Rosenbloom.

33. **A Modification of Gerhardt's Test for Diacetic Acid.** Jacob Rosenbloom.

34. **The Influence of Low and High Protein Intake on the Excretion of Acetone, Diacetic Acid, and Beta-oxybutyric Acid in Diabetes.** Jacob Rosenbloom.

35. **On the Adjustment of the Reaction of Bacteria Culture Media.** W. M. Clark.

36. **Final Hydrogen Ion Concentration of Cultures of *B. Coli.*** W. M. Clark.

37. **Relation of Propionic Fermentation to the Development of "Eyes" in Ementhaler Cheese.** E. H. Walters and W. M. Clark.

38. **On the Factor to be Used for the Calculation of the Phosphoric Acid in Neumann's Method.** S. L. Jodidi.

39. **On the Factor to be Used for the Calculation of Phosphoric Acid in Neumann's Method. I. The Factor as Influenced by the Water Used for Washing the Yellow Precipitate.** S. L. Jodidi and E. H. Kellogg.

40. **The Quantitative Estimation of Alantoin.** Robert E. Swain and E. R. Harding.

41. **The Influence of Certain Sugars on the Growth and Respiration of Vetch.** Lewis Knudson.

42. **The Influence of Certain Inorganic Substances on the Digestion of Starch by Penicillium camembert.** W. J. Robbins.

43. **Differentiation of Organisms of the Colon Group by Means of Indicators.** W. M. Clark and H. A. Lubs.

44. **Studies on the Saponins of Chlorogalum pomeridianum and of Agabe lechuguilla.** C. C. Johns and Arno Viehoever.

45. **On the Alkaloids of Amianthium muscaetorium.** C. C. Johns and Arno Viehoever.

INDUSTRIAL CHEMISTS AND CHEMICAL ENGINEERS DIVISION.

Geo. P. Adamson, *Chairman* S. H. Salisbury, Jr., *Secretary*

Symposium on the Contributions of the Chemist to American Industries: (See *April issue*, p. 273.)

1. **The Wine Industry.** Charles S. Ash.
2. **The Copper Industry.** J. B. F. Herreshoff.
3. **The Corn Products Industry.** E. T. Bedford.
4. **The Asphalt Industry.** James Lewis Rake.
5. **The Cottonseed Oil Industry.** David Wesson.
6. **The Cement Industry.** G. S. Brown.
7. **The Sugar Industry.** W. D. Horne.
8. **The Incandescent Gas Mantle Industry.** Sidney Mason.
9. **The Textile Industry.** Franklin W. Hobbs.
10. **The Fertilizer Industry.** H. Walker Wallace.
11. **The Soda Industry.** F. R Hazard.
12. **The Leather Industry.** William H. Teas.
13. **The Flour Industry.** J. A. Wesener and G. L. Teller.
14. **The Brewing Industry.** Gaston D. Thevenot.
15. **The Preserved Foods Industry.** R. I. Bentley.
16. **The Potable Water Industry.** William P. Mason.
17. **The Celluloid and Nitrocellulose Industry.** R. C. Schüpphaus.
18. **The Glass Industry.** A. A. Houghton.
19. **The Pulp and Paper Industry.** F. L. Moore.

20. **The Chemists' Contribution to the Industrial Development of the United States—A Record of Achievement.** B. C. Hesse (see This Journal, 7 (1915), 293–304).

21. **The Chemists' Corporation: A Plan to Make Research Possible and Enable the Investigator to Profit by the Results.** Alexander Silverman.

22. **The Chemist and Industrial Water Purification.** William M. Booth.

23. **What the Chemist Has Done for the Portland Cement Industry in the United States.** W. C. Hanna.

24. **The Industrial Chemist in His Relation to Fire Prevention.** Frederick Dannerth.

25. **The Influence of Free Fatty Acids on the Flash and Fire Points of Fats and Oils.** A. Lowenstein and J. J. Vollertsen.

26. **The Influence of Pyridine on the Ammonia Determination of Concentrated Ammoniacal Liquor.** A. Lowenstein and J. J. Vollertsen.

27. **The Potash Supply.** Edward Hart.

28. **The Constituents of Portland Cement Clinker.** (Lantern.) G. A. Rankin.

29. **A Study of the Quality of Platinum Ware with Special Reference to Losses on Heating.** G. K. Burgess and P. D. Sale.

30. **A Study of Some Recent Methods for the Determination of Total Sulfur in Rubber.** J. B. Tuttle and A. Isaacs.

31. **Gas Washing Apparatus with Enclosed Filter.** E. R. Weaver and J. D. Edwards.

32. **A Simple Stone-Frame Chemical Hood.** E. R. Weaver.

33. **Apparatus for the Determination of Sulfur in Gas.** E. R. Weaver and J. D. Edwards.

34. **The Determination of Oil and Resin in Varnish.** E. W. Boughton.

35. **Tetraphosphorus Trisulfide.** W. O. Mitscherling.

36. **Discussion of Symposium.**

ORGANIC CHEMISTRY DIVISION

F. B. Allan, *Chairman* C. G. Derick, *Vice-Chairman and Sec'y.*

1. **The Classification and Nomenclature of Organic Compounds.** Edward Kremers.

2. **Dimethylsulfate as a Methylating Agent.** Victor P. Lee.

3. **Some Derivatives of Coumarin.** Francis D. Dodge.

4. **The Isolation of a Blue Hydrocarbon $C_{15}H_{18}$ from Milfoil Oil.** L. F. Augspurger.

5. **A Possible New Terpene from Monarda punctata.** Miss Nellie Wakeman.

6. **The So-called Alpha and Beta Isomeric Resin Acids.** C. H. Herty and D. H. Killeffer.

7. **The Structure of Certain Hydronaphthoic Acids.** Oliver Kamm and C. G. Derick.

8. **The Correlation of Ionization and Structure in Unsaturated Acids.** C. G. Derick and Oliver Kamm.

9. **Some Tests for Qualitative Organic Analysis.** Oliver Kamm.

10. **Qualitative Organic Analysis.** W. F. Moncreiff, Jr. and J. T. McGill.

11. **Recent Progress in the Study of the Quinone-Phenolate Theory of Indicators.** E. C. White and S. F. Acree.

12. **A Theory of the Mutarotation of Sugars and Their Derivatives by Acids and Alkalis.** S. F. Acree.

13. **On the Reactions of Both the Ions and Molecules of Acids, Bases and Salts. A Reinterpretation of the Reactions of Sodium Methylate and Sodium Ethylate with 1,2-Dinitrobenzene, 1,2,4-Dinitrochlorobenzene, and with 1,2,4-Dinitrobromobenzene.** S. F. Acree.

14. **Alkaloidal Tartrates. I. Strychnine Tartrate.** G. D. Beal and H. F. Lewis.

15. **A Comparison of the Optical Rotatory Powers of the Alpha and Beta Forms of Certain Acetylated Derivatives of Glucose.** C. S. Hudson and J. K. Dale.

16. **The Isomeric Alpha and Beta Octacetates of Maltose and Cellose.** C. S. Hudson and J. M. Johnson.

17. **The Isomeric Pentacetates of Mannose.** C. S. Hudson and J. K. Dale.

18. **The Isomeric Pentacetates of Galactose.** C. S. Hudson and H. O. Parker.

19. **The Crystalline-*d*-Fructose Pentacetate.** C. S. Hudson and D. H. Brauns.

20. **The Existence of a Third Pentacetate of Galactose.** C. S. Hudson.

21. **Some Derivatives of Chlor-Methyl Ether.** Friend E. Clark and Samuel F. Cox.

22. **Hop-Seed Oil.** Norman A. Dubois.

23. **Research on Purines. XVII. On a New Synthesis of Alkylamino-Purines. On 2-Oxy-8-thiopurine, 2-Oxy-8-methyl-mercaptopurine, and 2-Oxy-6,9-dimethyl-8-thiopurine.** C. O. Johns.

24. **Researches on Thioamino-Acids. On Thiohippuric Acid and Phthalyl-α-aminothioacetic Acid.** C. O. Johns.

25. **Citral, and its Determination.** B. G. Feinberg.

26. **The Preparation of Trimethylene Oxide.** C. G. Derick.

27. **The Use of Trimethylene Oxide in the Grignard Reaction. The Synthesis of Normal Primary Hexyl Alcohol.** C. G. Derick and E. H. Vollweiler.

28. **The Synthesis of δ-Acetyl-valerianic Acid and Adipic Acid.** C. G. Derick and R. W. Hess.

29. **The Ionization Constants of Certain Ketoparaffine Monobasic Acids.** C. G. Derick and St. Elmo Brady.

30. **On the Decomposition of Tertiary Amyl Esters.** M. A. Rosanoff and M. M. Harrison.

PHARMACEUTICAL CHEMISTRY DIVISION

F. R. Eldred, *Chairman* A. P. Sy, *Secretary*

1. **The Stability of Nitroglycerin Tablets.** Wilbur L. Scoville.

2. **Variation Clause of the Food and Drugs Act.** J. H. Beal.

3. **The Composition of Oil of Cassia.** Francis D. Dodge and Alfred E. Sherndal.

4. **The Chemistry of the Daturas. II. The Alkaloidal Content of Datura Leaves.** H. A. Langenhan.

5. **A Possible Explanation of the Reduction Phenomena Observed in Elixir Phosphate of Iron Quinine and Strychnine when Exposed to Light.** N. R. Mueller.

6. **Discussion of Papers 4 and 5.** Prof. Edward Kremers.

PHYSICAL AND INORGANIC CHEMISTRY DIVISION

G. A. Hulett, *Chairman* R. C. Wells, *Secretary*

1. **A Colorimetric Determination of Acetylene.** E. R. Weaver.

2. **The Ternary System K_2O–SiO_2–H_2O from 300–700°. (Lantern.)** George W. Morey.

3. **Rubidium Ammonosodate and Ammonopotassiate.** E. C. Franklin.

4. **Distillation of Liquid Air in a Magnetic Field.** R. S. McBride.

5. **A Systematic, Rapid, Electroanalytical Procedure for the Separation and Determination of Silver (Arsenic), Copper, Bismuth, Antimony, Tin, Lead, and Cadmium.** E. P. Schoch and Denton J. Brown.

6. **The Influence of the Potassium Ion upon the Potential of the Ferrocyanide-Ferricyanide Electrode.** E. P. Schoch and W. A. Fielding.

7. **The Rates of Solution of Metals in Ferric Salts and in Chromic Acid.** R. G. Van Name and D. U. Hill.

8. **The Electrolytic Preparation of Solid Alkali Amalgams in Quantity.** Paul M. Giesy and James R. Withrow.

9. **The Analysis of Silicates and Carbonates for Their Ferrous Iron Content.** O. L. Barnebey.

10. **The Permanganate Determination of Iron in the Presence of Fluorides.** O. L. Barnebey.

11. **The Phenomenon of Passivity in Connection with Ferrous Alloys of Different Composition and Structure.** H. W. Moseley.

12. **The Thermoelectric Properties of Carbon.** William C. Moore.

13. **Potassium Chloride Concentration Cells.** D. A. MacInnes and Karr Parker.

14. **The Precipitation of Lead Chloride in Qualitative Analysis.** J. P. Montgomery.

15. **Radium Content of Gulf of Mexico Water.** Stewart J. Lloyd.

16. **Studies in the Measurement of the Electrical Conductivity of Solutions.** W. A. Taylor.

17. **Electrolytic Rectification of Alternating Currents.** William J. Van Sicklen.

18. **The Changes of Mass and Weight Involved in the Formation of Complex Atoms.** William D. Harkins and Ernest D. Wilson.

19. **The Structure of Complex Atoms.** William D. Harkins and Ernest D. Wilson.

20. **Nuclear and Valence Electrons.** William D. Harkins and Ernest D. Wilson.

21. **A Periodic Table which Plots the Atomic Weights of the Ordinary and the Isotopic Elements.** William D. Harkins and Ernest D. Wilson.

22. **A Connection between Planck's Quantum Hypothesis, the Magneton, and the Balmer Series Formula.** Ernest D. Wilson and William D. Harkins.

23. **Cuprous Salts of Oxygen Acids and a New Method for Preparing Cuprous Salts.** Lloyd C. Daniels.

24. **A Rational Process of Fractional Distillation.** M. A. Rosanoff.

25. **Equilibria in the Systems of Methyl Alcohol, Ketones, Water, and Inorganic Salts, Part I.** G. B. Frankforter and Lillian Cohen.

26. **Equilibria in the Systems of Propyl Alcohols, Water, and Salts.** G. B. Frankforter and Sterling Temple.

WATER, SEWAGE AND SANITATION SECTION

Earle B. Phelps, *Chairman* H. P. Corson, *Secretary*

1. **The Use of Benzidene for Sulfates in Water Analysis.** F. W. Bruckmiller.

2. **The Determination of Arsenic in Filter Alum.** Edward Bartow and A. N. Bennett.

3. **The Manufacture of Filter Alum at the Columbus Water Softening and Purification Works.** C. P. Hoover.

4. **The Determination of the Biochemical Oxygen Demand by the Saltpeter Method in Stockyards, Tannery, and Corn Products Wastes.** Arthur Lederer.

5. **Ventilation Studies.** Earle B. Phelps.

6. **The Purification of Sewage by Aeration in the Presence of Activated Sludge.** Edward Bartow and F. W. Mohlman.

7. **The Sanitary and Mineral Properties of the Public Water Supplies of Georgia.** Ray C. Werner.

8. **Analytical Methods for Sewage Works Operation.** W. L. Stevenson and Others.

9. **The New Orleans Water Purification Works.** John L. Porter.

10. **Rat Proofing of Wharves as an Anti-Plague Measure.** H. P. Letton.

11. **A Comparison of Methods for Determining Putrescibility or Oxygen Demand.** F. E. Hale and T. W. Melia.

12. **A Sanitary Survey of Lake Michigan, Together with a Study of Stream Pollution along the Wisconsin Shore.** E. J. Tully.

13. **Report of the Committee on Standard Methods of Analysis for Potable Water and Sewage.**

EXCURSIONS

Water Purification Plant—Of the public works which have successfully overcome the natural difficulties that beset the city of New Orleans, none are more important than those of sewerage, water and drainage. These include 427 miles of sewers, with nine pumping stations; 312 miles of storm water drainage arteries, with seven great pumping stations; and 532 miles of water mains, with a purification plant and pumping station on each side of the Mississippi River, which take its muddy water and render from it a crystal-clear and highly-safe and desirable water supply, and distribute it to the entire populated area of the city under 70 lbs. pressure, thus giving a magnificent fire protection as well.

These great works of sewerage, water and drainage, so widely scattered, have involved an expenditure of over $30,000,000.

This plant, as it stands, has a capacity to purify and deliver to the city 60,000,000 gallons of water a day, with ample reserve pump and boiler capacity to take care of any probable accident to pumps or boilers which may put a portion of them out of service for repair. The machinery and boiler equipment are of the most modern and efficient design known to waterworks practice, and the coal consumption is below that of many plants for smaller cities which do not pump one-third as much water as is now being handled at this plant. The universal use of water meters for all water consumers has resulted in the prevention of waste of water; the present requirements of the city call for an average delivery of only 17,000,000 gallons of water per day. The plant, however, includes a sufficient area of ground and is laid out with a view of economical extension to a capacity of at least 168,000,000 gallons per day, which should serve a population of nearly 2,000,000.

Water is taken from the Mississippi River, three-quarters of a mile away, through a 48-inch suction line, which is laid level and with its top 2 feet below extreme low water in the river, and lifted by the low-lift pumps, through the head or controlling, house, into one of the two grit reservoirs, in passing through which it deposits about 10 per cent of the heavier suspended matter which it contains. From the grit reservoir the water passes through the head house again, and, in proportion to the amount of water passing and its condition, lime and sulfate of iron are added to it, after which it passes through one of the two sets of chemical mixing passages, which afford a runway back and forth and up and down of about a mile, during which any deposit is prevented by the motion of the water. This keeps the chemical solution thoroughly mixed with the water until the full chemical reaction required has taken place. Then once more the water passes through the head house, going this time to one of the two sets of settling reservoirs, through which its passage is very slow, for the express purpose of causing the deposit of the now coagulated masses of clay and precipitating lime and magnesia which were originally contained in solution in the water, as well as of the iron and lime which were added to bring about this precipitation. The result is that when the water has reached the outlet of the settling reservoirs and is ready once more to pass through the head house to the filters nearly all of the suspended matter and a large amount of the chemicals which were in solution in the river water, together with those which were added in the treatment, have been left behind in the settling reservoirs, and the remainder, about fifty parts per million out of an average of 750 parts of suspended matter contained in the raw river water, are in such changed condition that they are easily removed by the filters, which yield an effluent entirely free from suspended matter and containing less than half as much lime and magnesia and only about 1 per cent as many bacteria as the river water originally contained. The resultant water is bright and sparkling in appearance and safe and desirable for every use.

The filters are of the so-called mechanical or rapid type. They are, however, merely gravity sand filters, designed to handle large quantities of water and to be very easily and cheaply cleaned. In filtering, the water enters above the sand layer, passes through it and is collected by a system of drains into one effluent pipe for each of the ten filter units, which effluent pipe is automatically throttled to prevent a too rapid flow through the filters. As the suspended matter in the water accumulates in the sand layer, the latter is gradually choked up, until finally the filter will not pass as much water as is required of it with the throttle on its effluent pipe wide open. This stage is reached in from 100 to 300 hours of service under present operating conditions in New Orleans, and then the filter has to be cleaned. The process of cleaning consists in closing the inlet and outlet of the filter from its connection with the operating portion of the system and in forcing filtered water into the effluent pipe, through the drains, and up through the sand layer, at a high velocity, which stirs up the sand layer, loosens the mud and causes it to overflow through troughs placed at a higher elevation than that to which this velocity will raise the sand of which the filtering material is composed. It takes less than ten minutes to go through the entire operation of washing a filter, and only about one-half to one per cent of the water filtered is required for filter washing.

The entire cost of treating and filtering the water and pumping it into the distribution system is not over two cents per 1,000 gallons, and the cost of water delivered to domestic consumers through meters by the city is now usually less than one-fourth of what these same consumers had to pay for raw river water pumped direct from the river before the city constructed and operated its own waterworks plant.

The Weeks Island Salt Mine—Weeks Island, La., is 125 miles west of New Orleans, situated on Vermilion Bay, an arm of the Gulf of Mexico, and rises 204 feet above sea level. It has an area of 2500 acres and the salt underlies practically the entire island.

This wonderful deposit of pure rock salt was discovered by Gen. F. F. Myles in 1898. It analyzes 99.84 pure chloride of sodium. The deposit obtains in a solid mass and is found at a depth of 93 feet from the surface. It is several thousand feet thick. This company acquired the entire salt deposit, sank a shaft 650 feet into the salt and erected a plant, completed in 1903, with a capacity of 1500 tons daily, thoroughly equipped with every modern device for the economical production of all the commercial grades of rock salt. These are shipped to all parts of the United States, England, Australia, Central and South America, Cuba and the Philippines.

The mine chambers are opened from 80 to 100 feet wide and 85 feet high with the overlying mass of salt, supported by pillars of salt 80 × 85 feet. The interior is lighted by electricity and, being all translucent, clear, crystal salt, has the appearance of an enchanted palace, whose domes are studded with saline diamonds. The mine is, of course, perfectly dry and is different from most mines in that no artificial scaffolding is used, the strength of the pillars of salt being more than sufficient for the support of the roof.

Rock salt is mined in very much the same manner as are all the baser minerals. The first operation is the drilling of the holes for the insertion of the dynamic charges, rock salt having a resisting power of 5000 lbs. to the sq. in. This is accomplished by eleven-foot drills. The salt is cut out in tunnel form, arched columns being left to prevent a collapse. These tunnels are 750 to 1000 ft. long and 80 to 100 ft. wide, and of about the same height. The blasting is generally done at night, as well to prevent accident as to allow the atmosphere to clear in time for the following day's work. As blasted, the salt is loaded on regular narrow gauge mule trains, which carry it to the foot of the shaft.

The salt passes through a forty H. P. electric-motor-driven crusher, after which it is fed by gravitation into the cage and carried to the mill, where it is fed automatically into screens and separated into the various commercial grades. If shipped in bulk it is deposited by gravity into the cars; if not, it is automatically fed into sacks.

In the twelve years of the mine's operation, 1,000,000 tons of salt have been removed, and there remains 5,000 times that much on the level now being worked. Drillings to a depth of 250 ft. below the present level showed a continuation of the salt deposit.

The excursion to the mine was made over the Southern Pacific line by special train, 102 persons making the trip. A box lunch was furnished on the train before arrival at the mines. Delicious refreshments were served by Mr. Myles, owner of the mine; ice cream and cooling drinks were plentiful on the return trip. As the route passed through sugar plantations and truck farms, the journey gave a good idea of the importance and extent of agriculture in Louisiana.

INDUSTRIAL CHEMISTS AND CHEMICAL ENGINEERS DIVISION AMERICAN CHEMICAL SOCIETY

MINUTES OF NEW ORLEANS MEETING

The first meeting of the Division was devoted to the Public Symposium held at Tulane University and was presided over by *Vice-chairman* H. E. Howe. The program of papers is given on page 442.

The regular divisional meeting was held at the Grunewald Hotel, New Orleans, La., April 2, 1915, with *Vice-chairman* H. E. Howe presiding.

The Secretary reported for the Chairman and the Executive Committee the appointment of the following committees:

STANDARD SPECIFICATIONS AND METHODS OF ANALYSIS—A. M. Comey, J. O. Handy, Robert Job, F. G. Stantial.

NON-FERROUS METALS AND ALLOYS, a Sub-committee of preceding Committee—Wm. Price, *Chairman;* Allen Merrill, Geo. L. Heath, Gilbert Rigg, Bruno Woichiechowski.

SOAP PRODUCTS—Archibald Campbell, *Chairman;* C. P. Long, J. R. Powell, Percy H. Walker.

GLYCERINE, a Sub-Commitee of preceding Committee—A. C. Langmuir, *Chairman;* W. H. Low, S. S. Emery, R. E. Devine, J. W. Loveland, A. M. Comey.

NAVAL STORES—J. E. Teeple, *Chairman;* other members not yet selected.

ALUM—W. M. Booth, *Chairman;* Chas. P. Hoover, Wm. C. Carnell.

PLATINUM—W. F. Hillebrand, *Chairman;* Percy H. Walker, H. T. Allen.

The Secretary reported on the financial condition of the Division as follows:

Balance on hand April 6, 1914	$68.02	Expenditures for printing postage, etc.	$25.55
Received	1.00		
TOTAL FUNDS	$69.02		
BALANCE ON HAND April 1, 1915			$43.47

No Committee reports were received.

The reading of the papers was then continued in accordance with the program as given above.

The various methods for the analysis of alum which were offered by Wm. M. Booth, Chairman of the Committee on Alum, for discussion by the Division, were laid on the table as the time was too short for their attention.

Under new business the matter of the relation of the various committees to each other was brought up and it was moved by W. F. Hillebrand and seconded by A. H. Sabin that this matter be referred to the Executive Committee for settlement. The motion was carried.

LEHIGH UNIVERSITY
SO. BETHLEHEM, PA.

S. H. SALISBURY, JR., *Secretary*

FERTILIZER DIVISION AMERICAN CHEMICAL SOCIETY

MINUTES OF NEW ORLEANS MEETING

The Meeting was called to order, Friday morning, April 2nd, in accordance with the official program, by Chairman Breckenridge. About thirty members attended.

PAUL RUDNICK, Chairman of the Committee on Research and Methods of Analysis, presented a report in which tentative standard methods for the sampling and analysis of phosphate rock were proposed. The degree of fineness of the coarse moisture sample was discussed. It was generally agreed that 4 mesh (Bureau of Standards specification), rather than 20 mesh, as proposed, would be fine enough. There was a lively discussion as to whether all silica should be made insoluble before determining sulfuric acid. The motion that the analysis be so conducted that all silica be made insoluble was finally carried. The motion to otherwise adopt the Committee's report was carried.

F. B. CARPENTER, Chairman of Committee on Fertilizer Legislation, presented a report regarding some fertilizer laws now in force.

After the Committee Reports the papers listed in the above program on page 442 were read.

The paper by H. C. Moore was referred to the Committee of Research and Methods of Analysis.

H. C. MOORE, *Secretary, pro-tem.*

REPORT OF COMMITTEE ON FERTILIZER LEGISLATION

During the past year, there have been no changes in the laws of the several states, which materially affect the fertilizer industry. There have been several bills presented in different states, which failed to pass and there is some legislation pending, but only a few minor changes have been noted, during the past twelve months.

There seems to be a growing tendency for the states to change from the brand tax to a tonnage tax. In some cases, this change has evidently been effected for the purpose of increasing the revenue, while in other instances, the reason assigned is to obtain statistical information, relative to the fertilizer business, which some companies now refuse to give. There seems to be no reason why any reputable company should be unwilling to furnish this information; on the contrary, the industry should be greatly benefited by having a reliable statistical bureau, through which it might be possible to ascertain the total tonnage of fertilizers sold in each state and the amount of plant food in these fertilizers. If such statistics were available, it is our opinion that they would become an important factor in increasing the sales of fertilizers.

In many of the states, the fertilizer laws have not been revised to meet present conditions, or when revision has been made, old forms have been copied. For instance, an expression commonly used is as follows: "It shall be unlawful to offer for sale any fertilizer or fertilizer material containing any hoof meal, horn, hair, leather, or any other substance in which the ammonia is largely unavailable." By this statement, it assumes that the ammonia in these articles is largely unavailable; while, as a matter of fact, from various tests, we find that hoof meal shows a satisfactory availability, and by modern practice, the ammonia in hair, leather, etc., can be made available by proper treatment.

When any of the state laws are undergoing revision, we should see that this form of expression is modified to read: "Any hoof meal, horn, hair, leather, or any other substance that has not been so treated as to render it largely available." This would allow the manufacturer to use materials which would cheapen the cost of fertilizers without in any way reducing their value.

Organic ammoniates, available for fertilizer purposes, are becoming scarcer each year, and if the manufacturer is restricted to such materials as Blood, Tankage, Cottonseed Meal, etc., the prices of ammoniated fertilizers will be largely increased in the future.

There seems to be little hope of getting a uniform law which will be applicable in the different states, but the fertilizer manufacturers should have the hearty co-operation of the agricultural departments in having only such laws enacted as will amply protect both the producer and consumer, without imposing unnecessary hardships on the manufacturer.

All unnecessary restrictions tend to increase the expense of production and must necessarily result in higher prices for the consumer.

J. E. BRECKENRIDGE PAUL RUDNICK
H. A. HUSTON H. J. WHEELER
F. B. CARPENTER, *Chairman*
COMMITTEE ON FERTILIZER LEGISLATION

REPORT OF THE COMMITTEE ON RESEARCH AND ANALYTICAL METHODS—PHOSPHATE ROCK

The following tentative standard methods for sampling and determination of moisture, phosphoric acid and iron and alumina in phosphate rock are recommended to the Division.

METHODS OF SAMPLING AND DETERMINATION OF MOISTURE

I. GROSS SAMPLE—*A*: CAR SHIPMENTS—100 lb. sample per car.

1—SAMPLING FROM THE CAR: In sampling car shipments in the car at least ten scoopshovelsful, aggregating 100 lbs., shall be taken from each car at approximately equal distances from each other so as to average the car. Care shall be taken to see that each scoopful shall cover the entire face of the pile from floor to top.

2—SAMPLING FROM THE CART OR BARROW: A small hand scoopful of 1 to 2 lbs. shall be taken from each cart or barrow either as it is being loaded or as it leaves the car.

B: CARGO SHIPMENTS—100 lb. minimum sample per vessel.

1—SAMPLING IN HOISTING TUB: In sampling cargoes generally running from 1000 tons upward a small hand scoopful shall be taken from approximately every tenth tub before it is hoisted from the hold.

2—SAMPLING FROM CONVEYOR: If unloading is being done with automatic bucket and conveyor, periodical sections of the entire discharge of the conveyor shall be taken of such intervals and quantity as to give a sample equivalent to approximately one lb. per each ten tons of cargo.

3—SAMPLING FROM CONVEYING VEHICLE: Samples shall be taken with a hand scoop from various cars at such regular intervals and in such quantities as to give approximately one lb. for each ten tons of cargo.

II. LABORATORY SAMPLE—The resulting gross sample obtained by any one of the methods outlined shall be crushed to pass a four mesh screen, thoroughly mixed on a clean, hard surface and quartered down to a 10-lb. average sample.

A. CRUSHING—This 10-lb. sample shall all be crushed to pass an eight mesh screen.

B. MIXING AND QUARTERING—This eight mesh sample shall be carefully mixed and quartered down to two 2-lb. samples.

C. GRINDING—1—MOISTURE SAMPLE: One of these 2-lb. samples shall be held in an air-tight container. This sample is to be used for the determination of moisture.

2—ANALYTICAL SAMPLE: The other 2-lb. sample shall be further mixed and quartered down to a 2- or 4-oz. sample which is then to be ground to pass a 60 mesh screen or preferably a 65 mesh screen. This sample is to be used for the analytical determination.

NOTE: It is essential that the taking of the gross sample be done with small hand scoops and that the practice of taking the sample in the hand be absolutely prohibited, for it has been found that there is considerable selective action in the finer materials sifting through the fingers while a scoop retains the entire sample.

The dimensions of the screens referred to above are to be as follows:

No. of Mesh	Size of Opening Inches	Diameter of Wire Inches
4	0.185	0.065
8	0.093	0.032
65	0.0082	0.0072

III. DETERMINATION OF MOISTURE—Moisture is to be determined on both the moisture sample and analytical sample. Of the moisture sample not less than 100 grams are to be weighed out for each determination. Of the analytical sample approximately 2 grams are to be weighed out for each determination. Both are to be dried to constant weight at a temperature of 105° C. in a well ventilated oven, preferably with a current of dry air passing through the oven. The containers in which moisture is determined should be provided with well fitting covers so that the samples may be cooled and weighed in the well covered container.

IV. CALCULATION OF RESULTS—The percentages of phosphoric acid and iron and alumina as determined on the analytical sample are to be calculated to a moisture-free basis and subsequently to the basis of the original sample as shown by the moisture content of the moisture sample.

DETERMINATION OF PHOSPHORIC ACID

REAGENTS—To be prepared as in Official Methods, A. O. A. C. Bureau of Chemistry, *Bulletin* 107 (Rev.), 1910, p. 2. Preparation of Reagents (*c*), (*d*), (*e*) and (*f*), except that the ammonium nitrate solution in (*d*) is changed to 5 per cent instead of 10 per cent.

METHOD OF SOLUTION—To 5 grams of the sample add 30 cc. of concentrated hydrochloric acid (sp. gr. 1.20) and 10 cc. of concentrated nitric acid (sp. gr. 1.42) and boil down to a syrupy consistency. The residue, which should be nearly solid after cooling, is taken up with 5 cc. of concentrated nitric acid and 50 cc. of water. Heat to boiling, cool, filter and make up to 500 cc. through the filter. This procedure eliminates practically all of the silica and it is necessary to filter as quickly as possible after digestion so as to avoid redissolving the silica.

DETERMINATION—Draw off an aliquot portion of 50 cc., corresponding to 0.5 gram, neutralize with ammonia, then add nitric acid until the solution is just clear. Add 15 grams of ammonium nitrate (free from phosphates), heat the solution to 50° C. and add 150 cc. of molybdate solution. Digest at 50° C. for 15 minutes with frequent stirring. Filter off the supernatant liquid and test the filtrate with molybdate solution to see if precipitation has been complete. (If not, add more molybdate to the filtrate and digest for 15 minutes longer.) Wash with 5 per cent ammonium nitrate solution by decantation, retaining as much of the precipitate as possible in the beaker. Dissolve the precipitate in the beaker in the least possible quantity of ammonium hydroxide (specific gravity 0.90) and dilute this solution with several times its volume of hot water. Dissolve the remainder of the precipitate on the filter with this solution, washing beaker and filter with hot water and keeping the volume of the filtrate between 75 and 100 cc. Neutralize with hydrochloric acid, cool to room temperature and add 25 cc. of magnesia mixture from a burette, drop by drop, stirring vigorously with a rubber tipped rod, then add 15 cc. of ammonium hydroxide (sp. gr. 0.90) and allow to stand for four hours or over night at room temperature. The time of standing may be reduced to two hours if kept in a refrigerator or still better in an ice water bath. Filter through a platinum or porcelain Gooch crucible, fitted with a platinum or asbestos mat carefully made and ignited to constant weight. Wash with 2.5 per cent ammonium hydroxide until practically free from chlorides; dry, ignite, cool and weigh as magnesium pyrophosphate. If desired, filtration may be made through an ashless filter paper, igniting in the usual manner. Calculate to P_2O_5 by multiplying by 0.6378 (log 80468).

DETERMINATION OF IRON AND ALUMINUM TOGETHER AS PHOSPHATES

I. SOLUTIONS REQUIRED: 1—Hydrochloric acid (1 : 1); prepared by mixing 1 part by volume of concentrated HCl (sp. gr. 1.19) with 1 part of distilled water.

2—A saturated solution of ammonium chloride, which should be filtered before use.

3—A 25 per cent solution of ammonium acetate, faintly acid to litmus paper.

4—A solution of ammonium phosphate (10 per cent), prepared by dissolving 20 grams of $(NH_4)_2HPO_4$ in 180 cc. of distilled water and filtering. (This should be prepared frequently in small quantity as it attacks glass containers on standing.)

5—A standard solution of ferrous ammonium sulfate, containing iron equivalent to about 0.0100 gram of Fe_2O_3 in 10 cc. and 50 cc. of conc. HCl per liter.

6—A solution of calcium and magnesium phosphates for blank determinations, prepared as follows: Dissolve 4 grams of MgO and 35 grams of $CaCO_3$ (both free of iron and aluminum) in 100 cc. of conc. HCl, add an aqueous solution of 30 grams of $(NH_4)_2HPO_4$, make up to 2 liters and filter.

7—A solution of ammonium nitrate (5 per cent) for washing precipitates. About 400 cc. are required for each determination.

All reagents used should be as pure as practicable and all solutions should be free of suspended matter.

II. PREPARATION OF ROCK SOLUTION—Place 2.5 grams of pulverized rock with 50 cc. of 1 : 1 HCl in a graduated 250 cc. flask, the glass of which contains less than 1 per cent of iron and aluminum oxides.[1] Boil gently with occasional shaking for 1 hour in such a manner as to avoid concentrating the solution to less than half of its original volume,[2] dilute, cool to room temperature, make up to volume and mix; filter immediately through a dry filter into a dry flask, discarding the first few cc. of the filtered solution.

Pipette a 50 cc. aliquot, representing 0.5 gram of rock, into a platinum dish and evaporate nearly to dryness.[3] Cool, take up with a few cc. of water and when the salts are loosened from the dish, add 5 cc. of 1 : 1 sulfuric acid and evaporate to fumes. Increase the temperature and evaporate nearly to dryness.[4] Cool, dilute with about 50 cc. of distilled water, add 10 cc. of conc. HCl and heat, with occasional stirring, until sulfates are dissolved. Filter into a 600 cc. Jena glass beaker through a 9 cm. paper (S & S No. 597), washing the paper thoroughly with dilute HCl and hot water.

III. FIRST PRECIPITATION WITH AMMONIUM ACETATE—To the solution in the beaker, add 25 cc. of the standard iron solution when the amount of combined iron and aluminum oxides in the rock does not exceed 5 per cent and 50 cc. of the standard iron solution when the combined oxides exceed 5 per cent.[5] Oxidize with about 3 cc. of bromine water and boil in covered beaker for about 15 minutes to expel the excess of bromine. Rinse cover and sides of beaker with distilled water and cool to room temperature.

(Run a blank determination containing 10 cc. of 1 : 1 HCl, 25 cc. of the calcium and magnesium phosphate solution, and the same quantity of standard iron solution as is added to the rock solution.)

Add 100 cc. of saturated ammonium chloride solution,[6] 3 cc. of 10 per cent ammonium phosphate solution, 2 drops of methyl orange indicator and conc. ammonium hydrate (free of spangles and dissolved mineral matter) to alkaline reaction. Then add dilute HCl (about 1 : 20) drop by drop, with constant stirring, until the solution becomes faintly acid and the pink color of the methyl orange is just restored.[1] Dilute to 450 cc.[2] with distilled water, heat to boiling, and add 25 cc. of 25 per cent ammonium acetate solution. Continue heating for about 5 minutes, after adding ammonium acetate, filter on a 12.5 cm. ashless filter paper (S & S No. 589 "White Ribbon" is suitable), in a 3 inch rapid filtering funnel, keeping the contents of the beaker and funnel hot.[3] Wash 3 times with hot 5 per cent ammonium nitrate solution, each time cutting the precipitate loose from the filter and stirring it thoroughly with the stream from the wash bottle and filling to within about $^1/_4$ inch of its upper edge. About 30 cc. are required for each washing. Return the precipitate to the precipitating beaker by washing it out of the filter with a stream of hot water. Dissolve the precipitate with dilute HCl (1 : 6), pouring about 50 cc. through the filter in successive washings and using about 25 cc. to wash down inside the beaker. Finish filter paper with distilled water.

IV. SECOND PRECIPITATION WITH AMMONIUM ACETATE—Cool the solution to room temperature, add 50 cc. saturated ammonium chloride solution, 4 cc. of 10 per cent ammonium phosphate solution, 2 drops of methyl orange, and adjust acidity as before. Dilute to 300 cc. with distilled water. Heat to boiling, add 15 cc. of 25 per cent ammonium acetate solution and continue heating for about 5 minutes. Filter on the same paper as used for the first filtration, scrubbing the inside of the beaker with a rubber-tipped stirring rod and rinsing with hot 5 per cent ammonium nitrate solution. Wash the precipitate 10 times with hot 5 per cent ammonium nitrate solution, each time cutting the precipitate loose, stirring it thoroughly as before and breaking up all lumps that it may contain. About 300 cc. of wash solution are required.

As a precautionary measure, boil the filtrate and washings from both the first and second precipitates, and recover any additional precipitate.

V. IGNITION OF PRECIPITATE—Transfer filter with precipitate to a weighed deep-form porcelain crucible (40 mm. in diameter is a good size) and heat gently over a low flame until the contents are dry, increase the temperature a little and continue heating until the paper is charred, increase the temperature again and continue heating until the paper is entirely burned. Ignite the *uncovered*[4] porcelain crucible for one-hour periods over blast lamp or No. 4 Meker burner to constant weight, each time cooling to room temperature in desiccator before weighing. Deduct the weight of blank from each determination, and after subtracting the weight of $FePO_4$ equivalent to the amount of iron found in 0.5 gram of rock by titration, calculate the remainder to Al_2O_3. $AlPO_4 \times 0.4184 = Al_2O_3$.

DETERMINATION OF IRON

I. SOLUTIONS REQUIRED—1—*Standard Potassium Permanganate*, $N/40$, containing 0.79015 gram of $KMnO_4$ per liter, and having a value of 0.001996 (or practically 0.002) gram of Fe_2O_3 per cc. Standardize with pure sodium oxalate (Bureau of Standards standard sample No. 40.)

2—*Stannous Chloride.* Dissolve 50 grams of the crystallized salt in 100 cc. of hot conc. HCl and make up to 1 liter with distilled water.

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[1] Experiments have shown that the solution cannot be made in flasks made of glass containing a higher percentage of alumina, because the fluorine in the rock partially dissolves the glass and adds alumina to the solution. Neither "Nonsol," "Jena" nor "Weber's" resistant glass "R" is suitable. Flasks made of glass containing little alumina, such as "Kavalier," "F Z resistant glass" or other Bohemian glass of lower alumina content have proven satisfactory. See "Chemical Glassware," P. H. Walker, *J. Am. Chem. Soc.*, **27**, 865.

[2] This may be accomplished by heating the flask over a low Bunsen flame or on a hot plate which is just hot enough to keep the solution boiling. A glass tube about 12 inches long by $^3/_8$ of an inch in diameter with a bulb in the middle makes a very satisfactory condenser when placed in the neck of the flask.

[3] It is advisable to remove as much of the HCl as possible before adding sulfuric acid so as to minimize the chances of loss by effervescence or bumping. The evaporation may be conducted in glass beakers of low alumina content. Kavalier glass has been used satisfactorily. In no case should the evaporation be conducted in porcelain.

[4] It is best to remove as much sulfuric acid as possible so that the calcium sulfate which might hold iron will dissolve readily in HCl.

[5] It has been found that when iron oxide is present in considerable excess over aluminum oxide the precipitation of the phosphates is more complete, the combined phosphates are more readily ignited to constant weight, and the precipitate does not become red on ignition.

[6] Ammonium chloride in large quantity increases the solubility of calcium and magnesium phosphates and decreases the solubility of iron and aluminum phosphates.

[1] This method of adjusting acidity was suggested by F. B. Carpenter and was found to give satisfactory results.

[2] All our work has confirmed Brown's statement (see Wiley's "Principles and Practice of Agricultural Analysis," 2nd edition, **1908**, Vol. II, p. 245) that the separation from calcium under the conditions of the method depends upon sufficient dilution.

[3] The contents of the funnel will remain hot if the solution in the beaker is kept hot over a low flame and filtration is fairly rapid.

[4] Heat over Bunsen to redness before placing over blast in order to prevent loss of precipitate by blowing out of crucible.

3—*Mercuric Chloride.* Prepare a cold saturated solution.

4—*Manganese Solution.* (Preventive solution): (*a*)—Dissolve 200 grams of crystallized manganese sulfate in 1000 cc. of water. (*b*)—Pour slowly, with constant stirring, 400 cc. of conc. sulfuric acid into 600 cc. of water and add 1000 cc. of phosphoric acid of 1.3 sp. gr. Mix solutions (*a*) and (*b*).

II. ANALYTICAL PROCEDURE—Determine iron according to Jones' and Jeffrey's modification of the Zimmermann-Reinhardt method[1] as follows: Place in a 250 cc. beaker an aliquot of the rock solution, containing not more than 5 cc. of conc. HCl, boil and reduce with the smallest possible excess of stannous chloride, added drop by drop while agitating the solution. Wash sides of beaker with distilled water and cool rapidly. Add 10 cc. of mercuric chloride solution and stir vigorously for about 30 seconds.[2] Pour the mixture into a large porcelain casserole or dish containing 20 cc. of the manganese solution in about 500 cc. of water which has just been tinted with the permanganate solution.

Titrate with $N/40$ permanganate solution to original tint and correct result by the volume of $KMnO_4$ required for a blank containing the same quantity of HCl (diluted), adding 2 or 3 drops of stannous chloride to the hot solution, cooling, adding 10 cc. of mercuric chloride and titrating similarly.

When the rock solution contains carbonaceous matter it is necessary first to oxidize this with a little potassium chlorate, evaporate to dryness to eliminate chlorine, and redissolve with 5 cc. conc. HCl and about 10 cc. of water.

Calculate the Fe_2O_3 found to $FePO_4$, using the factor 1.8898, and after deducting from the weight of combined phosphates found, calculate the difference ($AlPO_4$) to Al_2O_3.

F. K. CAMERON A. J. PATTEN
J. E. BRECKENRIDGE C. H. JONES } COMMITTEE ON RESEARCH AND ANALYTICAL METHODS
PAUL RUDNICK, *Chairman*

AMERICAN ELECTROCHEMICAL SOCIETY
TWENTY-SEVENTH GENERAL MEETING
ATLANTIC CITY AND PHILADELPHIA, APRIL 22-4, 1915

The Twenty-seventh General Meeting of the American Electrochemical Society was held at Atlantic City, N. J., and Philadelphia, Pa., April 22-4, 1915. The meeting opened in Atlantic City with headquarters at the Hotel Chalfonte. Sessions on the 24th were held in the Harrison Laboratory, of the University of Pennsylvania, Philadelphia.

PROGRAM OF PAPERS

The American Electrochemical Society in Its External Relation. Presidential Address. F. A. LIDBURY.

Some Mechanical Analogies in Electricity. Experimental Lecture. W. S. FRANKLIN.

Efficiency of Light Production. H. E. IVES.

Experimental Lecture in the Harrison Laboratories, University of Pennsylvania. E. F. SMITH.

1. **Depolarization in LeClanché Cells.** M. DE KAY THOMPSON AND E. C. CROCKER.
2. **The Thermal Conductivity of Refractories.** BOYD DUDLEY, JR.
3. **Chemistry in the Development and Operation of Flaming Arc Carbons.** W. C. MOORE.
4. **The Formation of Magnesium Suboxide in the Electrolytic Preparation of Magnesium.** F. C. FRARY AND H. C. BERMAN.
5. **Electrodeposition of Smooth Lead from Lead Nitrate Solutions.** F. C. MATHERS AND ASA MCKINNEY.
6. **The Coagulation of Albumin by Electrolytes.** W. D. BANCROFT.
7. **Neutralization of Absorbed Ions.** W. D. BANCROFT.
8. **Fibrox.** E. WEINTRAUB.
9. **Thermo-Electromotive Force of Certain Iron Alloys.** T. E. FULLER.
10. **Calorizing Metals.** W. E. RUDER.
11. **Commercial Nitrogen Fixation.** S. PEACOCK.
12. **Electroplating with Cobalt.** H. T. KALMUS, C. H. HARPER AND W. L. SAVELL.
13. **The Cyanamide Process.** F. S. WASHBURN.
14. **Fixation of Atmospheric Nitrogen.** L. L. SUMMERS.
15. **Cleaning and Plating in the Same Solution.** O. P. WATTS.
16. **Some Problems in Copper Leaching.** (General Discussion.)
17. **On the Temperature of Reaction between Acheson Graphite and Magnesia.** O. L. KOWALKE AND D. S. GRENFELL.
18. **Lighting of Electrolytic Tank Rooms.** R. E. HARRINGTON.

The annual business meeting of the Society and the announcement of the election of officers for the coming year were held at the opening of the Thursday (22nd) afternoon session. Following the lecture by Prof. Franklin, Thursday evening, an informal social meeting was enjoyed in the Café Alamac.

The morning session on the 24th was a joint session with the Illuminating Engineering Society, while that in the afternoon was held with the American Electroplaters' Society. The laboratories and museums of the University of Pennsylvania were visited by the members and guests.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
TENTATIVE ITINERARY TO SAN FRANCISCO

LEAVE	AUG.		ARRIVE	AUG.	
New York	6	5.04 P.M.	Chicago	7	2.00. P.M.
Chicago	7	6.00 P.M.	Colo. Springs	9	7.00 A.M.
Colo. Springs	10	6.45 P.M.	Grand Canyon	12	1.50 A.M.
Grand Canyon	12	8.00 P.M.	San Diego	13	6.00 P.M.
San Diego	15	11.59 P.M.	Los Angeles	16	3.30 A.M.
Los Angeles	19	7.30 A.M.	Santa Barbara	19	11.00 A.M.
Santa Barbara	19	11.20 P.M.	Del Monte	20	7.20 A.M.
Del Monte	20	1.43 P.M.	San Francisco	20	4.00 P.M.
San Francisco	21	9.40 P.M.	Yosemite	22	10.45 A.M.
			San Francisco	25	8.28 A.M.

Monday, Aug. 16 to *Thursday*, Aug. 19—Excursions, sightseeing trips and joint session with the Southern California Section of the American Chemical Society.

Saturday, Aug. 21 to *Wednesday*, Aug. 24—Members may visit the Fair for three days or take the trip to the Yosemite Valley.

Wednesday, Aug. 25 to *Saturday*, Aug. 28—Excursions and sessions of the Institute at the University of California and Leland Stanford University.

Members have the option of leaving San Francisco on Saturday, Aug. 28 at 10.30 A.M. by steamer for Astoria, reaching Portland on Sunday, Aug. 29, at 5 P.M., remaining in Portland one day and reaching Seattle on Tuesday, Aug. 31 at 6.50 A.M., in time for the meeting of the American Chemical Society.

Members may also go by rail from San Francisco to Portland by the Southern Pacific Shasta route, a very beautiful scenic trip, but must decide at time of purchase of ticket from starting point, or take the following schedule:

LEAVE			ARRIVE	SEPT.	
San Francisco	Aug. 31	10.30 A.M.	Portland	1	5.00 P.M.
Portland	Sept. 1	11.30 P.M.	Seattle	2	6.50 A.M.
Seattle	Sept. 2	7.10 P.M.	Butte	3	9.28 P.M.
Butte	Sept. 5	9.30 A.M.	Anaconda	5	10.30 A.M.
Anaconda	Sept. 5	6.35 P.M.			

TRIP TO THE YELLOWSTONE PARK

Arrive Gardiner..............	Mon., Sept. 6	10.15 A.M.
Leave Gardiner..............	Sat., Sept. 11	7.15 P.M.
Arrive Duluth...............	Mon., Sept. 13	2.05 P.M.

FOUR-DAY LAKE TRIP

LEAVE	SEPT.		ARRIVE	SEPT.	
Duluth	14	8.00 P.M.	Buffalo	18	12.30 P.M.
Buffalo	18	7.30 P.M.	New York	19	7.57 A.M.

Members may omit the trip to the Yellowstone Park, arriving at Chicago, *Tuesday*, Sept. 7, 9.00 P.M.

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[1] *Analyst*, **34** (1909), 306.

[2] Barneby has shown that only a short interval of time is necessary between the addition of mercuric chloride and manganese sulfate, if the solution is thoroughly agitated. *J. Am. Chem. Soc.*, **36** (1914), 143.

GIBBS MEDAL AWARD

The Willard Gibbs Medal, for the year 1915, was conferred upon Dr. Arthur A. Noyes, the celebrated physical chemist, at the April meeting of the Chicago Section of the American Chemical Society, held April 16, 1915.

After an introductory address by Chairman Otto Eisenschiml, of the Chicago Section, the medal was presented by Professor Julius Stieglitz, of Chicago University. Following the presentation and acceptance of the medal, informal addresses were made by President W. E. Stone, of Purdue University; Prof. James H. Tufts, representing the City Club; and by President Kenneth Lockett, of the Chicago Tech. Club. The presentation address, and a short abstract of Dr. Noyes' Willard Gibbs Address on "A System of Qualitative Analysis, Including Nearly All the Metallic Elements," are given below. It is expected that the papers dealing with this subject will be published later in the *Journal of the American Chemical Society*.

ARTHUR AMOS NOYES—WILLARD GIBBS MEDALIST, 1915

The Willard Gibbs Medal was founded in 1910 by William A. Converse. After serving for seven years as secretary and one year as Chairman of the Chicago Section, Mr. Converse was compelled by growing business responsibilities to retire from active connection with the Section. In token of his continued interest in its welfare, he donated a sum sufficient to enable the Section to bestow annually a gold medal in recognition and encouragement of eminent research in theoretical or applied chemistry—the recipient to be selected by a competent jury and to be obligated only to the extent of delivering an address before the Section on some topic in his field of research. The medal was called after J. Willard Gibbs, by permission of his nearest surviving relatives. The medal has now been conferred upon five great chemists:

Svante August Arrhenius	1911
William Theodore Richards	1912
Leo H. Baekeland	1913
Ira Remsen	1914
Arthur Amos Noyes	1915

Arthur Amos Noyes was born in Newburyport, Mass., Sept. 13, 1866. He was graduated from the Massachusetts Institute of Technology in 1886 and obtained the Master's degree from the same institution the following year. After a year spent as assistant in analytical and organic chemistry, he went to the University of Leipzig where after two years of study with Professor Wilhelm Ostwald he obtained the doctor's degree. Returning to the Institute he served four years as assistant and associate professor of organic chemistry and in 1899 was made professor of theoretical chemistry; in 1903 he became director of the Research Laboratory of Physical Chemistry. From 1907 to 1909 Professor Noyes was acting president of the Massachusetts Institute of Technology. He is a member of the National Academy of Sciences, and of numerous other scientific societies. During 1904 he was president of the American Chemical Society and served for many years as a member of its board of editors. He is the author of several books in the fields of physical, organic and analytical chemistry, and is especially well known for his many important contributions to the ionic theory and its applications. He is also a member of the editorial board of the *Zeitschrift für physikalische Chemie*.—[W. D. Harkins.]

PRESENTATION ADDRESS

By Julius Stieglitz

Mr. Chairman, Dr. Noyes, Ladies and Gentlemen:

Illustrious men, leaders of thought in our science, have added, by the dignity of their names, to the significance of the award of the Willard Gibbs Medal by the Chicago Section of the American Chemical Society: Svante A. Arrhenius, founder of the theory of ionization; Theodore Richards, genial leader of one of the earliest onslaughts on the secrets of the subatomic world; Leo H. Baekeland, inventor of Velox and Bakelite and through them and their followers dispenser of the pleasures of picture making and of music to millions of art lovers; Ira Remsen, sturdy sponsor for American chemical research in the days when it stood in sorest need of protection—we look with pride on the high purpose which these names show to be underlying the foundation and award of our medal. And tonight we are adding to the luster of the medal by bestowing it on another of those brilliant Americans, whose genius is fast making American chemical research in quality the peer of any in the world. Many of us will recall that when Arrhenius was here and told us his own picturesque story of the history of his theory, he remarked that the very finest work in developing his theory in the way of rigorous measurements was being done in this country in the research laboratory of the Massachusetts Institute of Technology under the direction of Arthur Amos Noyes. With accuracy as its goal and scientific honesty as its talisman, the laboratory of Dr. Noyes has produced classic after classic on the conductivity relations forming the basis of the theory of ionization. Every theory, however brilliant its success may be in its first qualitative and roughly quantitative garb, must, in order to survive and prove its permanent justification, conform ultimately to the test of minutely accurate quantitative measurement. This necessary and vital service to the theory of ionization was undertaken by Dr. Noyes and his associates and has been brilliantly carried out. Last year, in his Faraday address in London, Arrhenius again and again referred gratefully to the value of this work. It is interesting to note that this insistence on the utmost limits of accuracy is becoming the most striking characteristic of the genius of our best American scientists: to mention only a few names familiar to all of us. We saw it in Gibbs in his far-going mathematical analysis of chemical and physical changes; we find it in Michelson, in Richards, in Morley, in Millikan—and again, tonight, in our medalist. This insistence on accuracy is evident in all of the contributions of Dr. Noyes to chemistry: van't Hoff developed a method for determining the order of a given chemical reaction, but van't Hoff's formula was, after all, not a rigorous one and sometimes left one in doubt as to the result: a more reliable formula, based on rigorous analysis, was developed by Dr. Noyes and is displacing van't Hoff's. Accuracy again characterized the searching work of Dr. Noyes on the sensitiveness of indicators, on the correct use and understanding of which the reliability of so much of our technical and scientific research and practice depends.

Undoubtedly it was this same pressing need of accuracy that led Dr. Noyes into the monumental work on which we shall hear him speak tonight: his work on the revision of the methods of qualitative analysis. Bringing to this labor the ardor for exactness combined with a masterly knowledge of the laws of physical chemistry—an advantage not held by his greatest predecessor in this field, Fresenius—Dr. Noyes could be content with nothing less than methods which approach quantitative analysis in accuracy, content with nothing less than a system broad enough to include ultimately the rare as well as the common elements in its scope. He thus escaped the chance for error inherent in older methods, which results from the setting of limitations not recognized by nature.

I cannot close this short review of some of the contributions of our medalist to our science without a grateful recognition of two other important forms of service other than original investigation: Dr. Noyes has been uniquely successful in associating with himself a group of great chemists: Lewis, Whitney, Washburn, Kraus, Bray, Tolman, Harkins are carrying the traditions of accuracy and thoroughness of his laboratory into all parts of our country, in technical as well as scientific fields, in work fertilized by their own brilliant ideas, characterized by the standards of the research laboratory of the Massachusetts Institute of Technology. In the second place, Dr. Noyes has been and is a great teacher of the young, the undergraduate chemist-to-be: like A. W. Hofmann, in his day the greatest teacher of chemistry in the world, Dr. Noyes has insisted on presenting to the beginners in chemistry the new physico-chemical theories in lucid, transparent terms, and, in pursuance of this ideal, he has invented a long series of beautiful lecture experiments on physico-chemical relations—the best we have, which, like Hofmann's, are now incorporated, more or less consciously or unconsciously, into our best elementary courses. These lecture experiments, like the work on the theory of ionization, like the work on qualitative analysis, have already become classics of American chemical endeavor.

To Dr. Noyes:

In consideration of these great contributions to chemistry by you, Dr. Arthur Amos Noyes, as an investigator and as a teacher, the Chicago Section of the American Chemical Society decided to bestow upon you its highest honor, the Willard Gibbs Medal, founded by our service-loving fellow member, Mr. William A. Converse. In the name of the Section, I have the honor to present to you this, the Fifth Willard Gibbs Medal, with the best wishes for, and confidence in, further great productive work on your part on behalf of our common science and country.

ADDRESS OF ACCEPTANCE[1]

By Arthur Amos Noyes

In replying to the address of presentation, Dr. Noyes expressed his deep appreciation of the honor conferred upon him, particularly in being placed in a group with the four great chemists to whom the award has been given on previous occasions, and most of all in being presented with a medal given in the name of America's greatest chemist, Willard Gibbs. He also wished the Section to know how much more he valued such an honor on account of the fact that it came as a token of appreciation from his fellow chemists, of work done in the past.

On account of the fact that the work which he described in his address is still incomplete, even although it is finished in all its essential parts, Dr. Noyes has decided that it will be best at this time to publish only a short abstract written by one of the members of the Section. The work when completed will be published in full.

The driving force which kept him at work during fifteen years of investigation was his feeling of the great need of chemists for a systematic scheme of qualitative analysis to include all of the elements. The lack of such a scheme was most vividly impressed upon his mind when twenty years ago he received from Colorado an ore said to contain uranium. Even by making use of the best methods then available it took three weeks to determine that the rare element present was not uranium but vanadium. This incident he cited to illustrate the difficulties which then lay in the path of chemists when they started out to make analyses for the rare elements by using the isolated statements which were all that could be found in the literature at that time.

Now many of the so called rare elements have been found in such large quantities that they are no longer rare. The reason for the omission of these elements from the ordinary scheme for a qualitative analysis is twofold: (1) the historical development of analytical chemistry; (2) the fact that they are more difficult to detect than most of the common elements. On the other hand, many of these so-called rare elements have come to play an enormously important part in science and industry, and some of them, for example titanium, have been found to be much more abundant in nature than some of the members of the group of the 22 common elements. In steel, tungsten, vanadium, and uranium have found an extensive use; thorium and cerium have come to be enormously important in the making of mantles for gas lighting, while tantalum, and to a greater extent tungsten, have rendered the same service in connection with lighting by electricity.

In papers already published in the *Journal of the American Chemical Society* a revision of the usual scheme of analysis for the common elements has been described, and in this a few of the rare elements have been included. In the present scheme the aim has been to provide for the detection of nearly all of the rare elements as well as the common ones, and at the same time to develop such detailed and explicit instructions that the results of an analysis may be certain if carried out by a chemist of ordinary skill. The aim has been to provide a method which will detect the presence of 1 mg. of any element in a mixture with 500 mg. of any common element or elements, or with 100 mg. of any rare element. It is often stated that a qualitative analysis is unnecessary if a quantitative analysis is to be made, and that the former is only a waste of time. That this is not in general true is proved by the fact that many quantitative analyses are made inexact by a failure to realize the presence of an ele-

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[1] Abstracted, by consent of the author, by Professor William D. Harkins, of Chicago University.

ment which would have been detected easily by the use of the proper methods of qualitative analysis, while on the other hand a qualitative analysis can be so conducted as to enable the proportions of the various elements to be estimated roughly, thus making in many cases a quantitative analysis superfluous.

A former president of the society, Mr. Dudley, spoke on the dignity of analytical chemistry, and now it is necessary that the dignity ofqualitative analysis in particular should be upheld. Why is qualitative analysis so much discredited? This is due to the slack methods usually used in teaching the subject. Thus the manipulation is not given such painstaking attention as is considered necessary in the teaching of quantitative analysis.

In general, in making a qualitative analysis according to the system advocated, 1 g. of the sample is used, since in this case 1 mg. is equal to 1 per cent. However, the strict adherence to the rule that 1 mg. should be detected, is somewhat irrational, since the results of a test depend upon the number of atomic weights of an element present, rather than upon its weight in grams.

The idea of the present presentation of the subject is not to give a method for making a qualitative analysis, but to show rather the character of the research. The systematic treatment of the analytical schemes must be left for the final papers.

A great deal of attention has been paid to an investigation of the methods for the preparation of the solution. Nitric acid is used for the solution of the substance rather than hydrochloric since the latter gives the volatile chlorides or arsenic, germanium, and selenium, and also mercuric chloride, which is somewhat volatile. For the solution of the insoluble residue, hydrofluoric acid is used rather than fusion with carbonates, since the former method not only introduces less foreign substance, but at the same time it removes silicon. This residue is treated with hydrofluoric acid, and then evaporated with nitric acid. After this nitric acid treatment, tin, antimony, tantalum, columbium, titanium, and tungsten are left in the form of insoluble compounds, and the platinum metals and certain iron alloys are found to remain largely undissolved. The residue is heated with hydrofluoric acid, and after filtration the residue of metal is fused with sodium peroxide, which may now be obtained pure, and osmium is distilled off as OsO_4.

The solution is evaporated, concentrated hydrobromic acid is added, and arsenic, selenium, and germanium are distilled off as bromides. This process of distillation is, contrary to the usual opinion, somewhat quicker than the application of methods of filtration. Silver is left in the form of bromide.

Some of the most marked deviations from the usual method of procedure may be mentioned. Thus for the precipitation with hydrogen sulfide the solution is first saturated with the gas in a bottle, a cork is inserted tightly, and the corked bottle is heated for $^1/_2$ to 1 hour in boiling water. Arsenic, antimony, and tin have been removed before this; the platinum metals cannot be completely removed by ammonium sulfide, so the treatment with this latter substance is not used.

In a later part of the analysis, TiO_2 is removed from a residue containing Ta_2O_5, and Cb_2O_5, by boiling with potassium salicylate. The work has now proceeded so far that fairly good separations have been devised for almost every group, and considerable success has been attained in separations of certain of the rare earth elements. Those who have worked on the rare earths have neglected too much methods of separation which depend upon the fact that a number of these elements are capable of existence in several stages of oxidation.

NOTES AND CORRESPONDENCE

NOTE ON REVIEW OF DR. THOMPSON'S "OCCUPATIONAL DISEASES"

Editor of the Journal of Industrial and Engineering Chemistry:

My attention has been called to a review,[1] by W. A. Hamor, of Dr. W. Gilman Thompson's recent work on "Occupational Diseases, etc."

In this review the statement is made that "'Brass Founders' Ague' is more likely due to the inhalation of zinc oxide and not zinc fume." This statement is based on visits made to brass foundries, but zinc works, where this metal is handled in large quantities, were not visited, and those connected with such works, whose opinions and experiences would have been of value, were not consulted. For the past seven years I have been surgeon to one of the largest zinc plants in the country, and have just finished making a thorough physical examination of all of the employees. With this experience I have no hesitation in saying that I have never seen a case of illness which could be directly attributed to zinc.

Sir Thomas Oliver[2] states that zinc is non-toxic and described symptoms seen among brass founders which resemble those which he has seen in workers in copper, especially gastro-intestinal symptoms. Though he states that copper workers seem to be "as healthy as persons following other occupations elsewhere," he distinctly states that copper gives rise to acute attacks of illness, and also states "that animals exposed to oxide of zinc in the form of dust or who receive it in their food over a length of time" show no signs of poisoning. In his visits to the large smelting works at Bleiberg, Belgium, he could not find any evidence of ill-health among the workmen traceable to the zinc itself.

Rambousek, Professor of Factory Hygiene and Chief State Health Officer at Prague,[1] states that "Industrial poisoning, from zinc is unknown. The chronic zinc poisoning among spelter workers described by Schlockow, with nervous symptoms, is undoubtedly to be attributed to lead."

Armit[2] claims having seen a similar syndrome in the case of the inhalation of nickel-carbonyl, iron-carbonyl and cobalt fumes. It is generally conceded that copper has a toxicity, though according to Lehman (quoted by Rambousek) "opinions are divided on this point."

The experience of C. A. Hansen, of the General Electric Company, is worth giving in extenso:

"We have just had an experience here that seems to warrant the publication of this warning to any one who contemplates working with copper, in the electric arc furnace.

"We melted 5000 lbs. of electrolytic copper scrap—uncontaminated except for a small amount of admixed iron—in a three-phase arc furnace of the ordinary steel furnace type, the experiment lasting some five hours. A few hours after pouring off, all of the ten men in the furnace building suffered inconvenience in breathing. For the 24 ensuing hours severe nausea was experienced in each case and a soreness throughout the entire system similar to that of acute grippe.

"Since in all other respects the run resembled an ordinary steel run, I attribute the trouble we experienced to copper which was shown to be present in the furnace fumes. The temperature of the copper bath as a whole at no time exceeded 1300° C., so that probably the copper was volatilized only at points directly beneath the electrodes.

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[1] THIS JOURNAL, **6**, (1914), 871–2.

[2] "Diseases of Occupation," 1907.

[1] Rambousek, "Industrial Poisoning," 1913, translated by Sir Thomas Legge, p. 151.

[2] "Toxicology of Nickel Carbonyl," *Journal of Hygiene*, **7** (1911), 525–551; *Ibid.*, pp. 565–600.

"From the severity of the attack, coupled with the short time we were exposed to the fumes, and that in a building which was well ventilated, I am of the opinion that very serious results might obtain under less favorable conditions.

"I also attach more importance to the above from the fact that in five years of continuous research work on a large scale with furnace processes which involved, among others, tellurium, tellurides, arsenic, arsenides, zinc and sulfide ores, the only physical inconvenience suffered has been an occasional carbon monoxide headache."

The hypothesis that zinc is the cause of "Brass Founders' Ague" is to a large extent based upon the fact that the boiling point of zinc is 915° C., while that of copper is 2200°, and consequently that zinc, and zinc alone, forms the vapor that arises from the brass pot. That this is incorrect is shown by analyses of brass furnace flue dust, which shows as much as 10 parts of copper to 100 of zinc. The microscope also shows that copper is present as a true fume and not as splashes of metal.

The volatility of metals at temperatures well below their boiling points is well established. For example, in the case of common spelter: while lead has a boiling point of 1500° C. spelter made at a temperature of 1200° will contain about 1 per cent of lead. Hoffman, in his "Metallurgy of Copper" (McGraw Hill Book Co., 1914), states that in the case of copper, volatilization is noticeable *in vacuo* at 700°, and decided near the melting point.

(1) The symptoms of this disease are very characteristic and pronounced, and the fact that it is known as "Brass Founders' Ague" shows its close connection with brass. On the other hand, there is no name for this trouble among zinc smelters, and many of them have never heard of its existence.

(2) Hansen's communication is of peculiar interest in that symptoms of a very serious type developed where copper alone was being melted with the same equipment that had been used for zinc without any trouble whatever.

(3) Evidence collected by investigators of world-wide repute is negative as far as the toxicity of the zinc fume met with in spelter works is concerned.

(4) Our own experience in connection both with the manufacture of spelter and the manufacture of zinc oxide, has failed to show any symptoms whatever resembling those of the "spelter shakes." Under these circumstances it seems to me that the connection between zinc oxide or zinc fume and "Brass Founders' Ague" is not proven, and that the balance of evidence is in favor of the trouble being due to the vapor of copper.

THE PALMERTON HOSPITAL
PALMERTON, PA., April 15, 1915

J. W. LUTHER

NOTE ON ANALYSIS OF CHROME YELLOWS AND GREENS

Editor of the Journal of Industrial and Engineering Chemistry:

The April number of THIS JOURNAL, page 324, contains methods of analysis of chrome yellows and chrome greens which, it is believed, do not satisfy the requirements of commercial accuracy, especially in the case of chrome greens.

The method for greens in its essential features was employed for a time in our laboratory, but it was abandoned upon finding that the determination of blue in chrome greens, precipitated in whole or in part on china clay, gave results entirely too high when estimated by difference. The objection to the method of analysis named appears to lie in the presence of combined water in china clay. W. G. Scott, in "White Paints and Painting Materials," page 168, records the observation that when china clay is treated with hot, dilute hydrochloric acid, there is a decided loss in weight of the substance with no appreciable gain in the filtrate, which the observer attributes to combined water. The loss of weight by ignition of china clay has been noted by several chemists, the latest analyses that have come to the writer's notice being those of the Bureau of Standards and Bureau of Chemistry (*Proceedings of the American Society for Testing Materials*, 13, 409) which show a loss on ignition of from 12 to 13 per cent. It is obvious that no little error in the determination of blue would be involved with material of this character, if estimated by difference.

Furthermore, in our experience, the determination of lead as chromate in nitric acid solution is found unreliable in comparison with precipitation in acetic acid.

The quantitative estimation of Prussian blue from the percentage of iron, in all ordinary kinds of chrome greens, has proved fairly satisfactory, in all events more accurate than by the method of difference.

DAYTON, OHIO
April 16, 1915

THE LOWE BROTHERS COMPANY
Per L. H. MCFADDEN

ARREST OF PLATINUM THIEF

Upon a description furnished by the Bridgeport Testing Laboratory, a suspected platinum thief was arrested March 6th at the laboratory of Arthur D. Little, Inc., Boston, and was later identified by Mr. F. C. Barrows, of Bridgeport, Conn., as the man who had visited the Bridgeport Hydraulic Laboratory and the Bridgeport Testing Laboratory immediately prior to their discovery of the loss of a considerable amount of platinum.

When the man was searched, a flattened platinum crucible, from which the number had been cut, was found tucked between the slide and cover of a box of safety matches. The man was found to have a criminal record and to have served a State Prison term. He was held for the Grand Jury which, however, for lack of evidence failed to bring a bill against him.

The man was about 35 years old, with prominent nose, peculiar eyes, reddish hair, and freckles. He speaks with a down-East accent. His height is about 5 ft. 9 in., and his weight about 175 pounds. He gave the name of Rubin.

A few days ago an assay balance was stolen from the laboratory of Henry Carmichael at 15 Exchange Street, Boston.

The description published in THIS JOURNAL, 7 (1915), 358, in a note from the Hahnemann Medical College, leaves little doubt that the man is the same who was reported as operating in Philadelphia.

PERSONAL NOTES

Dr. Ira Remsen, president emeritus of Johns Hopkins University, will deliver the principal address at the formal opening of the new chemistry building of the University of Minnesota, on May 24th.

The address to the graduating class of the Michigan College of Mines was given this year by Prof. James F. Kemp, of Columbia University, on April 16th.

A pamphlet, prepared under the direction of the Chemists' Committee of the United States Steel Corporation, on the Sampling and Analysis of Alloy Steels is now being distributed to its various chemical laboratories. This makes the fifth pamphlet so distributed, the purpose of which is to unify and simplify methods of analyses. The first four pamphlets covered the Sampling and Analysis of Iron Ores, Pig Iron, Plain Steel and Gases. To curtail the requests for copies of these pamphlets a charge of one dollar each is now being made, to persons and firms outside the Corporation. Mr. J. M. Camp, Carnegie Building, Pittsburgh, Pa., is chairman of the committee.

Mr. Watson Smith, retiring Editor of the *Journal of the Society of Chemical Industry*, was entertained at dinner, on February 23rd, by members of the Council and Publication Committee. Opportunity was taken to present to him, as a souvenir of his 33 years' service as Editor of the Journal, an album containing a short address signed by the President and all available Past Presidents, the Members of the Council and Publication Committee, and the Abstractors. At the request of the President, the presentation was made by the Dean of the Chemical Press, Sir William Crookes, O.M., F.R.S.

The Southern California Section of the American Chemical Society through its President, Edgar Baruch, 804 Wright and Calendar Bldg., and its Secretary, H. L. Payne, 223 W. 1st St., Los Angeles, extends its welcome and hospitality to all members of the Society visiting the Expositions and Los Angeles this year.

At the annual meeting of the London Chemical Society, held on March 25th, the new officers elected were: *President*, Dr. Alexander Scott; *Vice-President*, Prof. F. R. Japp and Prof. R. Threlfall; *Treasurer*, Dr. M. O. Forster; *Ordinary Members of Council*, Mr. D. L. Chapman, Prof. F. G. Donnan, Mr. W. Macnab and Dr. J. F. Thorpe.

At the regular meeting of the Cincinnati Section of the A. C. S. on April 21st, the following papers were presented: "General and Historical Discussion of the Soap Industry," by Howard Dock; "The Manufacture of Laundry Soaps and Soap Powders," by A. Campbell; "The Manufacture of Glycerine," by C. P. Long.

Prof. Richard S. McCaffery presented a paper on "Some Defects in Steel Ingots," before the Wisconsin Section of the A. C. S. on April 21st.

Emil E. Lungwitz, chemical and industrial engineer located in New York City, announces a change of address from 80 Maiden Lane to 30 Church Street, to take effect May 1, 1915.

The second delivery of radium from the plant of the National Institute, being operated by the Bureau of Mines in Denver, has been made to the officers of the Institute. It consisted of 300 mg. of radium bromide having a market value of approximately $19,000. This delivery of radium bromide is a small fraction of the radium extracted from the first 240 tons of ore treated in the experimental plant first erected. The crystallization of the radium itself has not kept pace with the extraction from the ore, owing to the impossibility to obtain from abroad certain special apparatus not manufactured in this country. Deliveries will gradually increase until they are equal to the capacity of the combined plants which is approximately three tons of ore per day.

Notice has been given by the Society of Chemical Industry that the Annual General Meeting will be held in Manchester, England, on Wednesday, July 14th.

President Butler, of Columbia University, has announced an anonymous gift of $30,000 to be used in the reconstruction and new equipment of the laboratories of quantitative, organic and engineering chemistry in Havemeyer Hall.

Dr. Julius Stieglitz, professor of chemistry and director of analytical chemistry in the University of Chicago, has accepted an invitation to give courses in chemistry at the University of California during the summer term that begins June 21st and closes on August 1st. Prof. Stieglitz will give a seminar on special topics in organic chemistry and also a college course in organic chemistry.

Dr. Frederick Winslow Taylor, of Philadelphia, past president of the Society of Mechanical Engineers, known for his inauguration of methods of "scientific management," died on March 21st at the age of sixty-nine years.

Franklin C. Gurley, a graduate assistant in chemistry at the Massachusetts Agricultural College, has accepted a position as chemist with the Benzol Products Company of Philadelphia.

Dr. Augustus H. Gill, professor of technical analysis at the Massachusetts Institute of Technology, addressed the Detroit Engineering Society on March 19th, on "Lubricating Oils: Essentials and Characteristics."

Mr. George A. Rankin, of the Geophysical Laboratory, Washington, D. C., spent the week of April 12th in the Lehigh Cement District, making measurements of the actual working temperatures in the clinkering zones of Portland cement kilns.

The following members were present at the meeting of the Council at the New Orleans Meeting of the A. C. S., March 31st to April 3rd: Charles Baskerville, B. C. Hesse, E. J. Crane, Charles E. Coates, H. E. Howe, J. H. Long, Frank N. Smalley, Edward Bartow, D. K. French, W. A. Noyes, William Brady, W. D. Richardson, W. D. Bigelow, B. B. Ross, Floyd W. Robison, Charles A. Catlin, J. S. Goldbaum, F. E. Tuttle (substitute), C. G. Derick (substitute), L. F. Nickell, E. H. S. Bailey, Frank R. Eldred, Harry McCormack, L. H. Baekeland, George N. Prentiss (substitute), A. D. Little and Frank R. Cameron.

Prof. H. P. Talbot, of the Massachusetts Institute of Technology, lectured on "The Noble Gases," on March 25th before the Phi Lambda Upsilon of Columbia University.

The Pittsburgh Section of the A. C. S. is planning Saturday afternoon excursions to some of the manufacturing plants around Pittsburgh.

The Dorr Cyanide Machinery Co. announce that after May 1st, 1915, the address of their New York office will be Room 2843, Whitehall Bldg., New York City.

GOVERNMENT PUBLICATIONS

By R. S. McBride, Bureau of Standards, Washington

NOTICE—Publications for which price is indicated can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Other publications can usually be supplied from the Bureau or Department from which they originate. Consular Reports are received by all large libraries and may be consulted there, or single numbers can be secured by application to the Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington. The regular subscription rate for these Consular Reports mailed daily is $2.50 per year, payable in advance, to the Superintendent of Documents.

BUREAU OF FISHERIES

Report on Alaskan Investigations in 1914. E. Lester Jones. 155 pp. Paper, 50 cents. The investigations reported on relate principally to the fisheries but some attention is given to fur-bearing animals. The salmon industry is covered at length with discussion of modes of catching, canning and shipping.

BUREAU OF FOREIGN AND DOMESTIC COMMERCE

Canned-Tomato Industry in Italy. J. Alexis Shriver. Special Agents Series 93. 23 pp. Paper, 5 cents. This report gives interesting comparisons with the business as it is carried on in the United States, including a description of the varieties cultivated, modes of culture and methods of canning with suggestions of considerable interest to American packers.

Canned-Goods Trade in the Far East. J. Alexis Shriver. Special Agents Series 92. 78 pp. Paper, 10 cents. This report gives a detailed description of the markets for canned goods and the nature of competition to be expected and suggestions of interest to American packers as to development of trade.

Dyestuffs for American Textile and Other Industries. Thomas H. Norton. Special Agents Series 96. 57 pp. Paper, 10 cents. This extensive review of trade conditions was prepared in response to a resolution of the United States Senate. The dyestuff situation in the United States is discussed with summaries of the consumption of dyes, an outline of the coal tar chemical industry and coal-tar dye industry in so far as these are in existence in the United States and a summary of the supply of raw materials and general chemicals required for the development of the industry. The German industries of this general group are also explained and the processes of manufacture outlined. Particular emphasis is laid upon the American attitude toward the German industry and the economic necessity for a very complicated system if the dyestuff industry is to be developed in America. A considerable amount of the material presented duplicates that given before the New York Section of the American Chemical Society, particularly the reports which have been prepared by Dr. B. C. Hesse.

COMMERCE REPORTS—MARCH, 1915

The **corundum** industry of India is discussed. (P. 822.)

In the past most of the **vegetable-oil seeds** from India have been shipped to other countries, though some oil has been extracted in India. Among the oil-bearing materials exported are linseed, peanuts, rape seed, sesame, cottonseed, castor beans, copra, mahwa seed, poppy seed, mustard seed, and nigar seed. Efforts are being made to increase the oil production in India. (Pp. 828–31.)

The Swedish **iron industry** is almost paralyzed. (P. 857.)

The value of potatoes raised in Ireland is too high to warrant their use in the manufacture of **alcohol.** (P. 861.)

The **soy-bean** industry of Manchuria is discussed. (P. 863.)

Statistics of the **copper industry** in Austria are given. (P. 882.)

Prospects for **petroleum** in Papua are favorable. (P. 883.)

Canada has just put into effect a **white-phosphorus match** law. (P. 888.)

Norway has placed an embargo on **copper** and **brass.** (P. 897.)

A **beet-sugar** factory is proposed for Gloucestershire, England. (P. 899.)

The milling of **rape seed** and **soy beans** in Japan has increased because of the war. (P. 941.)

Statistics of the Russian **petroleum** industry are given. (P. 945.)

The embargo on **rattan** from Singapore has been removed with respect to America. (P. 945.)

Methods of mining **coal, sulfur,** and **petroleum** in Tuscany, Italy, are described. (P. 952.)

Owing to a shortage of vessels, the **trade of the Philippines** is practically paralyzed. The suggested use of United States colliers to relieve the situation is against existing laws. (P. 963.)

The Japanese **iron industry** is improving. (P. 971.)

Spain has placed am embargo on **potash.** (P. 977.)

France has placed an embargo on all **lenses** for optical instruments. (P. 993.)

The **Portland-cement** industry of Alberta, Canada, is described. (P. 996.)

The British **cyanide industry** produces large amounts of export, the largest factory being in Glasgow. (P. 998.)

The Standard Oil Company is equipping a new **candle factory** in Tientsin, China, with a daily capacity of 400,000 candles. (P. 1003.)

Efforts are being made to increase the output of **benzol** and **toluol** from by-product coke ovens in Canada. (P. 1010.)

Old abandoned **copper mines** of Cyprus are being reopened. (P. 1017.)

The **sugar industry** of the Philippines is increasing. (P. 1020.)

A **camphor-bearing plant,** "Blumes balsamfera," has been discovered growing in abundance in the Philippines, and efforts will be made to utilize it. (P. 1022.)

The German **pottery industries,** and especially the use of continuous kilns (Kanalofen), are described in some detail. (Pp. 1028–31.)

The Philippine **copra industry** is improving. (P. 1048.)

Additions to the British absolute contraband list include **tin, tin chloride, castor oil, paraffin, copper iodide, lubricants, hides, ammonia and ammonium salts, urea,** and **aniline.** (P. 1057.)

Aniline oil and **salts** have been placed on the British embargo list. (P. 1058.)

The Brazilian **monazite** industry is described in some detail. (Pp. 1059–62.)

The British importation and crushing of **oil seeds,** including castor, cotton, flax and rape seeds, soy beans and copra, shows an increase. (Pp. 1069 and 1220.)

The export of **senna** from Egypt has been prohibited except to the United Kingdom and France. (P. 1073.)

The nut of the tree known as "Chisochiton cuningianus" contains 45 per cent of an oil suitable for **soap making.** (P. 1088.)

The **metric system** has been adopted in the new British Pharmacopoeia. (P. 1103.)

Italy is experiencing a great shortage of **dyestuffs.** (P. 1108.)

The Scotch **shale-oil** industry is flourishing, there being a great demand for the oil, **paraffin,** and **ammonium sulfate.** (P. 1108.)

Sales of **cottonseed meal** in Canada for stock food are increasing. (P. 1141.)

The **kelp industry** of British Columbia is to be placed under government supervision. (P. 1152.)

The embargo on **graphite** from Ceylon to the United States has been removed. (P. 1153.)

RECENT DEMANDS FOR AMERICAN GOODS

SPAIN—821
Coal

ALGERIA, CANADA, CHINA, and IRELAND—838-43
Window glass
Plate glass
Mirrors
Cut glass

INDIA—850, 862
Glass
Matches

SIBERIA—893
Matches
Paints
Tanning materials

ENGLAND—901, 908
Hardware
Steel billets
Brass
Gold plate
Bronze
Glass

CANADA—990
Cottonseed meal

SOUTH AMERICA—1055
Soap

COLUMBIA—1099
Drugs
Caustic soda
Sodium silicate

IRELAND—1266
Gypsum
Metal lath
Plaster board

The mineral industries of Brazil include **iron, manganese, coal, copper, diamonds,** and **semiprecious stones.** (P. 1163.)

The fiber of the water hyacinth in French Indo-China has been used in the manufacture of rope, twine, matting, as a substitute for rattan, and as a fuel. (P. 1182.)

The condition of the **rubber industry** in England is discussed. (P. 1190.)

An embargo has been placed on **tin** from the Straits Settlements to other than British ports. (P. 1201.)

Imports of **potash salts** except carbonate and cyanide into the United States show a marked falling off. (P. 1202.)

Indications of oil in Chile are promising. (P. 1239.)

Efforts are being made to cultivate the Japanese **camphor** tree ("cinnamonium camphora") in the Malay States. (P. 1243.)

New fuels being used for German automobiles include mixtures of **gasoline, benzene,** and **alcohol;** 25,000 automobiles have been ordered to cease operating. (P. 1271.)

STATISTICS AND OTHER INFORMATION REGARDING EXPORTS TO THE U. S.

WINNIPEG—Sup. 23*a*
Fertilizer
Glycerine
Flaxseed
Hides
Paper
Paper pulp
Pulp wood
Seneca root
Sulfur ore

NICARAGUA—Sup. 34*a*
Dyewoods
Gold
Hides
Rubber
Silver
Sugar

ARGENTINE—Sup. 38*a*
Hides
Linseed
Quebracho
Sugar
Tallow
Copper
Fertilizer
Bones

SHEFFIELD—Sup. 19*a*
Pipe clay
Chemicals
Cutlery
Electroplate (silver, etc.)
Glass
Glue
Grindstones
Platinum
Steel

BRAZIL—968, 1156
Ipecacuanha
Hides

OTTAWA—Sup. 23*b*
Gold
Hides
Mica
Paper
Pulp wood
Wood pulp
Corundum

BRITISH COLUMBIA—Supplement 23*c*
Brewers' grits
Bullion
Explosives
Fertilizer
Glycerine
Hides
Copper
Gold
Tin
Silver
Coal
Whale oil

CARDIFF—Sup. 19*a*
Glue
Cardboard
Paper
Steel plates

HUDDERSFIELD, ENGLAND—Sup. 19*b*
Chemicals
Copper
Dyes
Explosives
Iron and steel
Hides
Soluble starch

DUBLIN—Sup. 19*d*
Hides
Liquors

NOTTINGHAM, ENGLAND—Sup. 19*c*
Artificial silk
Cement
Glue
Leather
Hides
Sod oil
Stoneware
Oxide of iron
Rotten stone
Umber

SWEDEN—Sup. 16*a*
Ammunition
Hides
Iron and steel
Ferro-manganese
Ferro-silicon
Matches
Paper
Caustic soda and potash
Wood pulp
Cocoa butter
Enameled ware
Milk powder
Pine tar

BOLIVIA—1252
Hides
Peruvian bark
Rubber

DENMARK—Sup. 4*a*
Casein
Cinematograph films
Flint pebbles
Glycerine
Hides
Safety matches
Rennet
Soya bean oil

The tin industry of the Malay States has fallen off greatly. (P. 1290.)

Special supplements issued in March include the following:

CANADA
Prairie Provinces—23*a*
Ottawa—23*b*
British Columbia—23*c*
Nicaragua—34*a*
Malaysia—56*b*
Sweden—16*a*
Denmark—4*a*

UNITED KINGDOM
Huddersfield—19*b*
Nottingham—19*c*
Ireland—19*d*
Cardiff and Sheffield—19*a*
Turkey—Harput—18*a*
Argentina—38*a*

BUREAU OF STANDARDS

Electric Wire and Cable Terminology. ANONYMOUS. Circular 37, 2nd edition. 13 pp. A revision with minor changes.

Temperature Coefficient of Magnetic Permeability within the Working Range. RAYMOND L. SANFORD. Scientific Paper 245. 10 pp. It is shown that errors of large magnitude may be introduced by neglecting the temperature coefficient of magnetic permeability.

GENERAL SUPPLY COMMITTEE

Specifications and Proposals for Supplies for Executive Departments and Other Government Establishments for the Fiscal Year 1916. These specifications and forms for proposals to supply materials are of interest in some cases to the chemical industry. The various classes which contain items of chemical interest are as follows: Class 1, stationary and drafting supplies. Class 2, hardware, metals, leather and saddlery. Class 5, laboratory apparatus, hospital appliances and surgical instruments. Class 6, electrical, engineering, and plumbing supplies. Class 8, brushes, glass, lubricants, painters' supplies, and paints. Class 9, furniture and floor coverings. Class 12, photographic supplies, meteorological instruments, etc. Class 13, engraving, printing, and lithographic supplies.

These specifications can be secured on application to the General Supply Committee by those interested in offering bids. Some of the contracts have already been closed and others are still open. Full information can be had from the General Supply Committee, Washington, D. C.

TREASURY DEPARTMENT

Lubricant-Standard Specifications. Department Circular 42. 1 p. This circular calls attention to the regulations regarding sampling of all deliveries of lubricants. Each delivery whether accepted or not must be sampled and the sample forwarded to the Bureau of Standards for test, with a statement of use for which the oil was intended and whether or not it was satisfactory with statements as to the cause of rejection if delivery is not accepted. Persons contemplating delivery of lubricants to any Federal official should take account of this regulation.

PUBLIC HEALTH SERVICE

Efforts to Curb the Misuse of Narcotic Drugs. MARTIN I. WILBERT. Public Health Reports, 30, 893–924. This is a comparative analysis of the Federal and State laws designed to restrict or to regulate the distribution and use of opium, coca, and other narcotic or habit-forming drugs. There is included a detailed review of each of the laws now in force. The part of particular interest to chemical dealers is the summary of the drugs which are included under the provisions of each of these regulations. In this connection see also an article entitled:

"Harrison Anti-Narcotic Law—The Effect of Its Enforcement on the Drug Addict." MURRAY GALT MOTTER. Public Health Reports, 30, 979–81.

Foot and Mouth Disease. ANONYMOUS. Public Health Reports, 30, 892–93. A brief discussion of the relation of this disease to public health with particular emphasis of the possibilities of the conveyance of the disease in milk and a discussion of the efficiency of pasteurization for preventing the transmission.

Quinine To Be Sold at Cost in Venezuela. ANONYMOUS. Public Health Reports, 30, 981. A note to the effect that the Venezuelan government is contemplating distribution and sale of quinine at cost in order to extend the use of this drug and to ensure a good quality.

DEPARTMENT OF AGRICULTURE

Net Energy Values of Feeding Stuffs for Cattle. HENRY PRENTISS ARMSBY AND J. AUGUST FRIES. Journal of Agricultural Research, 3, 435–92. This is an extended summary of the result of 76 experiments with the respiration calorimeter upon 9 steers in which the balance of matter and of energy was determined.

Commercial Fertilizers, Their Composition and Use. EDWARD B. VOORHEES. Farmers' Bulletin 44. A new edition reprinted without changes. Paper, 5 cents.

The Eastern Hemlock. E. H. FROTHINGHAM. Department Bulletin 152. 43 pp. Paper, 10 cents. This Bulletin describes the more important characteristics of the hemlock, presents tables of its volume and rate of growth and gives important facts regarding the range, commercial value, utilization, and amount of standing, with many statistics of this valuable forest product.

Para-Dichlorobenzene as an Insect Fumigant. A. B. DUCKETT. Department Bulletin 167, from the Bureau of Entomology. 7 pp. Paper, 5 cents. This report gives directions for the use of *p*-dichlorobenzene both as an insecticide and as a fumigant with a discussion of costs.

Injury by Disinfectants to Seeds and Roots in Sandy Soils. CARL HARTLEY. Department Bulletin 169, from the Bureau of Plant Industry. 35 pp. Paper, 5 cents. This is a report on preliminary tests of disinfectants in controlling damping-off in various nursery soils.

The Production and Consumption of Dairy Products. EUGENE MERRITT. Department Bulletin 177, from the Bureau of Crop Estimates. 19 pp. Paper, 5 cents. This bulletin outlines the changes in geographic distribution of the dairy industry and gives information concerning the consumption of dairy products on farms and in cities. It includes a statistical review of the subject, with comments on the influencing factors. It is of interest to those engaged in any phase of dairying or the distribution of dairy products.

Agricultural Alcohol: Studies of Its Manufacture in Germany. EDWARD KREMERS. Department Bulletin 182, from the Bureau of Plant Industry. 35 pp. Paper, 5 cents. This report discusses the problems of manufacture, the economic situation.

capacity, taxes, marketing sources, etc., with statistics. The report brings out the fact that "the success of agricultural alcohol in Germany is the result of long-continued experiments, backed by a determination on the part of those high in authority that the project should succeed."

Ammonification and Nitrification in Hawaiian Soils. W. P. Kelley. Bulletin 37. Hawaii Agricultural Experiment Station. 52 pp. Paper, 10 cents.

GEOLOGICAL SURVEY

The Inorganic Constituents of Echinoderms. F. W. Clarke and W. C. Wheeler. Professional Paper 90–L. 9 pp.

Springs of California. G. A. Waring. Water Supply Paper 338. 410 pp. "As a basis for the discussion of springs and spring waters of California this paper opens with a brief outline of the physical features of the State, together with a few notes on the character of the rocks and their structure, then proceeds to explain the usual or possible composition and properties of most natural waters as well as the source of their constituent substances, and concludes with discussions of the springs of California classified under the following groups: hot, carbonated, sulfur, saline, magnesic, iron, artesian, large cold, and minor perennial springs. Accompanying the discussions of many of the springs are analyses of their waters, and at the end of the book are two tables, one of which gives an alphabetic list, by counties, of the best-known springs of the State, with name of owner, location, temperature, and yield, and the other a list of California spring resorts."

Underground Waters of the Coastal Plain of Georgia. L. W. Stephenson and J. O. Veatch, with a Discussion of the Quality of the Waters, by R. B. Dole. Water Supply Paper 341. 539 pp. "Gives the results of investigations made to determine the composition, structure, and stratigraphic relations of the formations of the Coastal Plain of Georgia and the geologic position, quality, quantity, and economic adaptability of the waters they contain." It is concluded that "all the underground waters of this province may be used advantageously for domestic and industrial purposes, although those from the later formations may require a little softening. The surface waters of this section are even better for industrial use than the ground waters, because they are lower in mineral content."

NAVY DEPARTMENT

Description of Navy Standard Boiler Water-Testing Outfit and Instructions for Use. Revised edition. 12 pp. A brief and simple description of methods and apparatus for alkalinity test and chlorine test of boiler water is given.

BUREAU OF MINES

Probable Effect of the War in Europe on the Ceramic Industries of the United States. A. S. Watts. Technical Paper 99. 15 pp. Paper, 5 cents. This report discusses the sources of china clay, ball clay, cornwall stone, chert pebbles for grinding, and indicates the probable effect of the war on the mining and transportation of these supplies. The white-clay resources of the United States are also discussed with suggestions as to the possibility of substituting domestic product for those formerly imported. The value of imports and extent of domestic trade are indicated.

WAR DEPARTMENT

Report on Fuel Tests and Issue of Fuel, 1914. Frank T. Hines and Others. War Department Document 473. 145 pp. and 18 maps. Cloth, $1.00. This report is principally of interest in connection with the question of utilization of fuel for heating of residences, apartment buildings and other buildings of similar heat requirements. There is included a set of maps giving zones of equal temperature over the United States for the various months of the year and averages for different seasons and a map showing the mean annual temperature in different parts of the Philippine Islands.

BOOK REVIEWS

Chemistry of Cyanogen Compounds. By Herbert E. Williams. Published by P. Blakiston's Son & Co., Philadelphia, Pa. No illustrations. 423 pp. Price, $3.50 net.

In the 27 chapters which make up the body of this work the author has compiled practically all the information available on the chemistry of cyanogen compounds, and has used unusual judgment in his abstracting, evidently having checked most of his information personally; there is little inserted in the book that is not of value, and much has been left out that is found in the usual dictionary or similar compilation that should never have appeared in print in permanent form because of inaccuracy.

The chapters on Simple Cyanides and the Iron Cyanogen Compounds forming Part I are particularly interesting because these seem to be the special field in which the author did most of his laboratory work, and we have, therefore, a catalogue here of these compounds, more complete than anything heretofore published, and as far as the reviewer can check the same, very much more authoritative. The book is worth its purchase price alone for this extremely valuable listing and description of the general properties of the cyanogen compounds.

There have been a number of treatises which have recently appeared on the manufacture and application of cyanogen compounds, and the 100 pages of Mr. Williams' book devoted to this portion do not balance up well with some of the very recent publications nor with the rest of his own book; he has not exercised the same care in choosing his processes of manufacture that he has in cataloguing the properties of his compounds. While the information given in Part II on Manufacture is carefully chosen from the standpoint of accuracy, it does not always present the most modern and standard practice.

In Part III of the work, covering the detection and estimation of cyanogen compounds, the methods of determination have again been very carefully chosen and compare in this respect with the catalogue of compounds in Part I. Many of the methods here described are in use in the reviewer's laboratory and are giving excellent results.

The arrangement of the work is excellent, and leads to very ready reference to the subject matter contained. Such quick reference is particularly assisted by the extremely liberal use of heavy font type for designating the various compounds discussed, and the chapter headings and special divisions stand out most prominently in this heavy type.

The literary style is excellent, and the author is to be complimented upon the clearness with which he has presented certain of the complicated chemistry of this field.

One of the most valuable features of the book is the care which has been taken to reproduce reference to the original sources of the information, a task which has too often been shirked in cases of preparing a mere catalogue of chemical compounds.

On the whole, the work certainly demands a place in every working library concerned with cyanogen compounds, for it is so complete in itself that it will largely supplant reference to the unwieldy periodicals, and is far superior, from the purely chemical standpoint, to anything which has heretofore appeared on cyanogen compounds, but it must not be misunderstood as replacing several of these recent works which concern themselves solely with the industrial phase.

W. S. Landis

The Iron Ores of Lake Superior. Second Edition by Crowell & Murray, Chemists and Metallurgists, Cleveland, Ohio. Pp. 258 + v. The Penton Publishing Co., Publishers, Cleveland, O. Price, $3.50.

The authors, in the second edition, have corrected and redrawn the maps, rewritten much of the general matter, secured the latest descriptions of the mines on the different ranges and added data concerning their locations.

The book contains facts of interest relating to the mining and shipping of iron ores and is a very useful reference volume.

William Brady

Dyestuffs: Lehrbuch der Farbenchemie. By Dr. Hans Th. Bucherer, Direktor der Chemischen Fabrik auf Actien in Berlin. Published by Otto Spamer, Leipzig, 1914. 557 pp. Price, 22 Marks.

This book is a greatly enlarged edition of Dr. Bucherer's smaller handbook on the same subject which appeared several years ago. The subject matter is divided in the general method of all such books, into three parts: the first dealing with the raw materials including a good deal of matter relating to distillation of various kinds of tars, the second relating to the intermediate products derived from the previous raw materials, and the third dealing with the synthetic methods for the preparation of various classes of dyestuffs. The chemistry relating to methods of preparation of the intermediate products in this book is given in a very complete manner and takes up over 160 pp. The subject is dealt with, however, in a rather general manner and the manufacturer or works chemist would refer to this volume in vain for definite methods of manufacturing specific products. The same is also true of the third and main section relating to the dyestuffs themselves. The matters are gone into with the usual German thoroughness regarding theoretical considerations and relations, such, for instance, as the relation between color and constitution, to which subject alone thirty-three pages are devoted. There is, however, a distinct lack of definiteness in describing the methods for the preparation of the dyestuffs, and very little concerning factory practice is given. Indeed, this side of the subject, which is really the most valuable from the practical point of view, is entirely neglected. In fact, this book of Bucherer's is rather an extensive discussion of the general chemistry of dyestuffs and the methods of sulfonation, nitration, halogenation, etc. In this sense it cannot but be of considerable help to any chemist interested in the manufacture of dyes as the matter is put before the reader in a rather concise and simple manner and the author even goes so far as to give the synthetic methods, by various simplified diagrams, of how one product is derived from another. Also a very large number of structural formulas are given including the more important dyestuffs and the reactions which are usually given in terms of their structural formulas throughout, so that the reader can easily follow the synthesis of the product in question. This helps a great deal in the understanding of these complicated organic reactions as the reader is enabled to more or less visualize the bodies entering into the reaction and can thus follow more intelligently the up-building of the synthetic product than if the formulas of the different substances were merely given in their empiric form.

On the whole, this book is rather complete in its presentation of the subject if we consider that subject limited to the pure chemistry of the dyestuffs, and this, of course, limits the usefulness of the book to the technical chemist. It is a book primarily to be employed as a text-book for the student rather than as a technical handbook for the works chemist. It also requires that the reader should be well drilled in rather advanced organic chemistry; but in the hands of such a student it will have a distinct value in developing his knowledge of this special field.

J. Merritt Matthews

NEW PUBLICATIONS

By John F. Norton, Massachusetts Institute of Technology, Boston

Agriculture: The Chemistry of Agriculture: for Students and Farmers. By C. W. Stoddart. 8vo. 364 pp. Price, $2.00. Lea and F., Philadelphia.

Bio-chemistry: Chimie Biologique médicale. By J. Vile and E. Derrien. 8vo. 400 pp. Price, $1.25. Paris.

Blowpipe Analysis: Lötrohrprobierkunde, Anleitung zur qualitativen u. quantitativen Untersuchung mit Hilfe des Lötrohres. By H. Krug. 8vo. 88 pp. Price, $1.00. Berlin.

Chemistry: A Manual of Chemistry, Theoretical and Practical, Inorganic and Organic. By A. P. Luff and H. C. H. Candy. 2nd Ed. 12mo. 680 pp. Price, $2.25. Cassell, London.

Distilling: Brennerei Lexikon, Herausgegeben unter Mitwirkung von W. Behrend, E. Duntze, F. Kehrmann, u. a. By M. Delbrück. 8vo. 787 pp. Price, $7.00. Berlin.

Food: Das Lebensmittelgewerbe, Handbuch für Nahrungsmittelchemiker u. s. w. Band I. By K. v. Buchka. 8vo. 906 pp. Price, $9.50. Leipzig.

Food: Food Industries: an Elementary Text-book on the Production and Manufacture of Staple Foods. By H. T. Vulte and S. B. Vanderbilt. 8vo. 309 pp. Price, $1.75. Chemical Publishing Co., Easton, Pa.

Food: Nahrungsmittelchemie, mit besonderer Berücksichtigung der modernen physikalisch-chemischen Lehren. By T. Paul. 8vo. 77 pp. Price, $1.00. Leipzig.

General Chemistry: Jahrbuch der Chemie. Bericht über die wichtigsten Fortschritte der reinen und angewandte Chemie. By R. Meyer. Ed. Jahrgang 28. 8vo. 642 pp. Price, $5.00. Braunschweig.

Iron: The Cementation of Iron and Steel. Translated from the Italian by J. W. Richards and C. A. Rouiller. By F. Giolotti. 8vo. 407 pp. Price, $4.00. McGraw-Hill Book Co., New York.

Irrigation: Practical Irrigation and Pumping. By Burton P. Fleming. 8vo. 226 pp. Price, $2.00. John Wiley & Sons, New York.

Masonry: A Short Text-book on Masonry Construction, Including Descriptions of the Materials Used, Etc. By M. A. Howe. 8vo. 160 pp. Price, $1.50. John Wiley & Sons, New York.

Microscopy: Praktikum der klinischen chemisch-mikroskopischen und bakteriologischen Untersuchungsmethoden. By M. Klopstock and A. Kowarsky. 3rd Ed. 8vo. Price, $2.00. Wien.

Minerals: Die Lagerstätten der nutzbaren Mineralien und Gesteine, nach Form, Inhalt und Entstehung dargestellt. Bd. I. By F. Beyschlag, P. Krusch, u. J. H. L. Vogt. 2nd Ed. 8vo. 578 pp. Price, $4.50. Stuttgart.

Minerals: Die nutzbaren Mineralien, mit Ausnahme der Erze, Kaliumsalze, Kohlen u. des Petroleums. Bd. II. By B. Dammer and O. Tietze. 8vo. 539 pp. Price, $4.00. Stuttgart.

Paints: A Manual of Oils, Resins and Paints. Vol. I. By H. Ingle. 8vo. 138 pp. Price, $1.00. C. Griffin, London.

Poisons: Inorganic Plant Poisons and Stimulants. By W. E. Brenchley. 8vo. 110 pp. Price, $1.25. Cambridge University Press, London.

Radioactivity: Acquired Radioactivity. By Sir William Crookes. 4to. 14 pp. Price, $0.50. Dulau, London.

Sanitation: Practical Tropical Sanitation: a Manual for Sanitary Inspectors and Others. By W. Alex. Muirhead. 8vo. 288 pp. Price, $3.50. E. P. Dutton, New York.

Sewage: Sewage Purification and Disposal. By G. B. Kershaw. 8vo. 350 pp. Price, $3.00. Cambridge University Press, London.

Steel: Steel and Its Treatment. By E. F. Houghton and Others. 2nd Ed. 12mo. 104 pp. Price, $1.00. E. F. Houghton & Co., Philadelphia.

Varnish: Die Fabrikation der Lacke, Firnisse usw. By E. Andres. 6th Ed. 8vo. 270 pp. Price, $1.00. Wien.

Ventilation: Heating and Ventilating Buildings. By R. C. Carpenter. 6th Ed. 12mo. 598 pp. Price, $3.50. John Wiley & Sons, New York.

Wastes: Utilization of Waste Products, Translated from the German. By T. Koller. 2nd Ed. 8vo. 340 pp. Price, $2.00. London.

Water Supply: Country Plumbing Practice: Design, Installation and Repair of Systems of Water Supply and Sewage Disposal. By W. Hutton. 8vo. 310 pp. Price, $2.00. D. Williams Co., New York.

RECENT JOURNAL ARTICLES

Absorption: Fur l'absorption des gaz par le charbon aux basses températures. By G. GLAUDE. *Bulletin de la Société Chimique de France.*

Cellulose: Recent Progress in the Analysis of Cellulose and Cellulose Derivatives. By J. F. BRIGGS. *The Analyst,* Vol. 40, 1915, No. 468, pp. 107–20.

Concrete: Basis of Current Practice in Concrete Design. By C. A. P. TURNER. *The Cement Era,* Vol. 13, 1915, No. 4, pp. 50–1.

Copper: Hydrometallurgical Treatment of Michigan Copper Tailings. By R. D. LEISK. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 233–4.

Cyanide: Copper Cyanide Plating Solutions. By M. C. WEBER. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 255–6.

Electrolysis: Electrolysis and Its Mitigation. By E. B. ROSA. *Journal of the New England Water Works Association.* Vol. 29, 1915, No. 1, pp. 49–72.

Gas: Burning Blast Furnace Gas. ANONYMOUS. *The Iron Age,* Vol. 95, 1915, No. 11, pp. 612–3.

Ice: The Economical Ice Plant of Today. By THOMAS SHIPLEY. *Ice and Refrigeration,* Vol. 48, 1915, No. 4, pp. 204–9.

Ice: Suggestions for the Improvement of Refrigerating and Ice-Making Plants. By ROBERT P. KEHOE. *Refrigerating World,* Vol. 49, 1915, No. 2, pp. 27–9.

Inorganic Chemistry: Experimentelle anorganische Chemie und Elektrochemie im Jahre 1914. By A. GUTBIER. *Zeitschrift für angewandte Chemie,* Vol. 28, 1915, No. 20, pp. 93–111.

Lighting: Street Lighting Practice with Incandescent Lamps. By G. H. STICKNEY. *Municipal Engineering,* Vol. 48, 1915, No. 2, pp. 80–8.

Minerals: General Principles Governing the Complete Analysis of Minerals and Ores. By W. R. SCHOELLER. *The Analyst,* Vol. 40, 1915, No. 468, pp. 90–106.

Nitrogen: The Fixation of Atmospheric Nitrogen. By W. S. LANDIS. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 213–20.

Organic Compounds: The Electrochemical Production of Organic Compounds. ANONYMOUS. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 211–13.

Ozone: The Use of Ozone as a Sterilizing Agent for Water Purification. By S. T. POWELL. *Journal of the New England Water Works Association,* Vol. 29, 1915, No. 1, pp. 87–93.

Paving Material: Misuse of a Good Paving Material Is Detrimental to Florida Road Development. By CHARLES E. FOOTE. *Engineering Record,* Vol. 71, 1915, No. 15, pp. 452–3.

Roads: Frost Action on Roads. By ANDREW M. LOVIS. *The Cement Era,* Vol. 13, 1915, No. 3, pp. 49–50.

Refractories: Refractories of the Rocky Mountain Region and Some of Their Products. By J. C. BAILAR. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 257–8.

Sanitation: The Federal Meat Inspection Service and Sanitation of Packing Houses under Its Supervision. By GEORGE H. SHAW. *American Journal of Public Health,* Vol. 5, 1915, No. 3, pp. 236–45.

Sewage: Sewage Aeration at Lawrence and Manchester Compared. By H. W. CLARK. *Engineering Record,* Vol. 71, 1915, No. 12, pp. 367–8.

Sewage: The West End Sewage Treatment Works, Hamilton, Ont. By BERNARD E. T. ELLIS. *Engineering News,* Vol. 73, 1915, No. 9, pp. 424–8.

Steel: Acid Open-Hearth Steel for Castings. By EDWIN F. CONE. *The Iron Age,* Vol. 95, 1915, No. 10, pp. 551–3.

Steel: "Areagrams" of Open-Hearth Furnace Flues. By A. R. MITCHELL. *The Iron Age,* Vol. 95, 1915, No. 11, pp. 607–8.

Steel: Heat Energy from the Bessemer Process. By G. BUTZ. *The Iron Age,* Vol. 95, 1915, No. 11, pp. 618–9.

Steel: Hysteresis Loss in Medium-Carbon Steel. By F. C. LANGENBERG AND R. G. WEBBER. *The Iron Age,* Vol. 95, 1915, No. 9, pp. 506–8.

Sulfates: The Formation and Decomposition of Sulfates during Roasting. By BOYD DUDLEY, JR. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 4, pp. 221–6.

Sulfuric Acid: Neuerungenbetreffend Bleikammern, Turmsysteme und andere Vorrichtungen zur Herstellung von Schwefelsäure. By OSKAR KAUSCH. *Chemische Apparatur,* Vol. 2, 1915, No. 4, pp. 53–5.

Turbines: Turbine Efficiency Test by Chemical Methods. ANONYMOUS. *Engineering Record,* Vol. 71, 1915, No. 12, pp. 358–60.

Valence: A Criticism of the Electron Conception of Valence. By ROGER F. BRUNEL. *Journal of the American Chemical Society,* Vol. 37, 1915, No. 4, pp. 709–22.

Water: Philadelphia Water-Filter Operations in 1914. ANONYMOUS. *Engineering News,* Vol. 73, 1915, No. 12, pp. 576–7.

Wood: Die Imprägnierung des Holzes nach dem Verfahren des Dr. Boucherie. By FRIEDRICH MOLL. *Chemische Apparatur,* Vol. 2, 1915, No. 4, pp. 49–53.

Zinc: Die Bestimmung des Zinks als Zinkammoniumphosphat und ihre Anwendung bei Trennungen. By P. ARTMANN. *Zeitschrift für analytische Chemie,* Vol. 54, 1915, No. 2, pp. 89–102.

Zinc: Leaching a Zinc-Lime Ore with Acids. By O. C. RALSTON and A. E. GARTSIDE. *Metallurgical and Chemical Engineering,* Vol. 13, 1915, No. 3, pp. 151–5.

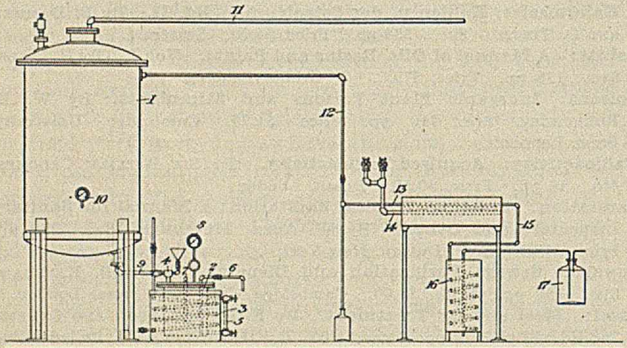
RECENT INVENTIONS

UNITED STATES PATENTS

By C. L. PARKER

Solicitor of Chemical Patents, McGill Building, Washington, D. C.

Manufacturing Mixed Hydrogen and Nitrogen. G. P. Scholl, Jan. 5, 1915. U. S. Pat. 1,123,394. A mixture of nitrogen and hydrogen having definite proportions is produced by vaporizing ammonia, holding it under a given pressure, which may be from 20 to 30 lbs. per sq. in., mixing with air and dissociating the ammonia at a predetermined pressure, which may be 10 lbs. per sq. in., by passing the mixed gases over copper turnings heated to approximately 720° C.



Preventing Accumulation of Moisture of Condensation upon Glass or Other Protected Surfaces. H. M. Pickering, Jan. 5, 1915. U. S. Pat. 1,123,367. The composition consists of 20 parts of glycerin, 2 parts of oil of turpentine, and 1 part of oil of eucalyptus.

Fixing Atmospheric Nitrogen. S. Peacock, Jan. 5, 1915. U. S. Pat. 1,123,584. A compound of sulfur, carbon and nitrogen is produced by bringing a mixture containing nitrogen and an oxid of sulfur into contact with carbon at a temperature of 800° C.

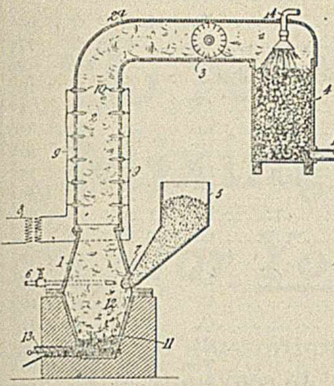
Precipitant for Recovering Metals from Solutions. G. H. Clevenger, Jan. 5, 1915. U. S. Pat. 1,123,685. The precipitant consists of a powder made from a brittle alloy composed of zinc and not more than 3 per cent sodium, the sodium being added to impart brittleness to the alloy.

Marine Protective Coating. D. F. Comstock, Jan. 5, 1915. U. S. Pat. 1,123,687. The composition consists of a water-resisting copper paint and a small amount of a radioactive substance, preferably pulverulent carnotite.

Pigments. C. D. Holley, Jan. 5, 1915. U. S. Pat. 1,123,743. Metallic lead is moistened with water containing a relatively small amount of nitric acid and the mass is allowed to undergo progressive spontaneous oxidation in the presence of air to form oxids of lead.

Alkali-Metal Compounds. H E. Brown, Jan. 5, 1915. U. S. Pat. 1,123,841. Potash is obtained from feldspar by fusing, in a non-reducing atmosphere, a mixture of feldspar with a sufficient quantity of potassium chloride to furnish combinable chlorine for all the potassium and a sufficient quantity of calcium carbonate to bring the calcium oxide content of the resulting fused material up to between 40 and 55 per cent.

Alkali-Silico-Aluminate. A. H. Cowles, Jan. 5, 1915. U. S. Pat. 1,123,693. Alkali-silico-aluminate and hydrochloric acid are produced by subjecting clay to the action of vapors of salt and water at a high temperature. A mixture of the salt and clay is fed into the furnace from the hopper 5, steam being introduced through the pipe 6. The suction of a fan, 3, draws the whirling charge up into the dust chamber 2 where it is electrified by the passage of electricity between the highly charged points 10, whereby, according to the process set forth by Cottrell and others, the dust particles attract each other into small masses and fall back into the furnace, the hydrochloric acid passing over into the acid-condensing systems where it is condensed.



BRITISH PATENTS

By D. Geddes Anderson

Chemical Engineer and Patent Chemist, Glasgow, Scotland

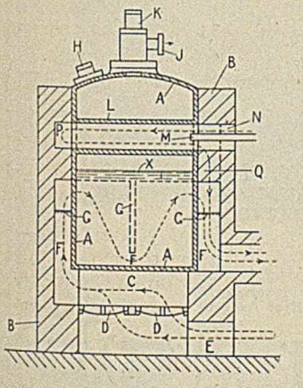
The following abstracts are taken from the latest published British specifications. The date at the end of the abstract is the date of acceptance.

Process for Converting Unsaturated Fatty Acids into Saturated Compounds. W. J. Mellersch-Jackson, Sept. 23, 1913. Brit. Pat. 21,477. A basic heavy metal salt of a fatty acid of high molecular weight is dissolved in, or intimately mixed with, the substance to be treated, and the material hydrogenated between 100 and 180° C. Basic oleates of nickel and copper are mentioned.—Feb. 2, 1915.

Improvements in the Manufacture of Tungsten. C. Gladitz, Oct. 23, 1913. Brit. Pat. 24,028. This invention relates to a new form of spool on which cold drawn tungsten wire is received, previous to undergoing heat treatment. By means of an auxiliary rotable pin the periphery of the spool is increased for the winding operation and decreased for the heat treatment. In this way any tension in the wire, caused by the differences in coefficients of expansion of the metal of the spool, and of the wire, during the heat treatment, is eliminated.—Feb. 4, 1915.

Submarine Varnishes. G. Paterno and C. Mannelli. Dec. 22, 1913. Brit. Pat. 29,524. Fluorides or fluosilicates of aluminum, zinc, or lead are used as ingredients in antifouling compositions.—Feb. 18, 1915.

Apparatus for Distilling Liquids. Crossley, Wheeler and Smith, Jan. 10, 1914. Brit. Pat. 707. A new type of apparatus for distilling liquids such as oil or tar, which are liable to froth. A superheater, L, passes through the center of the still, and is heated by means of the burner M. The superheater breaks up the froth and in addition is stated to increase the yield of distillate.—Feb. 10, 1915.



Preparation of Vegetable Textile Fibers for Bleaching. Jardine and Nelson, Jan. 12, 1914. Brit. Pat. 802. The process consists in treating the fibrous material in a digester with a solution of a magnesium or sodium bisulfite. The gases liberated in the course of the cooking are continuously removed.—Feb. 12, 1915.

Coagulation of Rubber Latex. N. W. Barritt and A. Street, Feb. 12, 1914. Brit. Pat. 3,632. Rubber latex is subjected to partial evaporation under reduced pressure, and exposed to the action of hot, dry vapors of acetic acid and formalin. The exposure is effected on a revolving drum.—Feb. 12, 1915.

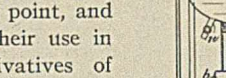
Accelerating the Vulcanization of Caoutchouc. S. J. Peachey, Feb. 19, 1914. Brit. Pat. 4,263. A small quantity of para-nitrosodimethylaniline, or of one of its homologues is added before vulcanization. It is stated that the isomeric nitrosamines produce no acceleration.—Feb. 18, 1915.

Nitrogen Compounds from Pulverized Carbides. T. Fujiyama, April 14, 1914. Brit. Pat. 9,259. Process does away with the application of external heat. A small quantity of pulverized carbide is ignited in an unheated chamber in presence of air. When the temperature has risen sufficiently nitrogen is introduced, and fresh carbide fed in, in such a manner that a heat insulating layer of the carbide is formed over the carbide undergoing reaction.—Feb. 11, 1915.

Treatment of Iron or Steel for the Prevention of Rust. Rudge-Whitworth, Ltd. and H. L. Heathcote, April 22, 1914. Brit. Pat. 9,926. Relates to iron and steel articles already coated with rust-resisting phosphates of iron. The phosphate coating is treated with linseed oil and stoved, or with celluloid varnish and subsequent stoving.—Feb. 18, 1915.

Rubber Composition for Outer Covers of Pneumatic Tires. C. Pacchetti, June 6, 1914. Brit. Pat. 13,779. Rubber when in a plastic state is mixed with lengths of horse hair or hog's hair and the mixture subsequently vulcanized. Said to give non-skid properties.—Feb. 18, 1915.

New Substituted Ureas. Fabriques De Produits De Chimie Organique De Laire, July 23, 1914. Brit. Pat. 17,501. Relates to tetra-substituted ureas of the general form



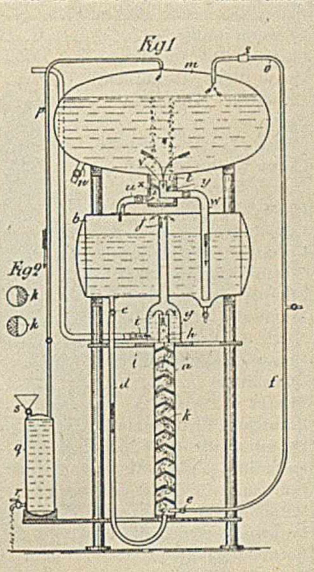
$$\begin{matrix} R \\ R_1 \end{matrix}\!\!>\!N\text{—}CO\text{—}N\!<\!\!\begin{matrix} R_2 \\ R_3 \end{matrix}.$$

R and R_2 represent alkyl radicles; R_1 and R_3, aryl radicles.

The chloride of an aryl-alkyl urea is first formed and then caused to react with an aromatic base having different radicles from those of the aryl-alkyl urea.

They are viscous liquids or solids of low melting point, and claim is made for their use in stabilizing nitro-derivatives of organic compounds.—Feb. 11, 1915.

Impregnating Liquids with Carbonic Acid or Other Gases. A. A. Pindstofte, Sept. 14, 1914. Brit. Pat. 19,769. The gas and liquid passing through the pipes *f* and *d*, respectively, are forced up the impregnating chamber *a*. The gas-charged liquid flows through the pipe *i* to the bottling chamber, and the superfluous carbonic acid and expelled air flow through *j* into the liquid reservoir *b* and fill the space caused by the displaced liquid: *m* is a supply reservoir connected with an air-discharge controller, *q*. The partitions of the impregnating chamber are perforated and are shown in plan in Fig. 2.—Feb. 11, 1915.



MARKET REPORT

AVERAGE WHOLESALE PRICES OF STANDARD CHEMICALS, ETC., FOR THE MONTH OF APRIL, 1915

ORGANIC CHEMICALS

Acetanilid	Lb.	1.25	@	1.40
Acetic Acid (28 per cent)	C.	2.00	@	2.25
Acetone (drums)	Lb.	21	@	25
Alcohol, denatured (180 proof)	Gal.	33	@	35
Alcohol, grain (188 proof)	Gal.	2.50	@	2.54
Alcohol, wood (95 per cent)	Gal.	45	@	47
Amyl Acetate	Gal.	2.70	@	—
Aniline Oil	Lb.	1.00	@	1.10
Benzoic Acid	Lb.	—	@	—
Benzol (90 per cent)	Gal.	1.20	@	1.40
Camphor (refined in bulk)	Lb.	41½	@	—
Carbolic Acid (drums)	Lb.	1.10	@	1.15
Carbon Bisulfide	Lb.	6½	@	7½
Carbon Tetrachloride (drums)	Lb.	16	@	17
Chloroform	Lb.	30	@	35
Citric Acid (domestic), crystals	Lb.	55	@	57
Dextrine (corn) (carloads, bags)	C.	3.00	@	—
Dextrine (imported potato)	Lb.	—	@	—
Ether (U. S. P., 1900)	Lb.	15	@	20
Formaldehyde	Lb.	8½	@	9½
Glycerine (dynamite)	Lb.	18½	@	20
Oxalic Acid	Lb.	19	@	20
Pyrogallic Acid (bulk)	Lb.	1.40	@	1.50
Salicylic Acid	Lb.	1.40	@	1.50
Starch (cassava)	Lb.	3¼	@	4
Starch (corn) (carloads, bags)	C.	2.25	@	—
Starch (potato)	Lb.	—	@	—
Starch (rice)	Lb.	—	@	—
Starch (sago)	Lb.	3¾	@	4
Starch (wheat)	Lb.	7	@	7½
Tannic Acid (commercial)	Lb.	60	@	66
Tartaric Acid, crystals	Lb.	38	@	39

INORGANIC CHEMICALS

Acetate of Lead (brown, broken)	Lb.	7¼	@	7½
Acetate of Lime (gray)	C.	2.50	@	2.55
Alum (lump)	C.	2.50	@	3.00
Aluminum Sulfate (high-grade)	C.	1.50	@	1.75
Ammonium Carbonate, (domestic)	Lb.	8¼	@	9
Ammonium Chloride, (gray)	Lb.	5½	@	6½
Aqua Ammonia (drums) 16°	Lb.	2¼	@	2½
Arsenic (white)	Lb.	4	@	5
Barium Chloride	Ton	60.00	@	65.00
Barium Nitrate	Lb.	16	@	20
Barytes (prime white, foreign)	Ton	—	@	—
Bleaching Powder (35 per cent)	C.	1.40	@	1.50
Blue Vitriol	Lb.	6¼	@	6¾
Borax, crystals (bags)	Lb.	4¾	@	5¼
Boric Acid, crystals (powd.)	Lb.	8½	@	10
Brimstone (crude, domestic)	Long Ton	22.00	@	22.50
Bromine (bulk)	Lb.	40	@	50
Calcium Chloride (lump)	Ton	11.70	@	12.00
Chalk (light precipitated)	Lb.	4½	@	5½
China Clay (imported)	Ton	14.00	@	18.00
Feldspar	Ton	8.00	@	14.00
Fuller's Earth (powdered, foreign)	C.	80	@	90
Green Vitriol (bulk)	C.	60	@	70
Hydrochloric Acid (18°)	C.	1.15	@	1.65
Iodine (resublimed)	Lb.	3.80	@	4.25
Lead Nitrate	Lb.	8	@	—
Litharge (American)	Lb.	5¼	@	5½
Lithium Carbonate	Lb.	1.00	@	1.10
Magnesium Carbonate	Lb.	4½	@	4¾
Magnesite "Calcined"	Ton	nominal		
Nitric Acid (36°)	Lb.	7½	@	8
Phosphoric Acid (sp. gr. 1.75)	Lb.	27½	@	28
Phosphorus	Lb.	35	@	95
Plaster of Paris	Bbl.	1.50	@	1.70
Potassium Bichromate	Lb.	15	@	16
Potassium Bromide	Lb.	80	@	81
Potassium Carbonate (calcined), 80 @ 85%	C.	14	@	14½
Potassium Chlorate, crystals spot	Lb.	35	@	36
Potassium Cyanide (bulk), 98–99%	Lb.	18	@	25
Potassium Hydroxide	Lb.	21	@	25
Potassium Iodide (bulk)	Lb.	3.15	@	3.25
Potassium Nitrate (crude)	Lb.	—	@	—
Potassium Permanganate (bulk)	Lb.	60	@	75
Quicksilver, Flask (75 lbs.)		65.00	@	—
Red Lead (American)	Lb.	6	@	6½
Salt Cake (glass makers')	C.	55	@	65
Silver Nitrate	Oz.	32	@	34
Soapstone in bags	Ton	10.00	@	12.00
Soda Ash (48 per cent)	C.	67½	@	72½
Sodium Acetate	Lb.	4	@	4½
Sodium Bicarbonate (domestic)	C.	1.00	@	1.10
Sodium Bicarbonate (English)	Lb.	3½	@	4
Sodium Bichromate	Lb.	5	@	5⅛
Sodium Carbonate (dry)	C.	60	@	80
Sodium Chlorate	Lb.	16	@	18
Sodium Hydroxide (60 per cent)	C.	1.70	@	1.80
Sodium Hyposulfite	C.	1.60	@	1.90
Sodium Nitrate (95 per cent, spot)	C.	2.27½	@	—
Sodium Silicate (liquid)	C.	85	@	1.15
Strontium Nitrate	Lb.	17½	@	18
Sulfur, Flowers (sublimed)	C.	2.20	@	2.60
Sulfur, Roll	C.	1.85	@	2.15
Sulfuric Acid (60° B)	C.	85	@	1.00
Talc (American)	Ton	15.00	@	20.00
Terra Alba (American), No. 1	C.	75	@	80
Tin Bichloride (50°)	Lb.	14¼	@	14½
Tin Oxide	Lb.	55	@	57
White Lead (American, dry)	Lb.	5¼	@	5½
Zinc Carbonate	Lb.	8½	@	9
Zinc Chloride (granulated)	Lb.	6¼	@	6½
Zinc Oxide (American process)	Lb.	5⅜	@	6⅜
Zinc Sulfate	C.	2.50	@	—

OILS, WAXES, ETC.

Beeswax (pure white)	Lb.	40	@	42
Black Mineral Oil, 29 gravity	Gal.	12½	@	13
Castor Oil (No. 3)	Lb.	9¾	@	10¼
Ceresin (yellow)	Lb.	10	@	25
Corn Oil	C.	6.26	@	6.31
Cottonseed Oil (crude), f. o. b. mill	C.	5.47	@	5.55
Cottonseed Oil (p. s. y.)	Lb.	6½	@	6⅝
Cylinder Oil (light, filtered)	Gal.	20	@	25
Japan Wax	Lb.	13	@	15
Lard Oil (prime winter)	Gal.	90	@	92
Linseed Oil (raw)	Gal.	60	@	—
Menhaden Oil (crude)	Gal.	37	@	39
Naphtha, 68 @ 72°	drums	—	@	12
Neatsfoot Oil (20°)	Gal.	93	@	95
Paraffine (crude, 120 & 122 m. p.)	Lb.	2½	@	3
Paraffine Oil (high viscosity)	Gal.	22	@	23
Rosin ("F" grade) (280 lbs.)	Bbl.	3.95	@	4.00
Rosin Oil (first run)	Gal.	25	@	—
Shellac, T. N	Lb.	14	@	14½
Spermaceti (cake)	Lb.	25	@	27
Sperm Oil (bleached winter), 38°	Gal.	70	@	71
Spindle Oil, No. 200	Gal.	17	@	18
Stearic Acid (double-pressed)	Lb.	12	@	12½
Tallow (acidless)	Gal.	62	@	63
Tar Oil (distilled)	Gal.	30	@	31
Turpentine (spirits of)	Gal.	48½	@	—

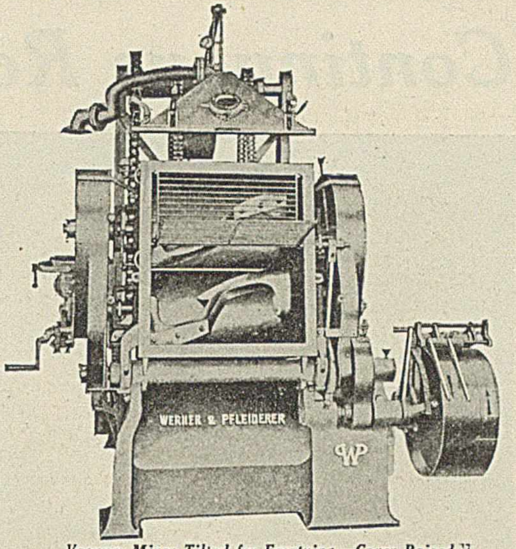
METALS

Aluminum (No. 1 ingots)	Lb.	19	@	19½
Antimony (Hallet's)	Lb.	28	@	30
Bismuth (New York)	Lb.	2.80	@	2.90
Bronze powder	Lb.	—	@	—
Copper (electrolytic)	Lb.	17¼	@	17½
Copper (lake)	Lb.	18	@	18½
Lead, N. Y	C.	4.17½	@	—
Nickel	Lb.	42	@	45
Platinum (refined)	Oz.	45.00	@	50.00
Silver	Oz.	50⅜	@	—
Tin	C.	50.00	@	—
Zinc	Lb.	11	@	—

FERTILIZER MATERIALS

Ammonium Sulfate	C.	3.15	@	3.20
Blood (dried)	Unit	2.70	@	—
Bone, 4½ and 50 (ground, raw)	Ton	30.00	@	—
Calcium Cyanamid	Unit of Ammonia	2.20	@	—
Calcium Nitrate (Norwegian)	C.	—	@	—
Castor meal	Unit	—	@	—
Fish Scrap (domestic, dried)	Unit	—	&	—
Phosphate, acid (16 per cent bulk)	Ton	7.50	@	—
Phosphate rock; f. o. b. mine:				
Florida land pebble (68 per cent)	Ton	2.25	@	2.50
Tennessee (70–80 per cent)	Ton	5.00	@	5.50
Potassium, "muriate," basis 80 per cent	Ton	1.15	@	1.25
Pyrites (furnace size, imported)	Unit	12½	@	—
Tankage (high-grade)	Unit	2.70	&	10

There's a Type of "UNIVERSAL" Mixing Apparatus *for Your Purpose*



Vacuum Mixer Tilted for Emptying—Cover Raised

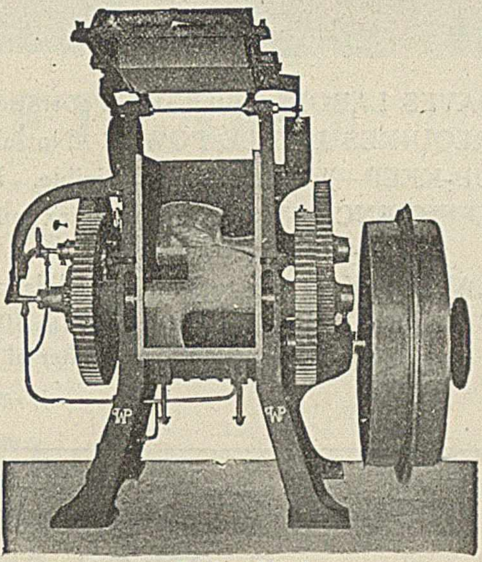
THE illustrations herewith show only a few of the types of "Universal" Mixing Apparatus which we make. For instance, a type for Laboratory and Experimental use is shown; also a Mixer and Incorporator for handling stiff materials, such as Gutta Percha, Rubber, etc.

We show a type for kneading and mixing under vacuum, then extracting and recovering the solvent, and also a mixer that has no center shaft to which materials can cling.

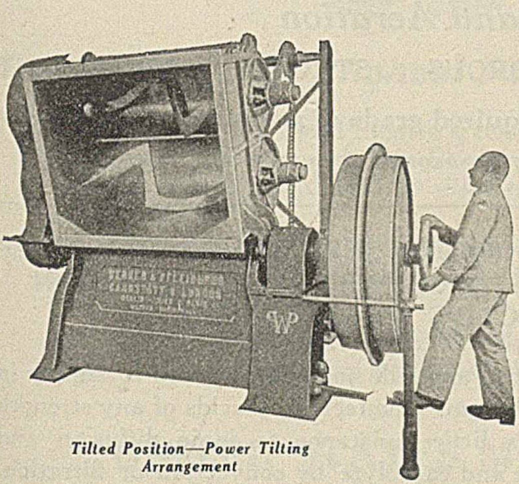
We can supply you with a type of "Universal" which will satisfy you—absolutely, and we will be pleased to take this matter up with you.

We manufacture:—

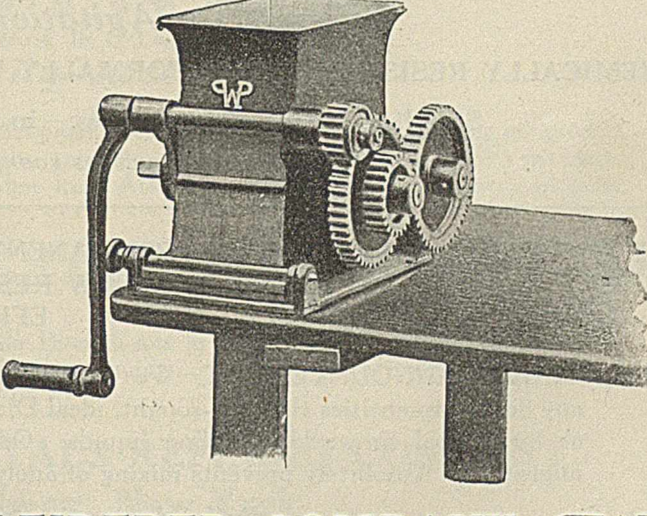
- *KNEADING AND MIXING MACHINES*
- *AUTOMATIC WEIGHING SCALES*
- *VACUUM KNEADERS*
- *FILTER PRESSES*
- *RUBBER WASHERS*
- *MASTICATORS and*
- *SOLUTION MAKING MACHINES*



Flap Door Raised



Tilted Position—Power Tilting Arrangement



WERNER & PFLEIDERER COMPANY

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