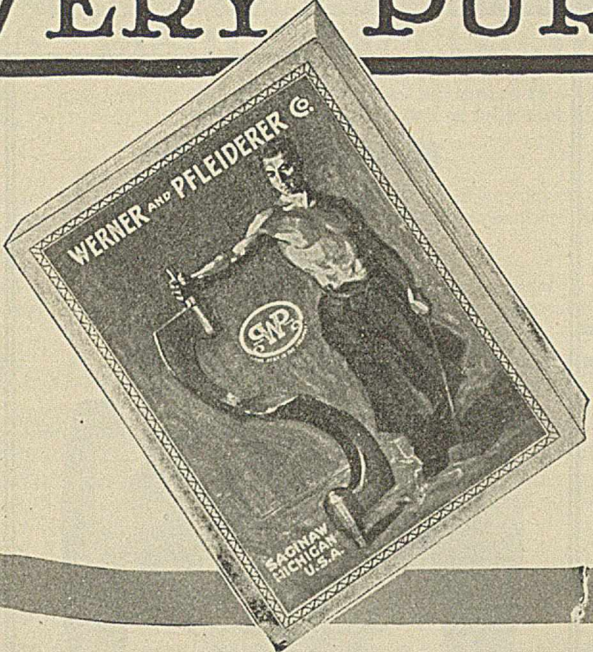
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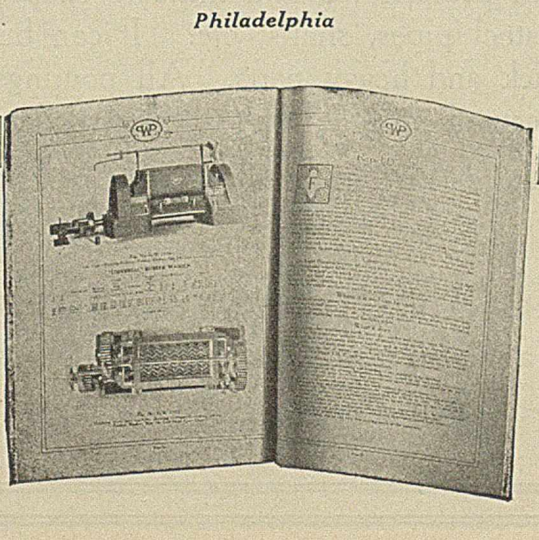

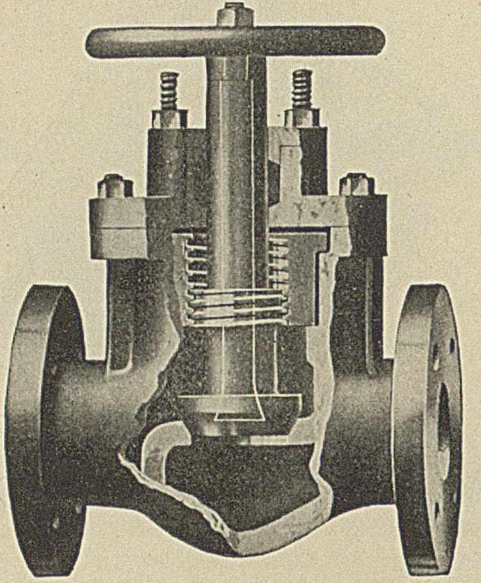

G-E Complete Electrical Equipment for Cranes Assures Speed with Safety

G-E engineers have studied crane requirements and designed electrical apparatus to meet known operating conditions. Every requirement for stopping or starting and the entire operating cycle is fully met by specially designed apparatus.

Motors

Interpole motors, capable of standing heavy overloads, are manufactured in any speed or horse power needed. These motors have split frames and large handholes for accessibility and can be disassembled without disturbing back gearing.

Brakes

G-E crane motors are furnished with automatic solenoid brakes which work without jar or shock and make automatic compensation for brake shoe wear. Brake shoes made of metallized asbestos compound give a high coefficient of friction with but little wear.

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The G-E Standard for crane equipments is to supply all resistor sections of uniform size, which reduces the number of spare parts needed to a minimum. The design of the cast iron grid resistance units is such as to avoid the danger of short circuits by vibration and double insulation protection against grounding is provided.

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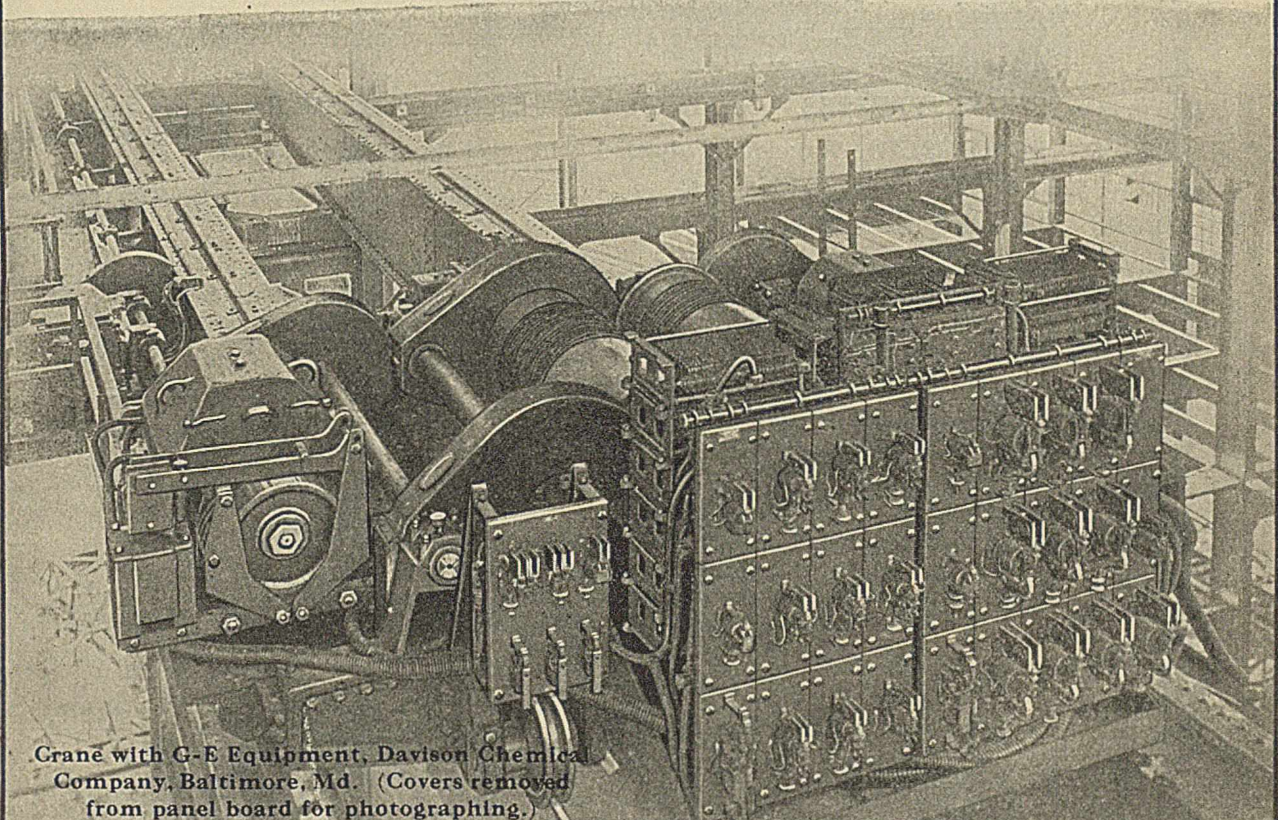
Horizontal or vertical handle controllers are furnished which are absolutely reliable and very accessible. They are equipped with magnetic blowouts, arc chute protecting covers and many refinements which twenty years of controller building suggested.

Your inquiry for complete electrical crane equipment is solicited.



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General Electric Company

General Office: Schenectady, N. Y.

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Boston, Mass. New York, N. Y. Philadelphia, Pa. Atlanta, Ga. Cincinnati, Ohio
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6876

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BARIUM CHLORIDE
BARIUM CARBONATE
SODIUM SULPHIDE

A brand new and thoroughly equipped plant for the production of the above articles will be available shortly for interested manufacturers.

With slight changes and additions the factory can be employed to make

LITHOPHONE

and various sulphides, and, indeed, any chemicals in which part or all of the following equipment can be utilized:

CRUSHING—10″ x 16″ Jaw Crusher; Rotary Crusher, and 30″ Vertical Emery Mill.

FURNACING—Two Rotary Kilns, 6′ 0″ diameter.

SOLUTION—A large number of round and rectangular iron and wood and lead-lined tanks. Metal tanks mostly 3/8″ steel.

EVAPORATION—Two double effect Evaporators, complete. Total heating surface 1786 sq. ft.

FILTER PRESSES — CENTRIFUGES — CRYSTALLIZING PANS

POWDERING—Raymond Pulverizer with cyclone air separator and filter.

LABORATORY—Well equipped.

The property comprises ten acres and a main building, 310 x 125, of interlocking hollow tile, reinforced concrete and steel, with concrete roof, etc. It is served by a railroad main line siding and industrial tracks in interior.

Power plant—two B. & W. Boilers, 150 H. P. each, and one 250 H. P. Ball-Corliss Engine.

Ample water supply from own artesian wells, and two steel tower tanks 35′ high. Electric lighting system. Machine shop and machinery spares, etc.

We are not in the real estate business, but this exceptional property is in the hands of friends that we are most anxious to serve and who have asked us to bring it to the attention of chemical manufacturers. We shall be glad to send you further particulars if you are interested.

FRANK HEMINGWAY, INC.

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Manufacturers, Importers and Exporters
Intermediates, Dyestuffs, Chemicals, Pharmaceuticals

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Dinitrobenzol Diphenylamine Benzyl Chloride Picramic Acid
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Badger=Webre EVAPORATORS

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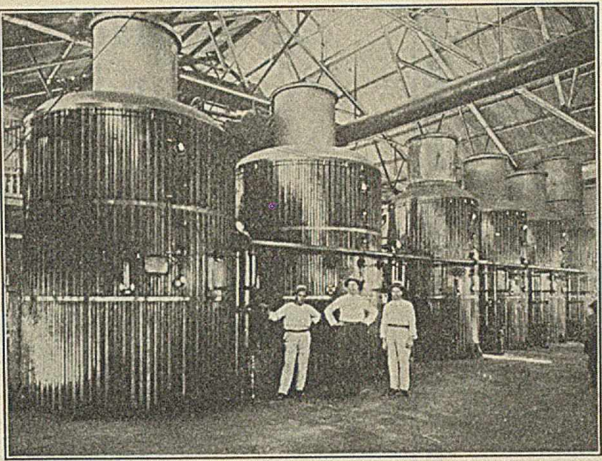
control



The standard WEBRE construction permits the use of this machine for practically any material and the removal of volatile constituents and non-condensable gases permits its use where many other standard types cannot be employed.

The Standard WEBRE involves:
- Simple construction
- Removal of non-condensable and corrosive gases
- Ease of cleaning
- Exact and efficient level control
- High velocity circulation
- Reversible liquor flow
- High efficiency permitting use with low temperature drop

There are, of course, special features in the design of evaporators for particular work.

We can furnish these types in any size and for the efficient handling of all materials, such as:

Sugar, Salt, Glycerine, Potash, Tanning Extracts, Dye-wood Extracts, Sulphates, Caustic Soda, Sodium, Benzosulphonate, Ammonium Phosphate, Urea, Water, Tomato Pulp, Glucose, Glue, Gelatine, Black Liquor, Sulphite Waste, Calcium and Magnesium Chlorides, Pyroligneous Acid, Calcium Acetate, Sodium and Potassium Nitrates, Mercerizing Liquors, Garbage Water, Distillery Waste, etc.

E. B. BADGER & SONS CO.
BOSTON, MASS., U. S. A.

ESTABLISHED 1841
WEATHER VANE ON FANEUIL HALL
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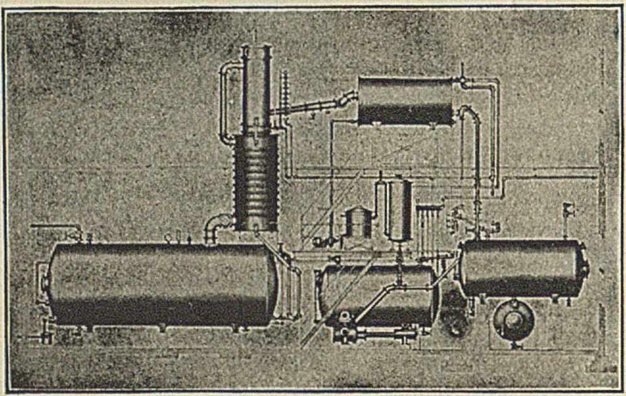
Badger STILLS

can be had for the Largest Work and Highest Degree of Refinement



There are few industries where problems involving distillation or condensation do not arise. More mistakes are made in the installation of improper apparatus of this type than in any other line of chemical equipment.

Our experience in handling all classes of material, and our organization and association, are such that we are able to handle any distilling problems with the assurance that the best results will be obtained.

If the material is to be handled commercially, we can furnish apparatus for distilling; if not, we will undertake to design special apparatus to meet the conditions involved.

Our main object is to furnish the most efficient still possible for the purpose, and to give an apparatus which can be easily operated, which will be durable and will also give the highest grade of product possible to obtain.

BENZOL

We have constructed a larger number of stills for benzol, toluol, etc., than any other concern in the United States. Our cast-iron construction, automatic flow pressure regulation and general design are distinctly advantageous for this work.

ACETONE

The production of acetone for smokeless powder work from acetate of lime, or direct from acetic acid, requires expert knowledge of distillation and very efficient stills. We have constructed, or have under construction, acetone refining stills of proved design with an aggregate capacity of 8000 gallons per day finished product.

AMMONIA

We have designed special types of cast iron ammonia stills which are a great improvement over the ordinary type as regards efficiency, ease of cleaning, etc. The special problems involved in handling ordinary ammonia liquor, produce pure aqua-ammonia, and in producing ammonia from calcium cyanamid, have been solved by the use of our apparatus.

ETHER

We are constructors of probably 95% of the ether stills required for smokeless powder work in the United States and Canada. Of more than 75 units installed for this work we have none giving other than absolute satisfaction.

METHYL ALCOHOL

The demand for refined methyl alcohol for formaldehyde and dye work, as well as for ordinary solvent purposes, requires the use of continuous stills for economical production. For years we have been perfecting this type of equipment, and orders for four large stills received during the past few months indicate that our equipment is preferred almost exclusively for this work.

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The handling of products such as sulphur chloride, carbon tetrachloride, mono- and dichlor benzol, tetrachlorethane, etc., involves special problems of design and construction such, for instance, as the design of homogeneous lead-lined vacuum stills.

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ESTABLISHED 1841
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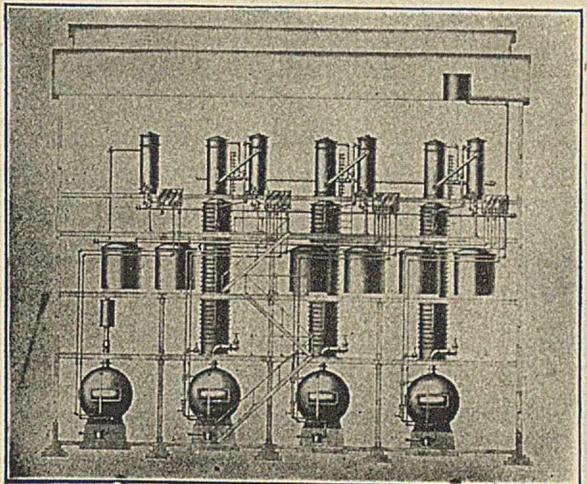
Badger STILLS

of Special Design are handling practically every Commercial Volatile Product



Outside of the general design of stills, such as the arrangement and the proportions of the parts involved, BADGER Stills possess special features, which include Boiling Cap construction, liquid flow and feed regulators, pressure regulators, etc., none of which are embodied in the design and construction of other stills.

We construct practically all of our apparatus in our own shops. Our engineers have designed and patterned Badger Stills much after the principle of the famous Barbet Stills and in carrying out their specifications the work of construction is placed in the hands of expert workmen who have a complete knowledge of the metal working industry and its application to the building of stills.

All of the products enumerated on the margins of these two pages are being successfully handled by means of Badger Stills. We will be glad to furnish you with any information which you may require regarding your problems of Distillation or Condensation.

E. B. BADGER & SONS CO.
BOSTON, MASS., U. S. A.

ALCOHOL

The production of pure ethyl alcohol from fermented mash was for many years handled in a very inefficient manner. The perfected stills which we have developed for this purpose, in conjunction with the Barbet Co., give a better product with enormous economy. These stills will gradually replace all of the old type now in use in the United States.

ACETIC ACID

Units for the distillation, refining or concentration of acetic acid require expert knowledge of construction and design. We have recently furnished and have under construction, several complete plants for this work which are essential to the successful operation of the plants in question.

SALICYLIC ACID

The special design of still, with special lining required for handling this valuable product, is right in our line. Apparatus which we have furnished and which is in successful operation, involves special features which only long experience in design and construction has put us in a position to work out.

ANILINE

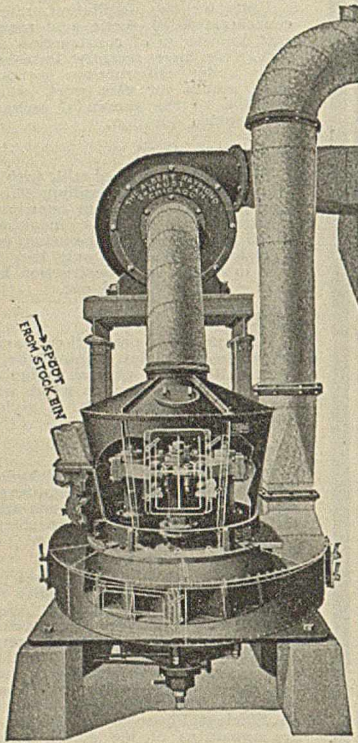
The economical production of aniline of proper boiling point requires the use of stills of the same general design as our phenol stills. Apparatus which we have furnished for this work is giving excellent results.

ACETALDEHYDE

The distillation of acetaldehyde from solutions is a problem requiring very careful design; our continuous stills for this purpose have solved the problem.

PHENOL

Any cast-iron still will produce phenol, but safety, economy and quality require carefully designed apparatus. We have installations in operation having an aggregate capacity of 150,000 pounds of pure phenol per day. The fact that our stills are the most expensive in the market, in conjunction with the above, testifies to results. The most recent article on Efficient Phenol Plant Design specifies apparatus of the design which we have developed as the best.


SPOUT FROM STOCK BIN

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EDITORIALS

CHEMISTS AND PREPAREDNESS

The following letter is now being sent to every chemist in America whose name could be secured:

> By request of the Council of National Defense, the Bureau of Mines, in coöperation with the American Chemical Society, will procure a Roster of Chemists of the United States. Data covering the qualifications, experience and skill of each chemist are desired to determine the line of duty in which he could best serve the country in time of need.
>
> European experience has shown that nothing is more important in time of war or other national emergency than a knowledge of the qualifications and experience of the country's expert technical men. Men whose knowledge was invaluable to the production of munitions ordnance, and supplies were killed in the trenches during the first months of the European war. This was due to lack of early information regarding individuals and has now been remedied in every European country. It is therefore important, especially at present, that this information be available in the United States.
>
> You are accordingly requested, as a patriotic duty not only to fill out the card which you will receive herewith, but to see that every chemist within your acquaintance receives one and does likewise. Additional cards will be furnished upon request. You will please check only those subjects in which you are expert, especially where you have had actual manufacturing experience. Please return the card promptly, using the enclosed franked envelope. The information received will be carefully classified, carded and indexed. Your prompt response to this matter will be very much appreciated.
>
> Van H. Manning, *Director, Bureau of Mines*
> Julius Stieglitz, *President, American Chemical Society*

The letter is accompanied by blank forms on which is requested information as to personality, experience and special qualifications. This information will be carefully classified, indexed, and carded for future use. It is the hope of the Bureau of Mines to keep this work up-to-date in future years.

For the purpose of mobilizing chemical investigators the following letter is also being mailed:

> To assist the Chemistry Committee of the National Research Council in its efforts to prepare for the use of the Government a classification of our chemical investigators, it is requested that you fill out the reverse side of this card. As the matter is urgent, it is hoped that you will give it your careful attention.
>
> Marston Taylor Bogert, *Chairman,*
> *Chemistry Committee, National Research Council*

The information requested includes lines of work, willingness to aid the Government in the solution of problems affecting the security and defense of our country, preference in research and available time for such work.

No word of appeal is needed for this patriotic duty. Through President Stieglitz we have already offered our services to our country. This is the first request made of us. The answers to these questionnaires should be immediate and unanimous.

The subject matter is so timely, and the experience of England is so vitally interesting that we reproduce elsewhere an article on "Chemistry in Wartime" from the English Journal, *The Chemical Trade Journal and Chemical Engineer.*

AGAIN I SAY "AMERICA FOR AMERICANS"

In our last issue we announced the policy of always being willing to publish criticisms of matter appearing in This Journal, with the further statement that those so criticized would be given opportunity to reply. With complete willingness we include ourselves among those subject to criticism, at the same time reserving to ourselves the same privilege of reply.

On the evening of March 9th I was handed the following communication in person by Professor Alexander Smith, Head of the Department of Chemistry in Columbia University and a Past-President of the American Chemical Society, with the request that it be published in This Journal.

....

CRITICISMS OF CHEMICAL LEGISLATION WHICH ARE NOT WISE, BUT OTHERWISE

By Alexander Smith

The editorials in This Journal, and the reports of addresses by the Editor, Dr. Herty, have called the attention of chemists, and all interested in chemistry, to the wording of one paragraph of the tariff bill of September 1916, in which the dyes relieved from the 5 per cent per pound tax are specified. The classes mentioned include "........natural and synthetic indigo and all indigoids whether or not obtained from indigo......" My purpose is not to discuss the matters of public policy involved in these exemptions, but simply to call attention to a serious error in the arguments used by the critics of the section in question.

Dr. Herty refers to Nietzki's *Chemie der Organischen Farbstoffe,* and says "that if our chemists did not know what 'indigoids' were, Professor Nietzki did know." "In the fifth edition (1906) I found the group of dyes known as 'indigoids' completely specified. The list included all forms of sulfur dyes."

Now no argument is really supported by a misrepresentation of the facts, although in this instance the misrepresentation was entirely unconscious and unintentional. In 1906 Nietzki did not know what "indigoids" were, because the word does not occur in the book, and was in fact first introduced to the science two years later by Friedländer[1] in a paper entitled "On Indigoid Dyestuffs." In 1896, aside from some halogen derivatives of indigo, and one or two dyes related to indigo and found in natural indigo, practically no dyes closely related to indigo were known, and there was no need for a class-name. The invention of thio-indigo red in 1905 was followed by the production of a large number of substituted indigoes, all of which contained the chromogenic group —CO—C = C—CO— and so in 1908 the term "indigoid" was suggested to cover the members of this group. Authoritative works[2] now all mention indigoids, and define them as indicated above, and the definition in every one of these books absolutely excludes the possibility that any chemist could even think of sulfur colors in the same connection. Numerous other references could be given to show that the word "indigoid" is always used with the meaning stated above. It is sufficient to quote Thorpe:

"Indigoids.—The congeners of indigo may be divided into two different classes. One of them contains the true derivatives of

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[1] *Ber.*, **41** (1908), 772.

[2] Cain-Thorpe, "The Synthetic Dyestuffs," **1913**, 174.
Green, "Analysis of Dyestuffs," **1915**, 123 and 38.
Thorpe, "Dictionary of Applied Chemistry," **1912**, **3**, 130.
Wahl, "L'industrie des Matières Colorantes Organiques," **1912**, 317, 346.

> indigo, in which one or more of the 8 hydrogen atoms of the two phenylene groups are replaced by other substituents; the other embraces substances which are strictly analogous to indigo in their constitution, but different from it in the construction of the complex connecting the two phenylene groups, which in this case as well as in that of indigo may have their hydrogen atoms replaced by other substituents. An enormous variety of new dyestuffs may thus be synthesized, all of which contain the characteristic chromophoric group of indigo:—CO — C = C — CO—."

An examination of Nietzki's book shows clearly that he distinguishes between sulfur dyes and indigo dyes, for he divides dyes into thirteen classes, and places the former in Class X and the latter in Class XII, and uses this classification consistently. Dr. Herty's misunderstanding seems to have arisen from a superficial examination of a more condensed classification occurring in Nietzki's volume. In one place he mentions five classes determined solely by the properties used in dyeing, namely (1) basic colors, (2) acid dyestuffs, (3) mordant dyestuffs, (4) neutral or salt dyestuffs, and (5) an unnamed group which includes insoluble dyestuffs, such as indigo, certain azo-dyestuffs, and the sulfur dyestuffs. But he does not say, or even imply that these dyes—mostly vat dyes—are similar to indigo, but only that the sulfur dyes do not belong to the other four classes, and he does not use the term indigoids, because that term did not then exist. These are simply a somewhat heterogeneous collection of dyes, which do not belong to the first four classes. Furthermore, an examination of Nietzki's book shows that he would have felt grossly insulted if anyone had stated that he classed sulfur dyes with indigo dyes. He not only puts them in separate classes, but on page 291 he defines sulfur colors on the basis of the method of manufacture and on page 295 gives their general properties. On page 325 he says "indigo dyestuffs are all derivatives of indol C_8H_7N," and not one of the sulfur colors he mentions in Class X, thiazol and sulfur dyestuffs (p. 288, *et seq.*) is derived from indol. There is, therefore, no possibility that anyone would include a sulfur brown as an "indigoid," either on the basis of anything Nietzki says, or on the definition of indigoids now found in many recent authoritative works, for these definitions absolutely exclude any such interpretation.

Dr. Herty seems to think that Mr. Caesar Cone, who died on March 1, 1917, and cannot now make any reply, caused the introduction of the word "indigoids," and did so with the deliberate intention of widening the exempted group, so as to make it include sulfur dyes. Since the word "indigoid" is a purely scientific term, and is not used as a trade classification, there is no reason to suppose Mr. Cone ever heard of the word before it appeared in the act. All who knew Mr. Cone personally are well aware that he would never have been guilty of using a subterfuge of this description. The introduction of the word indigoids is easily explicable in an entirely different way. In a case[1] tried before the General Appraisers, and reversed by the Court of Appeals, the word indigoids made its first appearance in connection with the chemical trade. Its introduction into the act was undoubtedly based on this case.

A reading of the two reports shows that the act of 1913, ¶ 514, places "indigo and dyes obtained from indigo" on the free list. The Lower Court decided that dyes, chemically similar to indigo (such as thio-indigos) and made from the same fundamental substances, but not made from finished indigo itself, were covered by this exemption. The Higher Court reversed this decision, claiming that the act applied only to dyes made with indigo as one stage in the actual manufacture.

Incidentally, the indigoid group is also defined in the report by references to Thorpe's Dictionary, in a way that excludes all dyes not containing the characteristic indigo chromogenic group. The new act differs from the old, therefore, in the fact that chemical cousins of indigo, now known as indigoids, even if not made from indigo itself, are included in the exemption. But there is not the slightest possibility of the word indigoid being interpreted so as to cover any dyes not actually containing the indigo chromogenic group.

....

When Professor Smith handed me this communication in an envelope bearing the printed inscription "Columbia University in the City of New York, Department of Chemistry" I confess I was surprised, for, as far as I could remember he had never published an article before in the field of industrial chemistry. This surprise was largely increased when I learned that the communication was on the subject of dyestuffs.

I have been pretty closely associated with every stage of the fight for an American dyestuff industry, have followed the discussions in all available journals, and, through the aid of clipping bureaus, have followed closely the discussions in the daily press. Never before had I seen or heard of anything written or spoken by Prof. Smith on this subject. This surprise, however, was increased to amazement when I first read the above communication. Let me explain.

The title of Prof. Smith's article is a paraphrase of an article which I wrote for the *Annual Review* of the *New York Journal of Commerce*, published on February 5, 1917, which article was reproduced in the March, 1917, issue of THIS JOURNAL as a part of my editorial "America for Americans." In his opening sentence above Prof. Smith states, "The editorials in THIS JOURNAL, etc." I have written only two on this subject, so it is evident that Prof. Smith has seen the one containing the *Journal of Commerce* article.

In his second paragraph he quotes me, and strange to say, in a contribution to a scientific journal, he gives no reference as to the source of the quoted matter. This is a curious oversight for one so accustomed to publication as he is. As a matter of fact he quoted sentences written by Mr. Isaac Russell, a reporter of the *New York Evening Mail*, who, after a 15-minute interview with me one day in my office and having no knowledge of chemistry or German and with only a few rough notes written on a piece of paper not larger than an ordinary envelope, wrote a three-quarter column story about indigoids and tariff legislation which was printed in the *Evening Mail* of January 3, 1917.

Reading the story I felt that Mr. Russell had done a pretty good piece of reportorial work for so technical a subject and was gratified to note that in recording my discussion of the subject he did not use quotation marks, for there were a number of errors in his article. Knowing that the evening newspaper public would not be interested in a correction of such inaccuracies of chemistry and of German translation, I determined to put the matter straight before those who would be

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[1] Treasury Decisions, 36450, **30**, No. 23, 11–15 (June 8, 1916), and 36965, **32**, No. 5, 64–67 (February 1, 1917).

interested in such matters and so tore up the partly written article on "Chemical Legislation: Wise and Otherwise" which I had been requested to write for the *Journal of Commerce* and wrote instead the article referring only to dyestuff legislation under the modified title "Chemical Legislation: Not Wise but Otherwise." Thus I gave over my own signature my views, for which I would therefore be solely and entirely responsible.

Among the inaccuracies of the reportorial statements were those quoted by Prof. Smith. I did not make such statements. Prof. Smith's unctuous sentence, "Although in this instance the misrepresentation was entirely unconscious and unintentional" smacks of insincerity for the merest tyro in chemistry could not have made such statements if they were "unintentional."

What I did say over my own signature was, "If a poll were taken of the dyestuff consumers in the United States as to what is an 'indigoid' which is 'not derived from indigo' how many could answer the question definitely?" and further that I had failed to receive an answer from "five of the most prominent American dyestuff chemists." I further stated that from information received there was good ground to believe that effort would be made to bring in sulfur dyes without payment of the special duty and that the basis of the effort would be the classification in the 5th edition of Nietzki's book. I did not seek to justify any such contention. I did refer to the misfortune that would befall the American dyestuff industry if such a contention should be sustained by the Board of Appraisers. I certainly hope that it would not be so sustained but that does not affect the intention of the importer who had determined to test the matter.

It was a public duty to call attention to this intended move against the revenue of the country and the American dyestuff industry. Regardless, however, of anybody's views as to "indigoids not obtained from indigo," one thing is certain—if Congress would repeal that excepting clause, no test cases of sulfur dyes could ever arise and that is the point for which all who are interested in the American industry should struggle. "Safety First" fits this case.

From the mere reading of Prof. Smith's communication I fail to see its purpose. Many things suggest that the natural thing for Prof. Smith to have done would have been to tell me frankly of his researches in the meaning of indigoids and to advise that I publish a correction. This would have enabled me to clear up his misunderstanding of the situation. Instead he hands me a paper fully prepared with the request that it be published in THIS JOURNAL of which I am the Editor.

Does he seek to safeguard the American industry? If so he should reserve his ammunition for the Board of Appraisers and aid the government attorneys should the case arise. Was it to exhibit great learning in this popular field? If so he seeks notoriety in a way which is extremely unusual, to say the least. Does he seek to bolster up the cause of the importers by allaying discussion of a matter which might sweep away with it indigo, alizarin and the other excepted dyes, or by lulling us into a false sense of security?

I regret to harbor the last thought but am impelled to it by the unexpected defense which he makes of the late Mr. Caesar Cone's motives. Mr. Cone made no secret of his position in this matter. In the brief of the Proximity Manufacturing Company (Mr. Cone's Company) to the Senate Committee on Finance, filed last July, these words occur: "and we respectfully submit that the second paragraph of Section 401 should be amended by adding:

> and natural and synthetic alizarin, and dyes obtained from alizarin, anthracene and carbazol: and natural and synthetic indigo and all indigoids, whether or not obtained from indigo, shall be returned to the free list and shall be exempt from duty."

Again, in an address by Mr. Cone before the National Association of Garment Manufacturers at St. Louis, Mo., on November 16, 1916 (a printed copy of which is before me bearing the imprint of Harrison Printing Company, Greensboro, N. C.), Mr. Cone said (page 10 of this address): "Now while we are on this dyestuff question—I don't know whether you gentlemen know it or not, but I have been personally villified somewhat by some of my friends because I was the only man, the only manufacturer in the United States that attempted to oppose the duty that they have put upon certain dyestuffs, and particularly on indigo.........On the 8th or 9th of September a bill was passed putting a duty of 30 per cent on indigo, and any indigo that comes to this country now bears that duty, and I dare say that it would have been 30 per cent plus 5 cents a pound but for the efforts made by my attorney and myself in Washington. And I thought at one time that I was going to be successful in keeping that 30 per cent off." Engaging frankness, amounting even to a boast. His own words confirm completely every statement I have ever made concerning Mr. Cone and this legislation.

No, if there is a joker in this tariff bill I have never thought that Mr. Cone was primarily responsible for it: he was not a chemist. There is good ground, however, for a reasonable inference at this date that if this discussion continues a little longer we shall know who is responsible for it.

Meanwhile, more light is thrown on Prof. Smith's remarkable contribution by a chain of interesting events which have happened recently. On February 7, a card was mailed to me from E. D. Lee, Librarian of the Chemistry Reading Room of Columbia University, requesting me to return the volume of Nietzki's which I had taken out on Prof. Metzger's card. Returning from Washington, D. C., on the 10th the volume was immediately returned. Then arose the following correspondence:

671 James Street
Pelham Manor, N. Y.
February 23, 1917

MR. CHARLES H. HERTY, Editor,
Journal of Industrial & Engineering Chemistry,
41st St. and Madison Ave., New York.

DEAR SIR:

In the *Textile Record* of February 2nd, I read the article mentioning that in the 5th edition of Nietzki, the group of dyes known as Indigoids is completely specified and that the list includes all forms of Sulphur dyes.

This classification of Sulphur dyes being quite new to me, I tried to find the information about Indigoids, but after getting hold finally of the above mentioned book and looking all over it, I cannot find it.

I would appreciate very much if you would write me the exact page of Nietzki dealing with this matter.

It may interest you to know that I have, however, found an exact definition of Indigoids in the following text books:

The Synthetic Dyestuffs, etc. by Cain Thorpe

The Manufacture of Organic Dyestuffs by Wahl

Analysis of Dyestuffs by Green

and also in Dictionary of Applied Chemistry by Thorpe.

Sincerely yours,
(Signed) Dr. H. Meyer

…………

35 East 41st Street
New York City
February 26, 1917

Dr. H. Meyer,
671 James Street,
Pelham Manor, N. Y.

Dear Sir:

Replying to your letter of February 23rd, I beg to refer you to the two concluding paragraphs of the introductory chapter, fifth edition, of Nietzki's "Chemie der Organischen Farbstoffe," page 27.

Very truly yours,
(Signed) Chas. H. Herty, *Editor*

…………

671 James St.
Pelham Manor, N. Y.
March 2, 1917

Mr. Charles H. Herty, Editor,
Journal of Industrial & Engineering Chemistry,
41st St. and Madison Ave.,
New York

Dear Sir:

I am in receipt of your letter of February 26th, and wish to thank you for your information.

In going over the two paragraphs on page 27 of Nietzki's Chemie der Organischen Farbstoffe, fifth edition, I can, however, not find anything about sulphur dyes being "Indigoids." Nietzki after giving the 4 groups of dyestuffs, namely, I Basic—II Acid—III Mordant and IV Neutral or Salt dyestuffs, puts in a fifth group all the colors which do not belong to any of these four groups and on account of their unsolubility have to be produced direct on the fiber, and mentions as examples, Indigo, insoluble Azo dyestuffs and also Sulphur dyestuffs, but I do not think it says that Sulphur dyestuffs belong to the Indigo class; it would then be just as correct to call Indigo a Sulphur dyestuff.

Sincerely yours,
(Signed) Dr. H. Meyer

As the two letters from Dr. H. Meyer were written on paper without letterhead and as I had never even heard of anyone in Pelham Manor, I did not care to continue such a discussion and so simply filed the letters. A few days later, however, I was somewhat interested to learn that a Dr. H. Meyer was a chemist of the Badische Company at 128 Duane St., New York City.

On the 9th of March Prof. Smith handed me his communication. I was at once struck by the similarity of literature references to definitions of indigoids given by him and by Dr. Meyer in his letter of February 23 and a somewhat similar treatment by both of Nietzki's "condensed classification," as Prof. Smith alliteratively describes it.

A few days later I was interested to learn that on June 30, 1913, an application for a patent on "Producing Hydrogen" (U. S. Patent 1,115,776, issued November 3, 1914) was filed by Carl Bosch and Wilhelm Wild of Ludwigshafen-on-the-Rhine, Germany, assignors to Badische Anilin & Soda Fabrik, of Ludwigshafen-on-the-Rhine, Germany, a corporation of Baden. The assignment was executed June 12, 1913, and recorded June 30, 1913. On July 3, 1914, the U. S. Patent Office, Division 31, received a communication labelled Paper No. 3 (a certified copy of which is before me) in which was recorded certain amendments to the patent and the substitution of new claims for the original claims. The paper further gives what the attorneys of these applicants assert to be a report "of Prof. Alexander Smith of Columbia University, a leading authority and who has reported as follows:" Here follows what purports to be from a report by Prof. Smith. I shall not take the space in This Journal to publish it unless these statements are questioned. This was the first definite knowledge I had of a direct connection of Prof. Smith with the Badische Anilin und Soda Fabrik.

With some light gained yet still puzzling over the meaning of all of this, I finally referred to Mr. Isaac Russell, the *Evening Mail* reporter who had written the first interview on this subject, the letters of inquiry sent to me by Dr. H. Meyer. I told Mr. Russell he would probably find Dr. Meyer with the Badische Company at 128 Duane St. Mr. Russell thanked me and said he would seek an interview with him and bring out the fact that there appeared to be definitions of indigoids not made from indigo which made the tariff revision, as drawn, perfectly safe. On March 21, Mr. Russell informed me that he visited the offices of the Badische Company at 128 Duane Street, and found that Dr. H. Meyer was out; he was informed, however, that Dr. Meyer lived at Pelham Manor and could be reached by telephone at the number given in the Westchester Section of the telephone directory. This number shows the address 671 James Street, thus agreeing with the address given on Dr. Meyer's letters to me. On March 22, Mr. Russell appeared at my office. He reported that he had been to the Badische Company's offices and met Dr. Meyer.

Instead of giving him an interview, Dr. Meyer said, as Mr. Russell reported to me: "I think you had better not take this up in the newspapers. It is a technical chemical subject and it had better be settled by the chemists and college professors in the chemical journals. A chemical journal is soon to appear with an article on this subject by a professor." Mr. Russell further said that Dr. Meyer had referred him to me as Editor of the paper in which the article was to appear. Mr. Russell asked me for a copy of this article out of which to make an article for the *Evening Mail* as a follow-up to the first *Mail* article. He said he had told Dr. Meyer he would go to me for a copy of the article and use it in lieu of the interview which Dr. Meyer had declined. He said Dr. Meyer approved this idea. I declined to give Mr. Russell a copy of this article as the galley proof of Prof. Smith's article had not yet been sent to him.

This article by Prof. Smith, about which Dr. Meyer was so well posted, is the only communication I have received on this subject. To my mind all of this establishes with reasonable certainty a Smith-Meyer-Badische connection and all that goes with it.

Only one thing more—all of the rest of us have been fighting to build up an American dyestuff industry, not simply as an economic necessity, but because we know how closely related this industry is to the production of high explosives for our army and navy.

Meanwhile, during the progress of the details recorded in this reply, our country has been drawn daily nearer and nearer into war with Germany, and even to-day when most of us hold strongly the conviction that we are already at war with Germany, Prof. Smith telephoned at noon to the office of THIS JOURNAL to learn whether his communication would be published in the April issue and was seemingly gratified to be assured that it would.

Again I say, AMERICA FOR AMERICANS!

CHAS. H. HERTY

March 22, 1917

NO TARIFF COMMISSIONER FOR CHEMISTRY

The announcement of the personnel of the Tariff Commission brought with it keen regret that President Wilson had not been sufficiently impressed by the many recommendations and arguments forwarded him to lead him to appoint Mr. Ellwood Hendrick as a member of that body.

It must be gratifying, however, to Mr. Hendrick to know that while he had from the outset declined to enter into any active canvass for appointment, nevertheless he received the unanimous endorsement of all the organizations of chemists and of those allied organizations whose needs could be thoroughly understood and comprehended only by one having a thorough grasp also of the chemical situation and the interlacing character of all of these industries.

A TIMELY PROPOSAL

We are very glad to feature in this issue the address delivered by Dr. B. C. Hesse before the Detroit Section on the subject of "The American Chemical Society and the Nation." In this address Dr. Hesse has put forward a constructive suggestion which deserves the serious consideration of every member of the Society and especially of the members of the Council who will assemble soon at Kansas City for the Spring Meeting.

The remarkable growth in membership in recent years has enabled the Society to do things which have excited the admiration of the chemical world. Its continuous and its present accelerated growth offer marked possibilities of still greater achievements in the future. This great numerical strength, however, contains within itself grave possibilities of danger through discord and consequent disruption, unless statesman-like provision be made for the logical and orderly expression of the convictions of members on matters in which they, as experts, have the right and the duty to be heard.

Things have moved rapidly in this world during the past three years, necessitating new viewpoints and new adjustments. The nation has suddenly awakened to the fundamental importance of the work of its chemists and now holds them in higher regard than ever before. In return for this national recognition we must assume a national obligation, namely, a national viewpoint. For the formulation and expression of opinions on national problems, the membership is too bulky; even the Council has grown too large, while the Directors are charged rather with the financial administration of the Society.

Furthermore, quick decision is often demanded. For these reasons a small group of experienced men is required whose judgment can be promptly gathered—a group somewhat continuous yet changing in its personnel and thoroughly representative of the Society. In its efforts such a group should have the hearty indorsement of the members or be abolished. Dr. Hesse seems to have had all such points in mind in working out the proposal which he has submitted.

So often during the past two eventful years, in the capacity of President of the Society, we have felt the need of such a body as the proposed Board of Control of National Policies. Without it we did the best we could in the many exigencies which arose, sometimes assuming authority to speak when we really doubted the possession of such authority. Many times, when occasion demanded action, we took the risk of rebuke, trusting solely to the good-will of fellow members and their confidence in our honesty of purpose. Fortunately we met with no rebukes, but such situations are dangerous for the Society, as well as somewhat embarrassing to its executive head.

There is also the constant danger of the action of a Local Section being misinterpreted as the action of the parent organization. On two occasions last year it was necessary for us officially to call attention to the fact that the recommendations regarding tariffs on dyestuffs were not those of the American Chemical Society, but were those of the New York Section of the Society, and that consequently such use of the name of the Society was not authorized.

It is not at all difficult to conceive a case where two Local Sections in different parts of the country might have opposite views on a question of public policy. The confusion which might arise incident to the publication of those opposing views and their misconception as views of the Society, might easily lead to a popular discrediting of the organization as a national influence. Such possibilities suggest that Local Sections could well forego their present privilege of unlimited public expression, confining themselves in this public capacity to local matters and privately presenting their views on national matters to a National Board.

As we see the matter now, Dr. Hesse's suggestion involves a change in the constitution, and it is possible that discussion of the proposal by the Council may lead to some changes in the details of the plan, but the fundamentals are essentially sound. We are all indebted to him for this thoughtful address.

....

Following the reading of Dr. Hesse's paper the Detroit Section passed a Resolution favoring the adoption by the Society of a policy along the lines suggested. Later the Board of the Detroit Section unanimously voted to propose at the Kansas City Meeting of the Council an amendment to the Constitution of the Society creating a Board of Control of National Policies.

PLANT PRECAUTIONS

At the outbreak of the European war this country was threatened with a serious shortage of barium salts. With fine energy and courage the Toch brothers immediately began the erection of a plant at Sweetwater, Tenn., to utilize the ores in that vicinity. This plant had been continuously enlarged and methods improved, thus constituting an important factor in our program of national self-containedness.

In spite of full provision of facilities for fighting fire, including the thorough training of both the day and the night forces, this plant was gutted by fire on the night of March 8th, although the time clock of the watchman showed that just ten minutes previously he had been at the place where the fire originated.

In view of such an occurrence it cannot be too strongly urged that no steps be left untaken which will insure the safety of our chemical industrial plants against incendiary fires.

We know full well the deeply conceived spirit of malicious destruction which has been evidenced in other lands during this war period. Let us quickly and completely awake to the fact that we too are now fully subject to that same malicious spirit and therefore let us take no chance of misfortune which alertness and abundant caution can avert.

THE AMERICAN CHEMICAL SOCIETY AND THE NATION

Address by BERNHARD C. HESSE before the Detroit Section of the American Chemical Society, March 15, 1917

The American Chemical Society has to-day over 8300 members meeting in 49 local sections in 32 States of the Union and the District of Columbia. In point of numbers it is the largest organization of chemists in the world. Each local section has its own Chairman, Secretary and Executive Committee for the treatment of its local affairs and further, it has representation from among its membership in the Council of the Society in accordance with the size of its membership. The Council of the Society controls the formulation and execution of all the policies of the Society and also receives from the entire membership of the Society by secret letter ballot suggestions for candidates for President, Councilors-at-large and Directors, and from among these suggestions the Council makes the final selection, also by secret letter ballot. The Secretary of the Society, the Treasurer of the Society and the Editors of the various publications of the Society are elected by the Council. Hence, those in positions of authority and responsibility receive that authority substantially directly from the membership and are responsible to and under the control of that membership. In this respect, then, our Society lives up to and practices so nearly as it can be done the great principle embodied in the Declaration of Independence that all governments derive their just powers from the consent of the governed.

The Society holds two general meetings of its Council and of its membership each year; its Board of Directors meets at the same time also and at such other times as the business of the Society requires.

The object of the American Chemical Society is "the advancement of chemistry and the promotion of chemical research."

In furtherance of these objects the work of the general meetings is carried out in 8 Divisions, namely: Industrial Chemists and Chemical Engineers; Physical and Inorganic Chemistry; Fertilizer Chemistry; Agricultural and Food Chemistry; Organic Chemistry; Pharmaceutical Chemistry; Biological Chemistry; Water, Sewage and Sanitation.

The American Chemical Society publishes three journals, one for pure chemistry, one for industrial and engineering chemistry and a third devoted to coördination of progress everywhere and in all branches and lines of chemistry.

Supplementary to this there are 33 standing and divisional committees appointed annually which look after the subjects confided to their care and 9 of these deal with topics of national scope.

OUR PLAN OF ORGANIZATION THE BEST

This plan of organization is unique in the chemical societies of the world and since the outbreak of the present war, German chemists of eminence have publicly praised that plan and have expressed regret at the absence of such a cohesive, elastic and coördinated organization among the chemists of their own country, and have cited it as a reason against further subdivision among German chemical societies. While this is not necessarily conclusive yet it is a matter of some satisfaction to have an admission that the chemists of the United States do something better than their professional brethren across the Atlantic. It may, therefore, be stated with confidence as a fact, and not at all as a vainglorious boast, that the American Chemical Society is the largest chemical society and has the best plan of organization of any chemical society in the world.

OUR GOVERNMENTS AND CHEMISTRY

The various states of the Union and their respective municipalities devote a considerable amount of effort and money toward the growth and diffusion of chemical knowledge and the application of chemistry to the welfare of their citizens. Our Federal Government likewise expends much effort and money toward the same ends. In this respect, also, we can invite comparison with any other country confident that it will not result to our disfavor.

OUR PAST POLICY

For the first thirty years or so of its existence the American Chemical Society practically entirely refrained from taking part in shaping national policies or in solving national problems, partly because it was not invited so to do and partly because it regarded its function to be fostering the science rather than the art and the industry of chemistry. Gradually this has been changed and quite markedly so with the founding of its JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY in 1908, which has come to be regarded as the best publication of its kind in this country. The actual participation of the Society, as such, in shaping policies of national scope did not increase much, if any, until during and after 1914.

OUR ACTIVITIES SINCE 1914

Since 1914 the American Chemical Society has participated nationally by having representation as follows:

1—On the Naval Consulting Board.

2—On Advisory Committees to the Bureau of Standards and to the Bureau of Mines.

3—On the National Research Council.

4—In conjunction with the National Academy of Sciences and four Engineering Societies for general lines of coöperation and also on the Nitrate Supply of the United States.

This, in itself, is an achievement and a recognition of no small significance and importance; it is a matter of justifiable pride and satisfaction that we have been able to render national service of worth and effect, but it is largely the result of invitation and not of our initiative. However, we must not dwell upon these results too long nor too exultantly.

OUR FUTURE

This new phase of our activities, upon which we have entered quite by force of circumstances and not at all with forethought or conscientious, deliberate and comprehensive planning or initiative must give us pause and compel us to consult among ourselves and with our friends as to the responsibilities we are thus assuming and as to the best and most effective way of discharging them patriotically, promptly and comprehensively, all for the best interests of the Nation.

There can be no doubt that if the membership of the American Chemical Society were specifically asked to pass upon these acts of its Council and of its executive officers, that each and all of these acts would be ratified and approved. As a matter of fact, while there has been acquiescence, there has been no such formal ratification and as a further matter of fact, those acts were each and all performed without the specific consent or authorization of the membership itself and in the final analysis the membership must so instruct its officers because for the forty years of its existence the policy of the Society as shown by its acts did not contemplate and has not contemplated any such steps on the part of those it had placed in authority, although there is nothing in that policy and in those acts that could be construed as specifically prohibiting acts of the kind we have performed in the past two years and a half.

WHY WE MUST AUTHORITATIVELY BROADEN OUR FIELD

For those in authority to proceed much further without such specific authority from the membership itself may be fraught with grave danger and may easily leave the door open for internal dissension and strife which could not do otherwise than disturb the magnificent structure of our organization and rob it of its just opportunity to serve the Nation. Those who devised this structure planned wisely and well; they laid their plans as far into the future as they safely could. Three years ago not one of us would have been willing to prophesy this expansion of our activities into the domain of national affairs in the concrete and direct manner that has taken place in the past thirty months. It is for us of to-day to plan as wisely for the future as did they who devised and developed this potentially strong and elastic organization of which every American chemist may well be proud; this structure is now entrusted to our care for its development and safe-keeping. Let us not fail to measure up to the responsibility which the course of events has placed upon us.

WE HAVE NOT FULLY UTILIZED OUR PAST ADVANTAGES

Taking into account the geographical extent and numerical strength of our Society, its exceptionally elastic and adaptable plan of organization and also all that which our federal, state and municipal governments do for chemistry, the question forces itself upon us: Have we in the past made the most of this condition of affairs? I think an impartial inquiry will develop that we have not done so and the reason for that is not hard to find. We have fostered the science of chemistry in an idealistic manner and have given much less thought to nationality of origin of scientific advancement, than to the actual advancement of the science as a whole; in this we have been encouraged by the general national and international political policy of our Nation, namely that of self-sufficient isolation from the Old World and the general attitude of friend of all the world, and all the world our friend.

OUR PAST ACTIVITIES INCOMPLETE

The events of the past thirty months have not shown that that was an intrinsically wrong course, but they *have* shown that it was not enough; we were all right so far as we went but we did not go far enough; that is, we should also have had an eye on what national advantage we could gain from the general advance of the science as a whole and what national disadvantage would flow from our not making the most of those advances for ourselves and as a Nation.

That is, while our course in the past has not been a mistaken one yet it did include an omission. I believe that we can cure that omission without in any wise interfering with our past policy; in fact, I believe that a cure for that omission will merely strengthen and foster that policy in its own field.

A PROPOSED REMEDY—A BOARD OF CONTROL

As to the remedy, I offer, of my personal initiative, the following plan as a feasible, practical and practicable means of so expanding our activities with authority and authoritatively. This plan is:

I—The membership, by secret letter ballot, to vote on the expansion of our activities to cover all fields of national endeavor, economic, scientific, commercial, industrial and the like.

II—In the event of the adoption of such an expansion of policy, the Society to have a Board of Control of National Policies of the American Chemical Society. This Board of Control to consist of five members: the President of the American Chemical Society, the Secretary of the American Chemical Society, the Editor of the *Journal of Industrial and Engineering Chemistry* of the American Chemical Society or of its successor-publication and the two available past Presidents of the American Chemical Society next preceding, each member to have one vote. The President of the American Chemical Society shall be the Chairman of this Board of Control. The Secretary of the American Chemical Society shall be the Secretary of this Board of Control. This Board of Control shall have complete and sole jurisdiction over any and all subjects of national scope to be taken up, shall direct what national matters shall be taken up, and no such work can be taken up without the consent of this Board. Further, as to the manner in and the extent to which they shall be taken up, the Board of Control shall appoint necessary committees and their needful officers and shall direct and supervise the work and reports of all such committees and such committee-reports are not to be made public until approved by the Board of Control and shall be published by the Board of Control in that publication of the American Chemical Society best adapted thereto and in any additional publications this Board may elect, and shall be communicated to such committees or public bodies as this Board may deem desirable. At each Fall meeting of the Society this Board of Control shall report to the general meeting what it has accomplished since the Fall meeting next preceding, the work in hand and the work in project and all the suggestions for added work or for betterments it may then have received from members of the Society or from others and this report to be printed in full, in the next succeeding issue of the Proceedings of the Society and in any other place or places the Council may designate. At the December letter-poll of members, in alternate years, the membership shall be asked to vote on continuance and discontinuance of the authority for such expansion of our activities and approval or disapproval of the work of the two years next preceding. If such continuance of authority be withheld, this Board of Control shall cease its activities forthwith.

FOR AND NOT OF THE AMERICAN CHEMICAL SOCIETY

It must be remembered that the ultimate work of this Board of Control cannot, in fact, be the opinion or recommendation *of* the American Chemical Society; all it can be or profess in fact to be is an expression of opinion or the making of a recommendation or a statement of fact *by authority and in behalf of* the American Chemical Society; such an expression of opinion or such recommendation or such a statement of fact in no wise prohibits any member or members of the Society from disagreeing or from publicly expressing their disagreement or non-concurrence in any way that they see fit so long as they do not directly or indirectly represent themselves as speaking for or by authority of the Society or of any part of the Society. Therefore, this Board of Control must see to it that membership on the various committees that it may find needful to appoint be conditioned upon fitness, disinterestedness and ability and willingness to ascertain all the facts, draw all the conclusions and make all the recommendations regardless and entirely independent of any personal opinion, prejudice, or interests prospective committee-members may have.

CONFIDENCE AND AUTHORITATIVENESS

Under these conditions the final work of this Board of Control would be entitled to respectful hearing without any quarrels or quibbles as to motives, etc., and, as such, to treatment on its merits—even by no matter how hostile a committee, say, of Congress. The work will have been done by authority of the membership renewed each two years, and the work itself will be authoritative because we can safely trust such a Board of Control to select the best available men for any given task because it would be made up of men who have reached that Board on the initiative of the membership and because that membership considered them to be of that broad-minded type required for successful leadership and the Society by so electing them had given them its confidence in their probity, honesty and ability; having gained that confidence of their fellow chemists in that way and in some cases through many years of honorable Society service in addition, the members of this Board of Control can safely be trusted further to conserve the best interests of the Nation and of their Society as well as their own personal honor.

Such a Board of Control, working in such a way ought and would merit and would soon gain and hold the confidence of the public and of those in authority in our government. For the Society, it would attend to it that there be continuity of effort and policy and that new circumstances were promptly met in the best available way and that our efforts were properly coördinated and further would prevent participation in minor matters, because it would be the sole mouthpiece of the Society in matters of national scope. We could depend upon it that such a Board would see to it that all the work would be done from the viewpoint of the Nation as a whole, that the Society would not be used as a cat's paw for individual ends because in matters of this nature we are American citizens first and American chemists afterwards and we must deal with them with the welfare of the whole Nation in mind first, last and all the time; the American Chemical Society cannot under any circumstances permit itself to be maneuvered into the position of spokesman for individual gain but it must at all times embody, present and advocate the best interests of the Nation and of the whole Nation; therefore, it must be circumspect, judicious, prompt, comprehensive and thorough in all such work and must at all times command and deserve the full confidence of the public; it must not promise more than it can perform and must live up to its promises.

SMALL COMMITTEES THE ONLY PRACTICABLE MODE

We must get at all relevant facts, deductions and conclusions and face them whether we like them or not; we must not fear nor solicit political favor, we must be comprehensive, complete, fair and just in our work. To my mind this can be accomplished by a Board such as I have just outlined and now is the time to start in on the work, for, under the most favorable conditions, it will be four or six years before a smooth-working organization can be effected.

From the practical point of view of getting things done, experience unequivocally teaches that to leave the execution of a piece of work to our membership at large is totally inefficient and non-productive of results within any reasonable time. A small committee of 3, 5 or 7 members, having received its general instructions from such a Board of Control, would get somewhere and with a reasonable degree of certainty and accuracy long before the total membership or a majority thereof, would have realized, understood and appreciated the trend, scope and purport of the instructions and of the work to be accomplished. Such a Board of Control, having all national threads in its hands, would attend to it that not too much was undertaken at one time, that the needful coöperation between different committees was forthcoming and relative progress kept in alignment, that the various results were promptly communicated where they would accomplish the most, and the entire activity kept in definite relationship to the campaign as a whole—something which the membership as a whole or our Council could never hope to realize or to accomplish.

EXCLUSIVE SPOKESMANSHIP NECESSARY

The title "American Chemical Society" belongs to the Society as a whole and no part nor member of the Society should make use of that title not in harmony with the aims and objects of the Society as a whole. If members, sections, or divisions of the Society disagree with any particular act of national scope of the Society they should in no wise be hampered nor interfered with in full and free public expression of that disagreement but they, on their part, must avoid everything that would tend to give their disagreement the appearance of sanction by the American Chemical Society or any part of it, otherwise confusion must result and consequently the name of the American Chemical Society may come to stand for much less than in reality it should.

SUMMARY

In order to have the greatest weight with legislative and similar committees, those appearing before them, professedly in behalf of the general good, must first show conclusively or at least very persuasively that they have no individual nor collective axes to grind either directly or indirectly. This would be taken care of by the plan just outlined which would be embedded in our membership, would take its right of existence from that membership and, based upon its record, must go back to that membership once every two years for a new lease of life. Secondly, they must show conclusively or persuasively that they know what they are talking about and that they are competent to perform the work they offer to perform. For this we shall have to rely upon the judgment of this Board of Control to pick the best men available for any particular piece of work. With a Board constituted as outlined this seems to me a matter of very small risk and of a very great degree of certainty.

Further, this Board being charged with the initiative and the sole and exclusive spokesmanship for the Society in matters of this kind would be put on its honor and on its mettle to see to it that important national matters were promptly discerned and properly treated as they arose and that not too much was attempted at any one time and that the scope of the work was confined to practical limits, all of which things a large body such as our Council and certainly our membership could never hope to accomplish.

THE AMERICAN CHEMICAL SOCIETY CAN ONLY GAIN

In so exclusively delegating the initiative, direction and execution of its participation in national affairs does the Society or do its sections or divisions relinquish anything fundamental? I think the answer must be "No." The membership itself cannot do this work nor can the Council and it is, therefore, a question of getting something constructively done nationally as against getting nothing done at all. The only risk that we run is that of placing all our national activities in the hands of five men. But all these men have already been tried and found true to our best interests and there is no real reason to believe that they would not continue so to be true.

As I see it, there is a positive added advantage in having such a Board of Control because the participation of the Society in national affairs should increase rather than decrease. As matters now stand, the President of the Society, who is generally new to such responsibilities, may appoint any committees he deems needful, inclusive of committees on affairs of national scope; while this plan would take away from him the *sole* appointing power of such national committees he would be given definitely and specifically four experienced advisors who must act with him and all five must act in concert; the President is thus officially given specific and experienced help in problems of national scope and the Society *gains* by having five men decide, guide and control its conduct in these matters as against but one, a usually inexperienced man, under our present arrangement. As against this we have loss of such rights as sections and divisions may now have for action in national affairs, but these rights should be formally surrendered, to the end that national action by the Society may be given greater force and effect; if at any time this Board of Control abuses its powers or is derelict in its duties such sectional or divisional rights can be recovered and exercised in the manner provided. To my mind, this temporary and controllable parting with sectional and divisional rights can only be in the interest of all since there can really be but one leader and we must all get back of the leader and should not be pulling in different directions.

THE POSSIBLE FIELDS

Those of our members who have accepted positions on committees and boards of national scope on behalf of or for our Society have every right to expect authoritative, prompt and efficient coöperation from the Society should occasion therefor arise and this without any strings tied to it, and they should have it. A Board of Control, such as suggested, will enable our Society to give that coöperation in the most efficient, authoritative and effective manner available and far better than any we could give under our present arrangement.

Questions of conservation of water power, mineral products, forest products and the like will no doubt offer additional opportunities to such a Board as also will questions of developing and diversifying our internal manufactures and trade, our export trade, transportation of materials, hours of labor, old age, accident, sick and pension funds, workmen's compensation acts, coördination of instruction, investigation and research, in addition to those national questions in which we have heretofore or only recently participated. Now that Congress, by creating a Tariff Commission, has conceded that Congressional committees such as the Ways and Means Committee and the Finance Committee of the Senate are unequal to the task of ascertaining fundamental facts and of determining what are fundamental facts, opportunity is given us to aid in that direction unhampered by the claptrap, sophistry, legerdemain, unfair tactics and browbeating that seem to be inseparable from so many congressional committee investigations, and paying attention solely to the merits of the subject; we will be in good position then to make recommendations to Congress as to specific tariff-treatment, something which the Tariff Commission itself cannot freely do. No doubt there will be further opportunities of aiding in other national fact-ascertainments which are not or cannot be efficiently executed by congressional committees but must be done by special commissions or the like.

To my mind, the time has come when we must think in terms of the Nation, with our eye on the map of the world and on our national requirements, but without in any wise diminishing our support of the science itself.

CONCLUSION

On the assumption that the membership will decide that the Society should systematically take definite part in all relevant national matters I suggest the foregoing plan as containing a fairly comprehensive and complete basis from which to construct and develop a real working and workable plan.

And why should not the Society decide to expand nationally? If we wish to live up to the finest and best traditions of a democracy there is every reason why we should so decide and none why we should not. Why are we not as well qualified to initiate and guide relevant national matters as are legislators or government officials? In fact, we are better qualified than either or both and, therefore, we should do it. By evading such opportunity we are not living up to our citizenship nor are we fulfilling our obligations. The American Chemical Society should walk right up to this opportunity and embrace it with enthusiasm and determination. Then—let us not backslide. Let us contribute our share towards making a democracy as efficient nationally as any other form of government. Eternal activity is the price of progress just as eternal vigilance is the price of liberty.

The American Chemical Society has such a comprehensively planned organization and so many points of contact with national endeavor, as expressed in our various divisions of government and our various scientific or technical associations, that it can readily add to its present activities systematic constructive work along lines of national and international polity. This is a gap in our work which we should at once proceed to fill effectively and efficiently lest our national citizenship be reduced to mere lip-service. The plan just outlined is, therefore, submitted as a starting point for such action and because of the great importance of the subject it is now commended to prompt and careful consideration by the Society.

Finally, whatever plan of national coöperation is evolved it must have the continued, continuous, prompt and whole-hearted support of the entire membership; each of us must give of his strength, time, thought and ability all that he can and whenever he can; otherwise these efforts cannot and ought not long endure.

25 Broad Street, New York City

ORIGINAL PAPERS

FERRO-URANIUM[1]

By H. W. Gillett and E. L. Mack

Uranium steel apparently dates from about 1897, when it was stated[2] that the French Government was trying to make use of uranium steel in guns. Merck's 1907 index (p. 452) states that the only technical use for uranium is in the form of an alloy in the manufacture of gun barrels.

Escard[3] states that it is reported that Krupp uses uranium steel in armor plate. There have been various rumors, naturally not capable of direct proof, that Germany is using uranium steel liners in big guns, in the present war.

Fischer[4] says, "a German firm is putting on the market ferro-uranium to be used in the manufacture of steel. England is also interested in uranium steel and as a permanent supply of ferro-uranium is guaranteed by Messrs. Geo. G. Blackwell Sons and Co., Ltd., of Liverpool, trials on a large scale will be made in the steel industry. The properties of uranium and tungsten steels are similar. Fischer[5] says, "some of the large (American) steel companies have tried to use uranium in their line of work, but with little or no success."

Tourchinsky[6] includes without further comment 0.23 per cent in the composition of steels made at the Sonoritz works in 1913.

Commercial use of uranium steel in the United States is quite recent. Keeney[7] states that in 1915 the Standard Chemical Company worked on the use of uranium in steel and put ferro-uranium on the market. He says, "although the applications of ferro-uranium have not been completely solved, the results are encouraging and indicate that in high-speed steel a small percentage of uranium may be substituted for a very large percentage of tungsten without injuring the cutting qualities of the steel. A high-speed steel showing excellent cutting qualities contained C 0.78 per cent, Mn none, Si 0.16 per cent, P 0.02 per cent, W 8.15 per cent, Cr 3.62 per cent, V 1.81 per cent, U 1.02 per cent." Two or three other American firms are contemplating the commercial production of ferro-uranium.

Comparative tests of uranium steels whose composition is not given, against other high-speed steels, also of unstated composition, have been given by the Standard Chemical Company.[8] Uranium steel has been widely advertised as "the last word in high-speed tool steel," and it has also been advertised that "ferro-uranium used in high-speed steels greatly increases strength, toughness and durability, producing a steel that will stand up on the job."

However, the reports of Hoffman and Johnson[1] were not so favorable, the former stating that a uranium steel with 5 per cent W and 3 to 4 per cent Cr made a very good tool and did good work for say two grindings, but after that did not hold its efficiency and had to be rehardened, and the latter, that a 40-point carbon steel with 0.3 per cent U was disappointing, being red short at ordinary forging heat and altogether uninteresting from a practical point of view.

It is also understood that in most attempts it has been found very difficult to produce uranium high-speed steel free from streaks or seams.

It will be necessary to have more definite data than have yet been published before the real value or lack of value of uranium in steel can be determined. All that can be said at present is that uranium deserves a careful trial both in tool steel and in ordnance, though the former is probably the more promising field.

Although the production of uranium steels was attempted ten years ago, the literature is singularly barren of really definite information on them, and is even more meager in regard to the manufacture of ferro-uranium.

The electrolysis[2] of fused mixtures of CaO and the oxide of the metal to be produced has been suggested as a method of making ferro-alloys. In a private communication, Mr. Beckman has outlined his process for making ferro-uranium, in which equimolecular proportions of CaO and rather impure U_3O_8 were fused in a magnesite-lined furnace and electrolyzed with an iron cathode and carbon anode. The furnace was not arranged to pour or tap, and the product was chiseled out after cooling. Mr. Beckman stated that he had thus made carbon-free ferros of 60 per cent U, and 9 per cent V with the balance mainly Fe and Si. He kindly sent the writers a small sample whose analysis he did not have, which was made by the above process.

The analysis[3] of this sample, the composition of the ferro produced by the Standard Chemical Company, as given by Keeney,[4] and the analyses of two shipments of commercial ferro made in 1916 and reported by the purchasers, are given in Table I. The absolute percentage of carbon and silicon in the ferro is not so

Table I

Ferro	Percentage Composition U	C	Si	V	Al	Ratio to 10% U C	Si
Electrolytic	57.2	4.2	4.3	Traces	1.5	0.73	0.76
Keeney	50.0	3.0	1.0	2.0	...	0.60	0.20
Commercial No. 1	41.2	4.9	2.4	2.3	...	1.12	0.58
Commercial No. 2	40.0	3.5	2.0 to 3.0	...	...	0.88	0.50 to 0.75

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[1] To be read at the Kansas City Meeting of the American Chemical Society. Published by permission of the Director of the Bureau of Mines.

[2] Dennis, L. M., "Uranium," "Mineral Industry," **6** (1897), 654.

[3] J. Escard, "Sur les differents procedes de preparation de l'uranium metallique pur ou a l' etat de fonte," *Rev. chim. industrielle*, **18** (1907), 81.

[4] S. Fischer, "Uranium and Vanadium," "Mineral Industry," **22** (1913), 773.

[5] S. Fischer, "The Carnotite Industry," *Trans. Am. Electrochem. Soc.*, **29** (1913), 374.

[6] K. Tourchinsky, "Nathusius Electric Furnace in the Steel and Tube Works at Sonoritz," *Rev. Russ. Soc. of metallurgy*, through *Rev. de met.*, **12** (1915), extraits, p. 180.

[7] R. M. Keeney, "Uranium and Vanadium," "Mineral Industry," **24** (1915), 706. See also J. M. Flannery, U. S. Patents 1,201,625; 1,201,626; 1,201,627, January 2, 1917.

[8] Standard Chemical Co., "Uranium in High-Speed Steel," *Met. and Chem. Eng.*, **15** (1916), 160; *Iron Age*, **97** (1916), 952.

[1] Hoffman and C. M. Johnson, in discussion, "Symposium on Electric Steel," This Journal, **8** (1916), 949; *Met. and Chem. Eng.*, **15** (1916), 448.

[2] J. W. Beckman, "An Electrolytic Furnace Method for Producing Metals," U. S. Pat. 973,336, *Trans. Am. Electrochem. Soc.*, **19** (1911), p. 171.

[3] By E. L. Mack.

[4] R. M. Keeney, *Loc. cit.*

important as their ratio to the uranium content, so, for comparison, the percentages of these impurities for each 10 per cent U have been calculated and included.

Johnson[1] states that he has encountered so-called ferro-uranium containing 15 to 20 per cent aluminum, and that vanadium was always present, from 2 to 3 per cent up to 28 per cent; he states also that one ferro-uranium analyzed by him contained 15 per cent silicon.

One steel company, according to a private communication, has made ferro-uranium on an experimental scale, in an Acheson graphite crucible, under an indirect arc, using silicon or ferrosilicon as reducing agent, and has produced ferro of 15 to 85 per cent U, with carbon averaging about 4.5 per cent in all lots. Quite a little silicon was also left in the ferro. On the 85 per cent ferro, this would give 0.53 per cent C for each 10 per cent U.

The price of American ferro-uranium in February 1917 was $7.50 per lb. of contained U, *i. e.*, $3.75 per lb. for a 50 per cent ferro. A German product was quoted[2] in 1914 at 450 Marks per kilo for a ferro of about 50 per cent U. A recent quotation[3] on uranium oxide is $3.60 per lb. of 96 per cent U_3O_8, with special prices on ton lots, equivalent to $4.40 per lb. of contained U at the price for small lots. This leaves a margin of $3.10 per lb. U to cover loss of U in reduction, cost of iron, coke, flux, power, labor, interest, depreciation and profit in the manufacture of the ferro.

Partly on account of the price, experiments on uranium steels seem to have been confined to those with a maximum of about 1 per cent U. While it is probable that uranium steels with such high percentages as the 12 to 20 per cent W in some tungsten steels may not be commercially desirable, it would be well to know what the properties are of steels really high in U.

In present practice in the addition of ferro-uranium to steel, $^1/_3$ to $^1/_2$ the U is lost. Experience will probably reduce this loss materially, but reports so far indicate that with a ferro much below 40 per cent U the U is not readily taken up and that with a very high U ferro—say 95 per cent, or practically a crude metallic U, the metal burns up so rapidly that much is lost before it can get into the steel. It seems probable that 45 to 65 per cent U will be about the proper percentage. Those who have attempted to use ferro-uranium find that it must be added just before pouring or during pouring, as, if added any length of time before the steel is cast, no U is found in the steel, possibly because of reaction with slag as well as oxidation. The steel should be very hot.

The C and Si ratios in the ferros whose compositions have been given are so high that, with the $^1/_3$ to $^1/_2$ loss of U, these ferros, even if added to a carbon-free iron, would reach the usual limit of carbon for a tool steel when about 5 per cent U remains in the steel, and in most cases the silicon would also be over the usual limit.

On the other hand, if experiments prove that only very small amounts of U are desirable, ferros of the composition given, or those even higher in carbon, could be used. But until a purer ferro is produced, experiments on steels really high in U and of normal C and Si content will be impossible.

The uranium oxide used in the work described below was produced by the National Radium Institute. It was mainly UO_2, with some U_3O_3. This runs about 83 per cent metallic U. The oxide contained about 2 per cent Fe_2O_3, 0.1 per cent Al_2O_3, 0.1 to 0.25 per cent V_2O_5, 0.20 to 0.35 per cent SiO_2, 0.3 per cent moisture, 1.3 per cent NaCl, 0.15 per cent carbon. Of these impurities, for use in a ferro-uranium made by reduction with carbon, only the Al_2O_3, V_2O_5 and SiO_2 can introduce impurities into the ferro. On the basis of metallic U + V + Si + Al, the total impurities that can go into the ferro are less than 0.5 per cent.

Beside the greater purity of this UO_2 than most commercial U_3O_3, the lower oxide is advantageous in that the first stage of the reduction, from U_3O_3 to UO_2, has already been accomplished, hence the further reduction, from UO_2 to U, will not require as much energy as would be the case when U_3O_8 is used. In order that the other materials used might approach this standard, a pure ingot iron, and a low-ash coke were used.

UO_2 is not reduced by carbon below 1500° C.,[1] and according to temperature measurements on the surface of the slag at the end of successful runs, a temperature of at least 1700° is required for efficient reduction, requiring an electric furnace.

UO_2 has a specific gravity of 10.2, that of iron is a little under 8, and that of metallic uranium is about 18.7. Hence if one melts UO_2, carbon and iron together without a slag, the iron will stay on top and will not collect the uranium. So it is essential to have some flux present which will combine with UO_2 to form a slag lighter than iron. This slag should also be a good arc-supporter, in order to use the direct arc type of furnace, since the bulk of the reduction seems to go on directly under the arc itself. The slag must not introduce undesirable impurities into the ferro. The furnace must be provided with a lining that will not be strongly attacked by the slag or introduce undesirable impurities, and which will stand up at the high temperature needed.

Attempts to produce the ferro in an indirect arc type of furnace soon showed that there would be an excessive power consumption to get the required temperature, and the direct arc type was then taken as the most promising. The Rennerfelt type, where the arc is deflected onto the charge, might serve, but was not tried, as only single-phase power was available, and there was no difficulty in getting slags that were good arc supporters for the direct arc type.

In preliminary experiments it was found that Al_2O_3 made a very fluid slag with UO_2, and as it was at first

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[1] C. M. Johnson, "Chemical Analysis of Special Steels," 1914 ed., pp. 288, 299.

[2] De Häen's price list, May, 1914.

[3] Foote Mineral Co. Mineral Foote-notes, January 10, 1917.

[1] H. C. Greenwood, "Reduction of Refractory Oxides by Carbon," *J. Chem. Soc.*, **93** (1908), 1483.

thought that Al would not be reduced rapidly enough to produce a very impure ferro, this was tried.

In order first to produce a ferro sufficiently high in U without regard to carbon content, experiments were made with both Girod and Héroult type furnaces with carbon or graphite hearths. Some of the first of these were not tilting or tapping and the product was taken out when cold, but it was soon found that even for preliminary work, a tilting furnace was desirable, since, by tilting the furnace to and fro slightly during the run, a fresh charge can be brought directly under the arc and far better results obtained.

TABLE II—RUNS IN TILTING FURNACES, GRAPHITE HEARTH—Al_2O_3 IN SLAG

Experiments 47, 48, 49, 50 and 65: Layer of UO_2 on Hearth

Expt. No.	Lbs. Fe	Lbs. Slag-Formers Charged with Fe Al_2O_3	CaO	UO_2	Lbs. Old Slag Charged	Lbs. SiO_2	Lbs. UO_2	Lbs. Coke	Time Hrs.	Min.	Furnace at Start	Kw. h. Used	Lbs. Ferro Poured	Percentage Analysis of Product U	C	Si	Al	Ratio to 10% U C	Si
39	3.0	1.0	0.25	1.0	...	...	4.0	1.25	1	8	Cold	51	4.75	47.5	4.2	0.3	Not det.	0.89	0.06
40	4.0	...	...	...	...	...	5.25	1.5(b)	1	12	Cold	60.5	8.1	42.5	4.5	0.3	Not det.	1.06	0.07
													1.0(f)						
41	4.0	0.5	0.3	0.5	...	...	6.0	1.25	1	3	Cold	58.5	10.8	45.0	4.2	0.4	Not det.	0.94	0.10
44	3.5				2.0 (No. 43)		6.5	1.5	1	0	Cold	59	6.0	52.0	5.8	0.5	Not det.	1.12	0.10
45	3.5				2.0 (No. 43)	0.5	6.5	0.25(c)		48	Hot	30	7.0	39.0	5.2	1.6	2.0	1.33	0.41
								1.5											
47	4.0	0.9					6.4	1.5	1	0	Cold	40	8.5	55.0	5.9	...	...	1.07	....
48	4.0				8.0			0.7	1	10	Cold	40.5	6.6	45.0	4.85	...	...	1.08	....
49	4.0				3.75		3.5	0.5		32	Cold	36	3.0	29.5	2.55	...	...	0.87	....
										52(e)		51(e)	1.5(f)	50.0	0.62(i)	0.3	...	0.12	0.06
50	4.0	1.0					10.6	0.9(d)	1	5	Cold	45.5	0.5(g)	52.0	5.3	...	...	1.04	....
									1	40		67.5	4.0(h)	60.0	5.3	0.4	3.4	0.90	0.17
													...(e)	50.0	3.2(j)	...	3.6	0.64	....
65	4.0		3.0(a)				8.75	0.6(d)	1	12	Cold	50.75	8.0	38.0	5.8	1.0	...	1.53	0.26

(a) Plus 1.0 CaF_2. (b) Charcoal. (c) For reduction of SiO_2. (d) Coke at end, after adding UO_2 not mixed with it. (e) Total. (f) Taken from furnace when cold. (g) Sample poured 3 min. after coke was charged. (h) Second pour. (i) This piece not in contact with graphite. (j) This piece probably not in contact with graphite.

Hence a small tilting, single-phase Héroult type furnace, with a graphite hearth, was built. This furnace, and those later used, all took 600 to 750 amperes at 60 to 90 volts; with 90 to 95 per cent power factor, *i. e.*, some 30 to 60 kw. It was regulated either by the length of the arcs or by regulating the voltage. The iron was charged into the furnace, slag formers added, the furnace heated till iron and slag were fluid, then the charge proper (UO_2 mixed with coke) added slowly and the furnace then heated 20 to 30 minutes more before pouring the ferro. Results in this furnace are shown in Table II.

TABLE III—RUNS IN STATIONARY WATER-COOLED FURNACE

Experiments 54, 56, 57 and 58 on Magnesite Hearth. Experiments 61, 62, 63 and 64 on SiC Hearth

Expt. No.	Old Slag in Hearth Lbs.	Lbs. Fe	Lbs. CaF_2	Lbs. Al_2O_3	Lbs. CaO	Lbs. UO_2	Lbs. Coke	Lbs. CaC_2	Ferro-Silicon (50% Si)	Time Hrs.	Min.	Kw. h.	Lbs. U-free Separable	Lbs. Ferro in Regulus	Per cent Analysis of Regulus U	C	Si	Al	Ratio to 10% U C	Si
54	28.0(a) (Nos. 45, 49 and 50)	4.0	....	...	1.0	0.5	1.0(e)	....	...	1	20	42.75	2.0	3.5	46.0	1.3	1.3	Trace	0.28	0.28
56	18.0 (No. 55)	3.0	....	0.4	....	3.0	0.75(f)	....	...	1	..	37	Much	1.4	28.0	3.4	1.8	4.9	1.21	0.65
57	23.0 (Nos. 55 & 56)	4.0	1.25	...	....	....	0.6(e)	....	...	1	15	40.75	2.25	2.25	33.0	2.7	1.4	0.7	0.82	0.42
58	8.0 (No. 57)	4.0	1.3	0.6	....	4.0	0.5(e)	....	...		53	40	....	6.0	1.6	...	...	...	....	....
61	1.5	4.0	....	...	1.25(b)	10.0(c)	0.6(e)	....	...	1	18	40	....	4.5	45.0	3.7	0.3	...	0.82	0.07
						6.5(d)				1										
62	11.0 (No. 61)	3.7	....	...	....	11.0(c)	None	2.0(g)	...		..	42	....	6.25	12.0	3.5	0.7	...	2.92	0.58
63	25.0 (No. 62)	3.9	....	...	....	....	None	0.9	0.5	1	..	40.5	....	5.25	9.0	2.5	4.5	...	2.78	5.0
64	19.0 (No. 63)	3.0	....	...	....	....	0.5	0.75	...	1	..	40	....	4.0	35.0	3.9	1.4	...	1.12	0.40

(a) Plus 1 lb. fine magnesite. (b) Also 0.35 B_2O_3. (c) In bottom. (d) In charge. (e) Alone. (f) Mixed with UO_2. (g) Also 0.3 Na_2CO_3.

In Expts. 39–41, 16.75 lbs. UO_2 were charged, and 24.65 lbs. ferro averaging 44.5 per cent U were obtained. The UO_2 charged was equivalent to about 14 lbs. metallic U and 11 lbs. metallic U were obtained in the ferro, or nearly an 80 per cent recovery, not counting the U in the metal and slag (about 3 lbs.) left in the furnace which bring the loss down to about 10 per cent. In other words, the loss of uranium is very small. There is a slight orange sublimate, apparently UO_3, given off in small amounts, some of which condenses on the electrodes.

In Expts. 47–50 inclusive, a layer of UO_2 was fused over the graphite hearth, in the hope that it might keep the ferro away from the graphite, but while some of this layer remained unfused, the ferro would break through and touch the graphite, and high carbon ferros resulted, giving a ratio of from 0.9 to 1.3 per cent C for each 10 per cent U, save in Expt. 49, where, after the furnace was cold, a small separate regulus was found that had been kept out of contact with carbon by the UO_2 layer. This piece, 49 B, analyzed 50 per cent U, 0.62 per cent C, or 0.12 per cent C per 10 per cent U.

It is evident that ferro-uranium can be readily produced on a carbon hearth with very little loss of U, but that there will be 4 to 5 per cent carbon in the ferro, and that without water-cooling of the hearth a layer of UO_2 cannot be satisfactorily preserved.

A magnesite hearth was tried in the same furnace shell as was used with the graphite hearth, with the Al_2O_3 slag and with excess carbon in the charge and ferros of 33 to 40 per cent U, 4 to 5 per cent C, produced, but the magnesite hearth was ruined in one to three heats. A zirkite hearth was ruined in one heat. Small scale tests of silica and chromite were made, but neither stood up and they introduced, respectively, large amounts of Si and Cr. Hence, a magnesite hearth, and later a carborundum hearth, water-cooled in order to maintain a layer of frozen UO_2 or slag over it, was tried in a stationary furnace. The product was dug out when the furnace was cold. This was usually in two parts, one which had not gotten under the arcs, as the furnace could not be rocked back and forth to stir the charge, and which had only a trace of U, the other the regulus, in the center. The results are given in Table III.

The Al_2O_3 in the slag introduced Al into the ferro. This may be more of an apparent than a real impurity, as Al_2O_3 and uranium oxides form a fluid slag, and as small amounts of Al might be expected to be oxidized before the bulk of the U is, the Al might even to some extent protect the ferro from loss of U and the Al_2O_3 be eliminated as a fluid slag instead of held as infusible Al_2O_3 inclusions, as when Al is used alone. It is possible that a Fe-U-Al alloy that would give a fluid slag on oxidation might be found to reduce the trouble from streaks and seams in uranium high-speed steel or at least prove a good deoxidizer and scavenger for steel. However, the present purpose is to produce a ferro-uranium as free as possible from all impurities. Experiments were made with other slags: one of B_2O_3-CaO-UO_2 was not satisfactory, but a CaO-CaF_2-UO_2 slag worked fairly well.

For the preparation of pure uranium from the oxide, Kuzel and Wedekind[1] suggest the use of metallic calcium, while another patent[2] suggests the use of CaC_2 or CaC_2 plus ferrosilicon. At arc temperatures CaC_2 will be decomposed into C and Ca, both of which should take part in the reduction. According to Expts. 62–64 (Table III), coke appears a more effective reducing agent than CaC_2, with or without ferrosilicon.

TABLE IV—TILTING FURNACE. WATER-COOLED HEARTH

Expt. No.	Charge Proper in Pounds Disregarding Slag Left in Furnace: Fe	CaO	CaF_2	Mill Scale	Old Slag	UO_2	Coke	Time Hrs.	Time Min.	Furnace at Start	Kw. h.	Lbs. Ferro Poured	Percentage Analysis of Product: U	C	Si	Ratio to 10% U: C	Si	Remarks
66	4	...	...	...	....	5	0.9	1	10	Cold	53.5	4.0	58.0	2.4	1.0	0.42	0.17	SiC hearth & sides. Little CaO & CaF_2 used or needed. Ferro touched SiC sides.
67	4	...	...	...	....	5	0.8		45	Hot	33	7.3	44.5	2.25	1.0	0.51	0.23	
68	4	...	...	...	....	5	0.7	1	10	Cold	53	6.5	37.5	2.1	3.0	0.58	0.80	
69	4	...	...	...	....	5	0.6		40	Hot	28.25	5.4	37.5	1.75	2.0	0.47	0.54	
70	4	...	...	...	....	....	0.6		32	Hot	18.25	6.5	25.5	4.2	2.5	1.64	0.98	
73	...	0.2	0.2	5.0	2.5	5.2	1.0 0.63	1	10	Cold	47.5	5.8	70.0	1.7	3.8	0.25	0.55	Magnesite hearth, carbon sides in this and all subsequent runs.
74	...	0.2	0.2	5.0	....	5.2	1.0 0.63		40	Hot	28.25	5.9	60.0	2.4	2.4	0.40	0.40	5 lbs. mill scale + 1 lb. coke charged before UO_2 and rest of coke.
75	4.0	...	...	...	11.0 (No. 74)	....	0.85	1	5	Cold	50.0	8.9	51.5	2.05	2.5	0.40	0.49	
76	4.0	...	...	...	4.5 (No. 74)	7.0	0.8		40	Hot	30.0	6.5	48.0	1.65	1.75	0.35	0.37	
77	4.0	0.1	0.2	...	5.0 (No. 76) & 3.5 (No. 71)	3.0	0.8	1	0	Cold	46.75	6.8	45.5	2.0	4.0	0.44	0.88	No. 71 slag contaminated with SiC.
78	4.0	...	...	...	....	10.0	0.8		40	Hot	27.5	6.9	46.0	2.1	1.8	0.46	0.39	
79	4.0	0.1	0.2	...	....	12.0	0.8		40	Hot	21.75	3.0	33.0	2.6	1.4	0.79	0.43	Too much slag in furnace, slag too stiff, magnesite spalled from roof.
80	4.0	0.3	0.3	...	6.0 (No. 79)	6.0	0.8	1	2	Cold	48.75	5.0(*a*) 5.2	67.0	1.1	0.9	0.17	0.14	
81	4.0	0.2	0.2	...	7.25 (No. 79)	5.0	0.8		40	Hot	25.0	6.8	53.5	2.4	1.2	0.45	0.23	
82	4.0	0.1	0.1	...	8.75 (No. 79)	4.0	0.8		32	Hot	23.5	8.0 2.0(*a*)	45.0	3.6	1.2	0.80	0.27	Slag stiffened by spalled magnesite from roof. Ferro touched carbon walls.
85	4.0	0.1	0.6	...	....	9.0	0.8	1	10	Cold	50	5.2	64	3.25	0.35	0.51	0.06	A. C. generator temporarily out of commission. Used D. C. at 50 volts 800 amps. on these two. This voltage would hold only one arc, so one electrode always touched slag or ferro, giving high carbon. 10 in. on each electrode used in the two heats. Fresh lining of UO_2-CaO-CaF_2 put in before No. 85 (not contaminated with SiC). Charge all added in center from No. 85 on.
86	4.0	...	0.6	...	....	10.0	0.8		50	Hot	33	14.9	68.5	5.00	0.25	0.73	0.04	
87	4.0	...	1.4	...	....	13.0	1.0	1	10	Cold	50.5	4.2	65.5	1.5	0.45	0.23	0.07	
88	4.0	...	2.7	...	....	10.0	0.8	1	7	Warm	52	6.6	59	1.3	0.60	0.22	0.10	Furnace cooled 2$^1/_4$ hrs. between Expts. 87 and 88.
89	4.0	...	0.9	...	....	9.0	0.8		42	Hot	32.5	9.2	56.0	1.2	0.65	0.22	0.12	
92	...	...	0.75	5.5	9.0 (No. 91)	4.0	2.0	1	10	Cold	50.5	9.5	63.5	2.15	0.65	0.34	0.10	No. 91 slag contained some emulsified No. 91 ferro.
93	...	...	1.25	5.5	9.0 (No. 91)	6.0	2.0	0	53	Hot	38.25	12.5	63.0	1.75	0.90	0.28	0.14	
94	...	...	1.25	5.5	9.0 (No. 91)	8.0	2.0	0	55	Hot	30.75	10.6	72.0	2.4	0.60	0.32	0.08	
95	...	...	2.40	6.0	....	9.0	2.0	1	15	Cold	45.00	3.2	58.5	3.65	1.20	0.62	0.21	Too much CaF_2. Slag too fluid. Ferro spattered against the carbon sides, giving a high carbon metal.
96	...	...	1.50	6.5	....	12.0	2.0	1	3	Hot	35.50	7.5	63.0	2.15	0.75	0.34	0.12	Nos. 96 and 97: entire charge added together.
97	...	...	1.50	6.5	....	13.0	2.0	1	11	Warm	41.25	4.75 5.0(*a*)	43.0	2.15	0.70	0.50	0.16	Ferro not hot enough to pour properly.

(*a*) Taken out when furnace was cold.

As the CaO.CaF_2 slag was fairly satisfactory and as the water-cooling preserved a frozen layer of slag over the lining of the stationary furnace, the next step was to combine these in a tilting furnace. An iron shell 18 in. × 18 in. × 14$^1/_2$ in. high in the body portion, and with a hearth portion 11 in. × 11 in. × 4$^1/_2$ in. deep extending downward from the bottom of the body portion, was made up, mounted on trunnions, provided with pouring spout, and the hearth portion arranged for water-cooling by being surrounded with a perforated spray pipe, the holes in which were at such an angle that the streams hit the main or upper bottom just outside the junction with the sides of the hearth portion, causing sheets of water to cover the junction and flow down the sides.

A pan 15 in. × 15 in. × 3 in. deep suspended by corner posts extending down from the main bottom was hung with its bottom 1 in. below the hearth bottom. A hole was cut in the center of the bottom of the pan of such size that it did not drain the cooling water all off, but some ran over the edges.

This covers the bottom and the lower 2 in. of the sides of the hearth portion continually with quite a volume of water, while the upper 2$^1/_2$ in. of the sides are cooled by sheets of water. The water falls from this pan into a large pan beneath the furnace, connected to the sewer.

A neater job could have been made by completely enclosing the hearth position and providing inlet and outlet pipes, but the open system was used instead of a closed one for greater safety in case something should go wrong and the bottom cut through, and, in order that the cooling might be watched.

An apron on the front of the furnace below the pour-

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[1] H. Kuzel and E. Wedekind, French Patent 419,043, Class VIII, 2. Application Oct. 15, 1909, granted Oct. 17, 1910, published Dec. 24, 1910.

[2] Electric Furnace and Smelters, Ltd., London, German Patent 247,993, Class 40*c*, Group 12, Application Apr. 8, 1911, patented June 11, 1912.

ing spout (which is 1$^1/_2$ in. above the main bottom) prevents the water from splashing into the ladle or mold, when the furnace is tilted to pour.

A carborundum lining was first used, both in the hearth and on the sides, but the sides were attached by spattered slag, crumbled off, and contaminated the ferro with Si. Had sides as well as hearth been water-cooled, this lining would have served.

Then split magnesite brick (1$^1/_4$ in. thick) were used in the hearth, and carbon on the sides. For sometime the charge was added between the electrodes and the outside of furnace, with the idea of making sure that the slag did not melt clear to the magnesite. It was found, however, that this was not necessary, and all charging was finally done in the center, between the arcs. Until a high CaF_2 content of slag was maintained, and until center charging was begun, the slag built up in the sump and after a few heats the ferro was brought up so far that it touched the carbon sides and gave high carbon ferros. To prevent this, some of the slag had to be removed from time to time and added to subsequent charges. After chiseling out some slag the rest was roughly shaped into a sump and the furnace heated without charge till the slag was melted, to form a tight frozen lining. In a run, the slag was first melted, the iron charged and melted, then the charge proper slowly added, and heating continued till the CO flame grew weak. The slag never poured out of the furnace with the ferro, but all remained in the furnace. The electrode consumption averaged 1 in. on each 2 in. diameter graphite electrode for each 26 kw. h. used, but much of this was due to oxidation in the air while cooling, so the electrodes were pulled out of the furnace while pouring, which would not be the case in a steadily-run commercial furnace.

The results in the water-cooled tilting furnace are given in Table IV on page 345.

Better results were obtained when the iron was charged in the metallic state, than as oxide (mill scale).

Including UO_2 for slag and lining, there was charged in Expts. 85–97 (see Table IV):

	Lbs. U			Lbs. Fe
151.5 lbs. UO_2 equivalent to	125.7		2.1	
18.65 lbs. CaF_2	..		..	
1.6 lbs. CaO	..		..	
20.0 lbs. Fe equivalent to	..		20.0	
35.5 lbs. mill scale equivalent to	..		25.7	
15.0 lbs. Fe for remelting equivalent to (see Table V)	9.7		4.7	
16.2 lbs. coke	..		..	
	135.4		52.5	
		Lbs. U		Lbs. Fe
There was obtained 107.45 lbs. Fe equivalent to		63.4		40.9
and 85.0 lbs. slag equiv. to		60.0	48.7	7.8
	123.4	123.4		48.7
Loss, lbs.	12.0		3.8	

Loss calculated on 75.4 lbs. U actually used, 16.5 per cent; on 44 lbs. Fe actually used, 8.5 per cent.

Loss calculated on total U, 9 per cent; on total Fe, 7.5 per cent.

Most of the loss was due to fine particles carried out by the CO flame (this might be reduced by briquetting), some to spatter, some to volatilization of UO_3 or of a fluorine compound, and some to mechanical loss in charging and pouring. Two of the thirteen heats included above were on remelting, and the loss therein makes the loss calculated above, too high, 15 per cent being probably nearer the true figure.

The average Si in the last 11 runs in Table IV (all others in that table being contaminated by SiC) was under 0.7 per cent.

The average carbon in all 26 runs, good and bad, of Table IV was under 2.5 per cent. Excluding those where the ferro touched or spattered against the carbon sides, which would not occur if the furnace had water-cooled magnesite sides, the average of 21 runs is under 2 per cent carbon. That of the three runs 87–89, in which the best conditions obtained, was 1.33 per cent C.

The power consumption in 6 runs, 87–89 and 92–94 was under 4 kw. h. per lb. for ferro averaging 63 per cent U, 1.8 per cent C, and on heats 89 and 94, with the furnace fully hot, about 3 kw. h. per lb., pouring about 9 lbs. per heat. In a large commercial furnace, the power consumption should be much lower than in the little experimental furnace.

For a commercial furnace, assuming a capacity of 200 lbs. ferro per heat, 200 kw. (say 100 volts, 1200 amperes per phase), on a three-phase tilting direct arc furnace of the Héroult type, would probably not be too much, as the best results on the ferro come when it is heated very hot, though such a furnace would be overpowered for steel. To withstand the high temperature, the thin magnesite walls and bottom (say 2$^1/_2$ in. thick) should be strongly water-cooled so as to maintain a solid UO_2 lining within them. The roof should be of carbon bricks on the inside, as the usual silica roof would drip and contaminate the ferro. The center of the roof should be open for charging.

A three-phase direct arc furnace like the Héroult is preferable to a single-phase like the Girod, and rather large carbon electrodes should be used, to give as many and as large arcs as are practical, since there is little reduction outside the arc itself.

Fluorspar alone is the best flux tried, if Al is to be kept out of the ferro. Its amount should be so regulated that the slag is not so stiff as to hold ferro in emulsion, and not so fluid as to spatter badly under the arc. The slag was good when 60 lbs. UO_2 (excluding that reduced and poured out as ferro, but including 30 lbs. used as original lining) and 10 lbs. CaF_2 had been charged.

Bleecker[1] suggests first making ferro alloys high in carbon, by reduction with carbon, then crushing the ferro, mixing it with iron oxide or oxide of the other metal in the ferro, and remelting, in order to decarbonize. Or, he states, one may first make a high carbon alloy and decarbonize by later adding to the molten ferro iron oxide or the oxide of the other metal. Remelting iron high in carbon with iron oxide to refine it is of course steel-making routine, and Moissan[2] and Escard[3] both long ago described decarbonizing metallic uranium high in carbon, by heating it with uranium oxide. Table V gives some results on refining high carbon ferros.

The finely crushed ferro emulsified badly with the slag, particularly in Expts. 83 and 84 when the slag was extra stiff because of adventitious magnesite.

[1] W. F. Bleecker, U. S. Pat. 1,094,114, Apr. 21, 1914.

[2] H. Moissan, trans. by V. Lenher, "The Electric Furnace," 1904 ed., pp. 167, 170.

[3] J. Escard, *Loc. cit.*

TABLE V—REMELTING FERROS FOR REFINING

Tilting Furnace, Water-Cooled Hearth

Expt. No.	CHARGE PROPER IN POUNDS Disregarding Slag in Furnace: Ferro	Analysis Ferro U	Analysis Ferro C	Analysis Ferro Si	Slag	UO_2	Mill Scale	CaF_2	Time Hr.	Time Min.	Furnace at Start	Kw.-H.	Lbs. Ferro Poured	Percentage Analysis of Product U	C	Si
71	6.0 (No. 70)(a)	25.5	4.2	2.5	None	5.0	....	....	1	0	Cold	49	3.5	36.5	0.9	4.7
83	9.0 (No. 82)(a)	45.0	3.6	1.2	9.0 (No. 82)	5.0	....	0.75	1	20	Cold	55	4.0	56	1.7	1.6
84	7.0 (No. 65)(a)	38.0	5.8	1.0	7.0 (No. 82)	...	1.75	0.75	..	50	Hot	31.25	4.0	47.5	2.45	1.4$_5$
90	7.0 (No. 89)(a)	56.0	1.2	0.65	...	3.0	....	1.2	1	..	Cold	49	2.25	43.0	0.95	1.5^5
91	9.0 (No. 86)(a)	68.5	5.0	0.25	...	6.0	....	2.5	..	50	Hot	36	7.0 5.0(b)	66.0	1.8	0.75

Expt. No.	RATIOS PER 10% U Original Ferro C	Original Ferro Si	Refined Ferro C	Refined Ferro Si	RECOVERY (POUNDS) In Ferro Charged U	In Ferro Charged C	In Ferro Charged Si	In Ferro Recovered U	In Ferro Recovered C	In Ferro Recovered Si	REMARKS
71	1.64	0.98	0.25	1.28	1.50	0.25	0.15	1.25	0.03	0.16	SiC hearth & walls, walls crumbled and contaminated Ferro with Si
83	0.80	0.27	0.30	0.29	4.05	0.25	0.11	2.70	0.07	0.06	Magnesite hearth
83	1.53	0.26	0.52	0.30	2.67	0.41	0.07	1.90	0.10	0.06	Magnesite hearth
90	0.22	0.12	0.22	0.12	3.56	0.07	0.04	0.97	0.024	0.035	Magnesite hearth. Increase in Si probably due to siliceous impurities in CaF_2
91	0.73	0.04	0.27	0.11	6.17	0.45	0.02	4.62 3.30	0.126 0.09	0.053(c) 0.038(d)	

(a) Crushed to pea size and smaller. Plus any ferro left in furnace from preceding run.
(b) Taken from furnace in regulus, when cold. (c) Poured. (d) Regulus.

In all of these runs the recovery of the ferro charged was poor, much less being poured than was charged, There was always some spatter, small globules of ferro being shot up into the air above the hearth, oxidizing, and dropping back into the hearth, the Fe_2O_3 thus produced tending to decrease the percentage of U in the recovered ferro, as metallic U in the ferro will be oxidized by Fe_2O_3. The experiments indicate that it is probably desirable to produce a low carbon ferro in one operation, rather than first to make a high carbon ferro and then to refine it.

Vanadium has not been determined in most of the ferros. It cannot average as high as 0.25 per cent, though individual ferros, made with a large amount of fresh UO_2, will run a trifle higher than the average because V is more readily reduced than U, while one made from a charge consisting largely of old slag from which the V is already largely extracted will run lower than the average. A few analyses of the ferros indicated that probably 0.4 per cent and certainly not over 0.5 per cent is the maximum. Traces of V were present in all.

As V is used in almost all tool steels, the very small amount of V that would be introduced into steel by the ferro-uranium certainly would not be classed as a harmful impurity, though for experimental work on the value of U in steel it is desirable to have a ferro-uranium as low as possible in V in order not to have another variable to contend with in the V.

It appears that by using a pure UO_2, a low-ash coke, and a pure iron as raw materials, with CaF_2 as slag former, and using a tilting direct arc type furnace with water-cooled magnesite hearth and sides, it should be possible to produce commercially, without a second refining operation, ferro-uranium of any desired U content, say 40–70 per cent, with carbon averaging below 2.0 per cent, silicon below 0.75 per cent, vanadium below 0.5 per cent, and with aluminum, sulfur, phosphorus and manganese all so low as to be negligible.

If experiments with such a ferro show that uranium steels high in uranium are not valuable, but that a little uranium is useful, and if the amount required is so low that the carbon introduced by a high carbon ferro is harmless, then the furnace might have an uncooled carbon hearth, and the ferros would contain 4–5 per cent carbon.

If uranium is found useful only as a deoxidizer or scavenger of oxygen and nitrogen, aluminum would not be harmful and might be advantageous, and the slag former might be wholly or in part Al_2O_3.

Grateful acknowledgment is made to the Department of Chemistry at Cornell University for the use, under a coöperative agreement, of its laboratory facilities, which are particularly well adapted to a problem of this nature.

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INFLAMMABILITY OF CARBONACEOUS DUSTS IN ATMOSPHERES OF LOW OXYGEN CONTENT

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INTRODUCTION

As was stated in a previous paper,[1] if dust could be entirely confined within the machinery of a mill in which combustible dust is produced, and a method could be found for preventing explosions in these machines, a long step would be taken in the prevention of dust explosions in mills. To keep a dust cloud from forming in the machines appears to be almost, if not utterly, impossible. It is possible, however, by proper cleaning to remove foreign material from the grain and thus lessen the possibility of a spark being formed in the machine which might ignite the dust. But cleaners and separators do not always take out all the foreign material, so that even under the best conditions foreign materials may get into the machines, or other conditions develop which might cause sparks, or other sources of heat, to be formed within the machine, thus creating a very dangerous condition. However, if there were present within the machine an atmosphere which would not support combustion, the dust could not ignite and an explosion could not take place.

For some time the possibility of preventing explosions within machines by the use of inert gases has been under consideration. In an article on "Coal Dust Explosions and Their Prevention," J. Harger[2] recommends a low oxygen content in the atmosphere of the mines as a preventive of explosions. The writer states in part as follows:

"The only way to absolutely prevent dust explosions is to reduce the oxygen percentage below the lower limit, which varies with the different coal dusts.

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[1] "Inflammability of Carbonaceous Dusts," THIS JOURNAL, **9** (1917), 269.

[2] *J. Soc. Chem. Ind.*, **31** (1912), 413.

A reduction of 2 per cent in practice will do this for all mines, but to get a guarantee of absolute immunity 17$^1/_2$ per cent oxygen is the figure. A 17$^1/_2$ per cent oxygen atmosphere is ideal for a coal mine, if it were not too expensive to obtain, which should not be the case."

He recommends not over 1 per cent carbon dioxide in this atmosphere, as a higher percentage would be dangerous from the point of view of respiration.

Referring to decreasing the oxygen content of the atmosphere he states:

"This method is, in my opinion, the only one which can be thoroughly applied to mines or machines making inflammable dust."

The most likely source of such inert gases around a mill are the flue gases. These contain a large amount of nitrogen, 79 per cent, the other 21 per cent containing varying amounts of oyxgen and carbon dioxide. Under normally good working conditions the oxygen content is about 11 per cent. Small amounts of carbon monoxide are often present, especially when the oxygen content is low, but this is usually under one per cent. For use in enclosed machines the carbon dioxide content would not necessarily have to be as low as in a mine or in an atmosphere where men were working so this would not have to be removed from the flue gases before they could be used in the grinding systems of mills.

The purpose of this investigation was to determine to what amount the oxygen content of the air must be reduced in order to prevent the propagation of explosions of various carbonaceous dusts.

EXPERIMENTAL

APPARATUS—The Bureau of Mines has made a number of tests upon the inflammability of coal dusts in mixtures of air and natural gas. For this work the apparatus used in the usual testing of coal dusts was adopted with but one change. This was an auxiliary attachment to the base plate for putting the gas into the globe.[1] It consists of a brass tube lying just above the glass injection funnel and passing upward through the base plate at the right of the funnel. After passing through the base plate it extends upward for a distance of 1 in. and then encircles the top of the funnel. The portion of the brass tube forming this circle has eight small holes, spaced at equal intervals from each other, drilled through its upper wall. The outward end of the brass tube is connected to the gas holder.

GAS MIXTURES—The gas mixtures used contained approximately 79 per cent of nitrogen, the remaining 21 per cent being made up of carbon dioxide and oxygen.

To obtain the gas mixtures, commercial carbon dioxide, oxygen and nitrogen were used. The gas mixtures were made in a large gas holder, the amount of each gas used being measured roughly by the height of gas in the holder. The mixtures were then analyzed before and after each series of tests.

METHOD OF OPERATION—To test the inflammability of the dusts in these gas mixtures in the apparatus referred to above, it was necessary to displace all the air in the globe with the gas mixture. Evacuating and refilling were considered, as were other methods, but the only method which proved to be practical was to allow a sufficient amount of the gas to enter to displace all the air. To determine the amount of gas necessary to displace the air in the globe (capacity of 1390 cc.), measured amounts of a gas containing 9.5 per cent carbon dioxide and 11.2 per cent oxygen were allowed to flow into the globe through the gas injecting tube around the top of the funnel, and to force the air out of a valve in the tube to which the pressure gauge is attached.

A sample taken after 4.5 liters had been allowed to flow into the globe showed 8.2 per cent CO_2 and 13 per cent oxygen. Four and a half liters more were allowed to flow into the globe. A sample taken showed 9.6 per cent CO_2 and 11.4 per cent oxygen.

Nine liters of the gas were allowed to flow through another globe. A sample of the gas in the globe showed 9.5 per cent CO_2 and 11.4 per cent oxygen.

These results indicate that 9 liters of gas will displace all the air in the globe. Therefore, to be certain that all the air is displaced, 10 liters of gas were allowed to flow into the globe before each test. The gas flowed at a rate of 0.9 to 1.0 liter per minute.

To blow the dust into this gas mixture by a puff of air would change the oxygen content and introduce an appreciable error. Therefore, a second connection was made to the gas holder so that gas could be drawn from it and compressed by a vacuum and compression pump, into the bulb attached to the funnel which contained the dust to be tested.

The method of testing was, therefore, not unlike that used for testing the explosibility of carbonaceous dusts in air, except that the explosion flask was filled with a known gas mixture and the dust was injected by the same gas mixture under a pressure of 20 cm. of mercury. The heating of the igniting coil was so regulated that the dust might be injected as soon as possible after all the air had been displaced. This was done to obviate any possible change in the gas mixture by leakage or any other way.

SERIES OF TESTS—A few preliminary tests were made with dusts which gave an indication of the lower limit to be expected. Five typical dusts were then tested, using the following gas mixtures:

Per cent O_2	Per cent CO_2	Per cent N_2
16.9	4.0	79.1
15.0	5.6	79.4
14.1	6.8	79.1
13.9	6.1	80.0
13.4	7.6	79.0
12.8	7.6	79.6
12.2	9.0	78.8
10.9	9.2	79.9
0.8	0.0	99.2

Pittsburgh Standard Coal Dust was tested with the following gas mixtures:

Per cent O_2	Per cent CO_2	Per cent N_2
19.8	1.2	79.0
19.2	1.9	78.9
18.1	2.8	79.1
16.9	4.6	78.5
16.0	8.8	75.2
0.8	0.0	99.2

It will be observed that the sum of the oxygen and carbon dioxide content does not always add to 21

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[1] "Inflammability of Carbonaceous Dusts."

per cent. This is due to the inaccurate method of measuring the gas as it was mixed. These figures are the mean of two analyses made before and after each series of tests. In no case was there a variation of over 0.2 per cent in the two analyses.

As in all cases where no inflammation was noticeable, a pressure was obtained above that given by the blank—that is a test made without any dust—it was thought that these might be due to a decomposition caused by the dust striking the hot coil and not due to a slight ignition. To determine this, a series of tests was made using 99.2 per cent pure nitrogen in the globe. With all grain dusts a pressure of 0.4 to 0.5 lb. more than the blank was obtained, that is, a pressure of 0.6 to 0.7 lb. The average of 0.6 lb. was therefore taken as the zero correction, in all tests where gas mixtures are used. Coal dust gave a pressure of 0.2 lb. more than the blank, or a pressure of 0.4 lb. This pressure was taken as the zero correction for coal dust.

RESULTS—The results obtained with the five typical dusts and coal dust are given in Fig. I, the average lbs. pressure being plotted against the percentage of oxygen in the gas mixture. This method was adopted instead of plotting pressures against percentage of CO_2, since it is the amount of oxygen in the air rather than the amount of carbon dioxide that determines inflammable limits. If the carbon dioxide replaced the oxygen in air, then plotting against carbon dioxide would give the same curves because the balance of the 21 per cent would be oxygen. But in the gas mixtures used, the carbon dioxide was sometimes one per cent lower than would be required to make the sum of it and the oxygen up to 21 per cent. This one per cent or less is nitrogen, an inert gas, and, therefore, would have a similar effect to that of the carbon dioxide in preventing combustion.

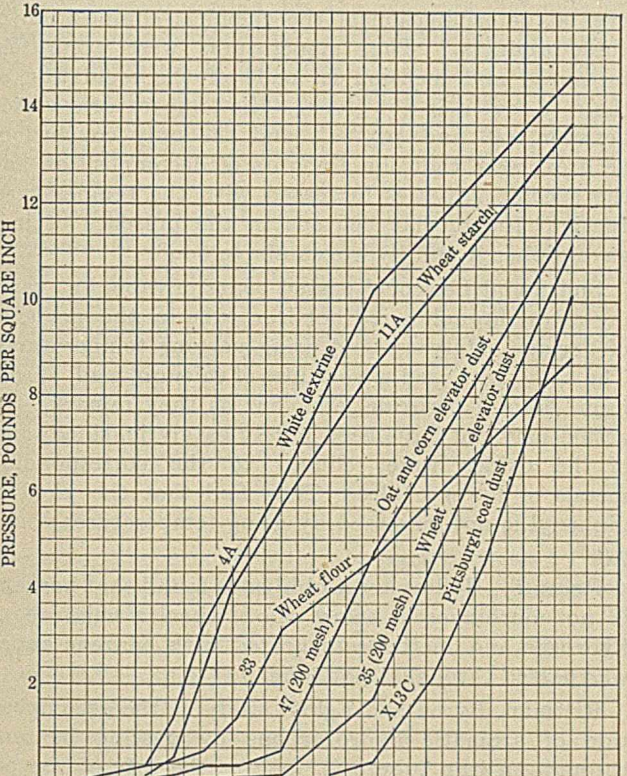

FIG. I

The values as given in the curves are the average of all results obtained in each series of tests. For the pressures above 2 pounds, the results given in each series were quite uniform and concordant. This is also true for pressures averaging under 0.5 lb. But those results between 0.5 lb. and 2 lbs. are less uniform.

It will be observed that these curves are quite similar in their direction, falling very rapidly as the percentage oxygen is decreased until a point is reached where the curves flatten. This point is in nearly every case at pressures near or less than 1 lb. It is considered that rapid oxidation will take place if the oxygen content of the atmosphere is above that indicated by the break in the curve, but cannot take place if the oxygen content is less than this amount.

CONCLUSIONS—Although no large scale tests have been made with which to compare these results, from the general action of the dusts in the tests, it may be concluded that an explosion of a grain dust cannot be initiated in a gas mixture containing 12 or less per cent of oxygen, the remainder being inert gases. And this limit could be extended to 14 or 14.5 per cent of oxygen if elevator dusts alone are considered. The results would suggest that the maintaining of an atmosphere of inert gases in all systems grinding or handling carbonaceous materials which form dangerous dusts would be an effective means of preventing many dust explosions; for even though an ordinarily dangerous amount of dust may be present and a spark or other source of heat may be formed, the dust would not be ignited or an explosion be propagated because the oxygen content of the atmosphere would be too low to support combustion.

The results of these tests show that a lower oxygen content in the inert gas mixture is necessary to prevent an explosion of grain dust than would be required to prevent a coal dust explosion. And, the results obtained with coal dust would indicate that a lower oxygen content in the mine atmosphere would be necessary to prevent a coal dust explosion than was recommended by Harger.[1] However, his recommendation of 17.5 per cent oxygen was very close to that determined by the authors.

It may be noted in this connection that the results published in a previous paper show that with one exception coal dust is less inflammable in air than the other dusts used in the tests with inert gases. This one exception is wheat flour, a comparatively coarse dust.

Large scale tests are being planned to demonstrate further the effectiveness of this preventive. The results which may be obtained then may alter the above results slightly. However, it is considered, as a result of the present tests, that an inert gas mixture containing 12 per cent or lower of oxygen will prevent a dust explosion from starting or propagating.

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[1] *Loc. cit.*

THE THERMAL DECOMPOSITION OF BENZENE

By J. E. Zanetti and G. Egloff

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HISTORICAL INTRODUCTION

The discovery of diphenyl by Fittig[1] in 1862 by the action of sodium on brombenzene opened up a new field in organic chemistry. His method, however, was costly and it was not till Berthelot[2] in the course of his classic researches on pyrogenetic reactions found that benzene, when passed through a red hot tube, decomposed chiefly into hydrogen and diphenyl, a much cheaper method of preparation, that impetus was given to the chemistry of that compound and methods of improving the yields were worked out by various investigators.

Berthelot found that by passing vapors of benzene through a red hot porcelain tube, at the rate of one gram per minute, he obtained hydrogen and a liquid product, from which he isolated diphenyl and other hydrocarbons which he claimed to be "chrysene" benzerythrine, and "bitumene." He stated unequivocally that between the boiling point of the undecomposed benzene and that of the diphenyl, there was no intermediate compound, and that no naphthalene, styrolene, or anthracene were formed. From the gas, which consisted of almost pure hydrogen, he claimed to have obtained a small quantity of acetylene, though the presence of hydrogen sulfide[3] interfered with the test for that compound and rendered it uncertain.

Following Berthelot's discovery, Schultz[4] introduced several improvements and pointed out the influence of rate and temperature. Instead of passing the vapors from boiling benzene through a hot porcelain tube, he used a hot iron tube and dropped the benzene into it at the rate of 1 drop every 3 seconds. Later, he used 100–200 g. per hour and a not quite "white-hot" tube. Schultz' yields were 50 to 60 per cent of the benzene used. Luddens[5] used a CO_2 stream to carry the vapors of benzene along the hot tube, a method likewise followed by Hübner.[6]

Schultz[7] studied also the tarry products obtained along with diphenyl, and identified *p*- and *m*-diphenyl benzene and claimed that Berthelot's "chrysene" was only a mixture of diphenylbenzenes and another hydrocarbon melting at 266° C. He obtained also another hydrocarbon melting at 196° C., which gave a compound with picric acid, whereas none of the others would. Berthelot[8] objected to Schultz' correction, basing his objections on analytical data and put forward the claim that Schultz' product was impure and consisted of a mixture of diphenylbenzenes with "chrysene."

Schmidt and Schultz[9] made an exhaustive investigation of the tarry products from the benzene decomposition and obtained the following products:

	M. P.	Picrate
(1) Diphenyl	70.5°	None
(2) *p*-Diphenylbenzene	205°	None
(3) *m*-Diphenylbenzene	85°	None
(4) Triphenylene	196°	Red needles
(5) Benzerythrine	307–308°	None
(6) Oily hydrocarbons		
(7) Pitch (b. p. above 450°)		

They again claimed that Berthelot's "chrysene" is identical with their "triphenylene." In their experiments, they used the method previously employed by Schultz, using a rate of 1 drop every 3 seconds. The yield of *p*-diphenylbenzene was 40 g. from 2 kg. of benzene.

Olgiatti[1] obtained diphenylbenzenes by likewise passing benzene through a red hot tube and collecting the 320 to 420° C. fraction of the decomposition products.

Haber[2] found that below 900° C. benzene was not decomposed and that only above 1000° C. was it effected with the formation of diphenyl. Haber noticed the formation of other crystalline compounds along with diphenyl but did not investigate them; he remarked that naphthalene was not obtained.

From that time on, owing to the importance of the use of benzene for carbureting water gas, many studies of the decomposition of benzene have been published. McKee[3] studied the decomposition of benzene by passing its vapors through a copper tube heated electrically and determining the specific gravities of the recovered products and their appearance under the polarizing microscope. He made no attempt whatever at determination of the chemical composition of these products. The temperatures were accurately measured and mention is made of the regulation of the rate, but it is not given. His temperatures varied between 448 and 765° C. and the only conclusions he drew were that the amounts of decomposition and the specific gravities increased with the temperature. Ipatieff[4] found that benzene in the presence of iron gave diphenyl and hydrogen above 600°.

Smith and Lewcock[5] passed benzene vapors at varying rates through a red hot iron tube in the presence of various catalyzers and using varying temperatures. The catalyzers used were oxides of calcium, lead, aluminum, barium peroxide, etc., but as they remark, the action may not have been purely catalytic, since some of the oxides were reduced to the corresponding metals or lower oxides. They find that the yield of diphenyl is not increased by using temperatures above 720°.

Recently, Hollins and Cobb[6] have found that benzene is not decomposed below 800° when a mixture of hydrogen and methane saturated with benzene vapor was passed through a hot tube.

Rittman, Byron and Egloff[7] studying the decomposition of aromatic hydrocarbons by passing benzene through an iron tube 6 ft. long at the rate of 200 cc. per hour, using varying temperatures and pressures, state that they obtained naphthalene and doubtless diphenyl, though they did not isolate it.

Summing up in review, the decomposition of benzene by heat takes place in such a way as to split off two or more hydrogen atoms from the ring, forming diphenyl and diphenylbenzenes. No investigator, previous to Rittman, Byron and Egloff, has claimed to

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[1] *Ann.*, **124** (1862), 276. [2] *Ann. de Chim.*, [4] **9** (1866), 445.

[3] From the thiophene in benzene. Thiophene not yet discovered.

[4] *Ber.*, **5** (1872), 682; *Ann.*, **174** (1874), 201; *Ber.*, **9** (1876), 547.

[5] *Ber.*, **8** (1875), 870. [6] *Ann.*, **209** (1881), 339. [7] *Ibid.*, **174** (1874), 230.

[8] *Bull. soc. chim.*, [2] **22** (1874), 437. [9] *Ann.*, **203** (1880), 118.

[1] *Ber.*, **27** (1894), 3387.

[2] *J. Gasbel.*, **39** (1896), 377–382, 395–399, 435–439, etc.

[3] *J. Soc. Chem. Ind.*, **23** (1904), 403.

[4] *J. Russ. Phys. Chem. Soc.*, **39** (1907), 681.

[5] *J. Chem. Soc.*, **101** (1912), 1453–1458.

[6] *Gas World*, **60** (1914), 879. [7] THIS JOURNAL, **7** (1915), 1019.

have obtained any naphthalene, and none at all of anthracene or phenanthrene. Indeed, those who devoted any attention to the point, as Berthelot and Haber, state unequivocally that they were unable to obtain any naphthalene. In other words, all investigators, previous to 1915, have been unable to adduce conclusive evidence that the benzene ring breaks up at temperatures below 800° C. and atmospheric pressure, in any except two ways:

(1) Benzene ⟶ Carbon + Gas,

or, (2) Benzene ⟶ Condensation Products, by the splitting off of hydrogen from two or more molecules.

Rittman, Byron and Egloff do not state in their publication what test besides the boiling point they used in determining the presence of naphthalene. Since their claims are entirely in opposition to all previous work, that the amounts of material obtained by them were small, that the boiling points of diphenyl and naphthalene, especially when mixed with other decomposition products, are dangerously near together to be of value in deciding the matter, further evidence on that point seemed desirable.

Berthelot's contention that he obtained chrysene was definitely settled by the work of Schmidt and Schultz[1] who proved that the hydrocarbon he believed to be chrysene melted sharply at 196° and not at "about 200°," and further by Lieberman,[2] who obtained pure chrysene melting at 250° and pointed out that Berthelot's product could not have been that compound.

In connection with other studies on thermal decomposition of hydrocarbons undertaken in this laboratory by one of us,[3] it seemed desirable to study more completely the course of reaction of the decomposition of benzene in order to arrive at some definite conclusions regarding its behavior at high temperatures and gradually gain insight into the complicated mechanism of formation of cyclic and polycyclic compounds from straight chain hydrocarbons.

EXPERIMENTAL

The plan of the experimental work consisted in studying the decomposition of pure benzene by passing it at measured rates through a furnace, the temperature of which could be accurately controlled. The plan included the following topics:

1—Influence of the temperature.
2—Influence of the rate.
3—Influence of the metallic catalyzers.
4—Composition of the gases.
5—Composition of the tar.

MATERIAL—The benzene used was pure thiophene-free benzene boiling at 80–81° C. of specific gravity 0.881, at 15.5° C. No test for thiophene was given by the indophenene reaction, and on treatment with C. P. concentrated sulfuric acid, no change of color was noticeable in the acid.

Three hundred cc. of benzene were used in each run whenever possible. In some cases, as when nickel and iron were used as catalyzers at the higher temperatures, not more than one-fourth of that amount could be used as the deposition of carbon would plug up the tube, and stop the run.

APPARATUS AND PROCEDURE—The heating apparatus used consisted of a Whitaker-Rittman furnace, the description of which has been given in detail in THIS JOURNAL[1] and will, therefore, not be described here. The arrangement of the apparatus is diagrammatically given in Fig. I. Essentially it consisted of an iron tube $1^1/_2$ in. in diameter, electrically heated and provided with a rheostat and a pyrometer to regulate and measure the temperature. The pyrometer was a base-metal thermocouple which was compared with a standardized platinum-iridium thermocouple and found to check up within 5 to 10°, according to temperatures. The temperature could be maintained constant within 5° C., for long periods of time. The benzene was led into the tube from a large oil feed cup with a sight tube by which the rate of flow could be accurately determined by counting the drops falling in a certain time. One drop per second gave a flow of 100 cc. per hour, two drops 200 and three drops 300 cc. These values were determined experimentally, as, of course, the size of the drop will vary with the size of the opening. The benzene did not drop directly into the heated tube, even at the higher rates, but flowed along the sides and vaporized before reaching

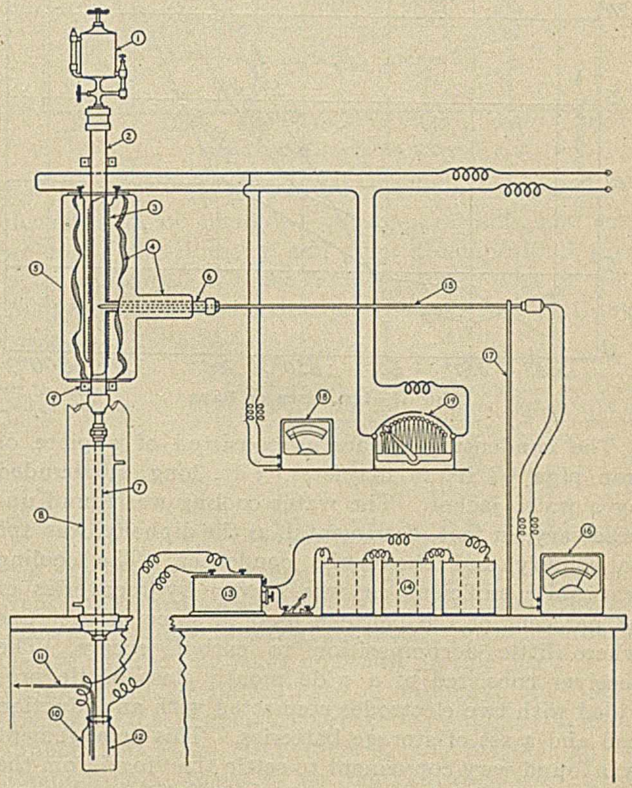

FIG. I—APPARATUS USED IN TESTS

1—Oil feed cup
2—Tube of furnace
3—Nichrome wire resistance
4, 5—Magnesia lining
6—Stuffing box for pyrometer
7—Condenser tube
8—Water jacket
9—Support of furnace
10—Wide mouth glass bottle
11—Exit for gases
12—Electrodes of copper gauze
13—Induction coil
14—Storage batteries
15—Pyrometer rod
16—Pyrometer scale
17—Pyrometer support
18—Voltmeter
19—Rheostat

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[1] *Loc. cit.*

[2] *Ann.*, **158**, 299.

[3] THIS JOURNAL, **8** (1916), 674, 777.

[1] **6** (1914), 472.

the area of high temperature. This is an important point in a vertical furnace since some of the benzene could readily fall through the tube without vaporizing, owing to the small surface of the spherical drop and the short time it would be exposed to heating.

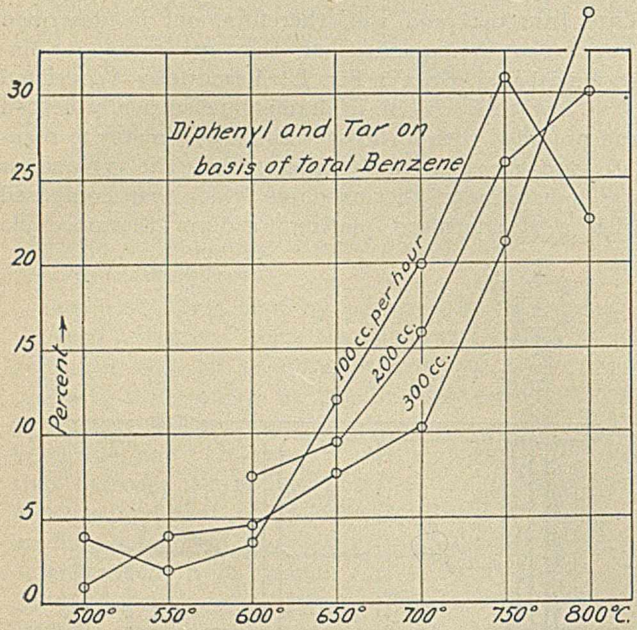

Fig. II—Influence of Rate

The condensing apparatus consisted of a piece of iron pipe $^1/_2$ in. in diameter, 3 ft. long, surrounded by a water jacket. The water cooling was found unnecessary, in fact, detrimental, as the diphenyl was apt to solidify and choke the condenser. The cooling was quite sufficient as was shown by recoveries of 98 per cent of the benzene used in some of the runs where little decomposition to carbon occurs. The receiver consisted of a wide mouth glass bottle provided with two electrodes connected with an induction coil and a set of storage batteries. This arrangement was found very convenient to settle the "fog" from the gases obtained by decomposition at higher temperatures, and afforded a means of accomplishing complete deposition in the receiver. The whole apparatus was washed with benzene before the beginning of a new run in order to avoid vitiating results by decomposition products from a previous run.

The decomposition products of the reactions were distilled in a 500 cc. flask provided with a Glinsky column and a 24-in. condenser for the lower boiling fractions (undecomposed benzene). The residues were transferred to a standard Engler distilling flask and the distillation carried on up to 300° C. Most of the distillate came over between 250 and 275° (diphenyl). A small fraction coming over between 200 and 250°, was collected separately and carefully tested for naphthalene. The residue (tar) was in most cases too small to be fractionated separately, so that the tars from a series of similar runs were added together and fractionated.

CATALYZERS—The catalyzers were pieces of metallic gauze 40 mesh in case of the copper and iron, 40 mesh and 50 mesh in the case of nickel, cut into pieces 10 in. × 12 in., rolled so as to fit the tube and inserted into the part of the tube above the pyrometer. Frequent changes were necessary as they quickly became coated with carbon. This deposition of carbon was particularly objectionable in the case of nickel and iron where plugging of the tube would occur before much of the benzene could pass through.

GASES—Samples of gas were collected for analysis at the exit from the tar separator. To test for acetylene, a large test tube half filled with an ammoniacal cuprous chloride solution, and provided with a two-hole stopper and a tube reaching to the bottom, was inserted at the end exit from the separator tube. To measure the amount of gas given off in the reaction a Referee meter graduated to 0.001 cu. ft. and provided with a thermometer was placed at the end of the tar separator.

The gases were analyzed over water for unsaturated, by absorption with fuming sulfuric, for hydrogen by passing over copper oxide at 290–300° and for methane by explosion with oxygen.

SOURCES OF ERROR—The chief source of error was the deposition of carbon in the tube and on the catalyzers as well as on the pyrometer rod. This tended to obstruct the passage of the gases and interfered with the temperature measurements. The higher temperatures are probably too low since the deposition of non-conducting finely divided carbon would act as a heat insulator. Since the pyrometer projected into the middle of the tube the temperature measured at the beginning of a run was the actual temperature of the vapors and gases and not merely that of the walls of the tube.

The carrying of undecomposed benzene in the form of vapor by the hydrogen introduces quite an appreciable error in some of the determinations. This error increases with increasing decomposition of the benzene and consequent increase in the volume of the gases. At ordinary temperatures (20° C.), the vapor pressure of benzene is 74.6 mm. or nearly 10 per cent of the total volume of hydrogen given off. As

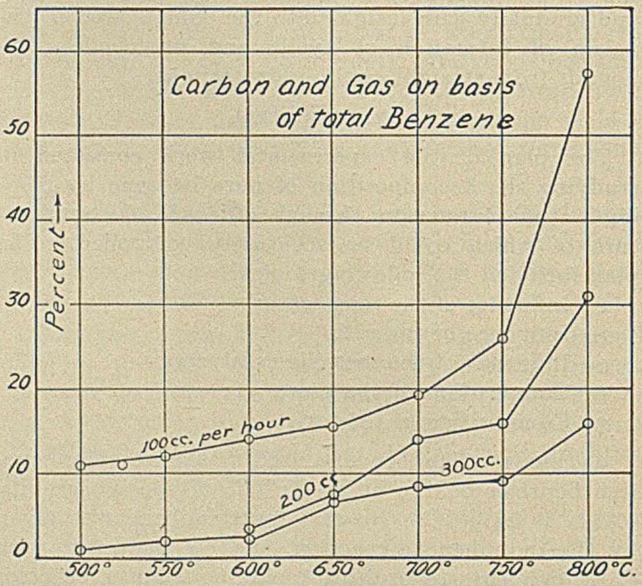

Fig. III—Influence of Rate

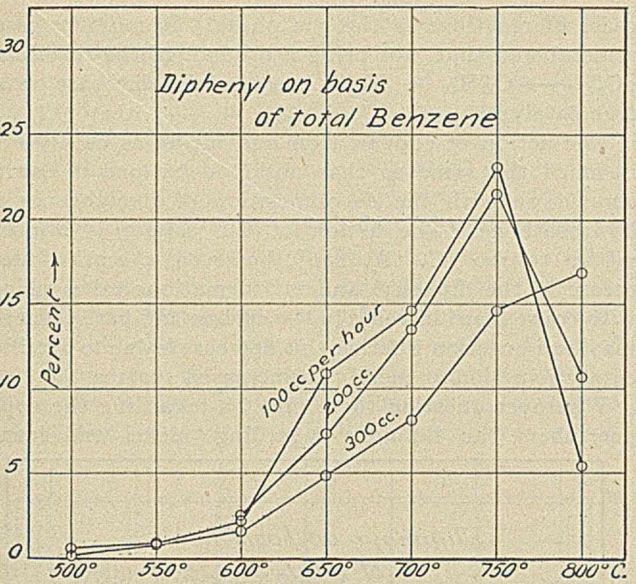

Fig. IV—Influence of Rate

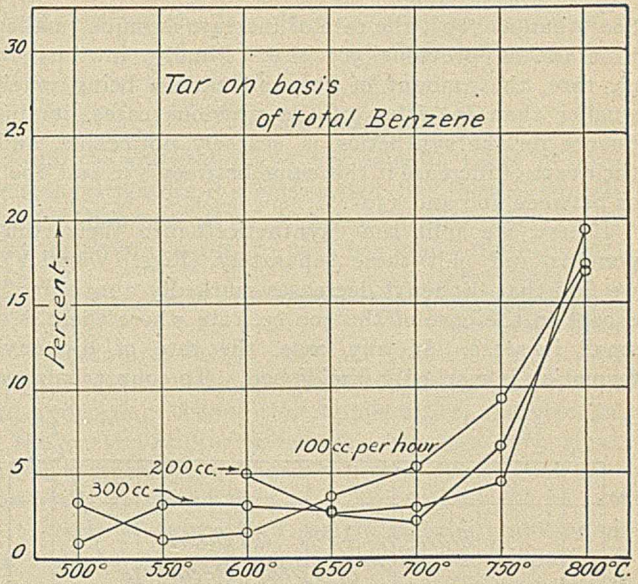

Fig. V—Influence of Rate

there is produced by the reaction, products which dissolve in the benzene and lower its vapor pressure, this amount of benzene in the gas is sensibly lowered. Experimentally we found this percentage to be about 7.3 per cent (see Table III). Calculations of per cent decomposition on basis of "actual benzene used" (*total benzene benzene recovered*) should be corrected by subtracting from the "actual benzene" the amount of benzene vapor which theoretically could be recovered by cooling the gases to a very low temperature. This correction may amount to nearly 13 per cent of the benzene used.

This correction applies likewise to the "per cent of carbon and gas" formation, if the latter is found by subtracting from the total benzene the amounts of diphenyl and tar obtained.

For this reason the percentages calculated in this paper are given on the basis of "total benzene." Moreover, in some cases, especially at lower temperatures, the amounts of "actual benzene" are so small as to introduce very large percentage errors if results are calculated on that basis.

DISCUSSION OF DATA

INFLUENCE OF RATE—The results regarding the influence of rate are given in Table I and Figs. II and III. Decomposition begins, even with the faster rates, as low as 500°. In all cases below 600°, the amounts decomposed are small, but quite appreciable, and leave no doubt that diphenyl and other decomposition products are formed at those temperatures. This is quite in opposition to the claims of Ipatieff and of Haber[1] but the precautions taken in these experiments to prevent contaminations from a previous run and the fact that we obtained diphenyl repeatedly at temperatures as low as 500° can leave no doubt on this point.

If the added percentages of diphenyl and tar as giving the total amount of synthetic products (diphenyl, diphenylbenzenes, etc.) formed, are plotted against temperatures, there is no marked regularity below 600° owing to the fact that the percentages are so close together as to come within the limits of experimental error. Above that temperature, the decomposition proceeds with regularity, being greater in the case of the slower rate which attains a maximum at 750°. Above that temperature, the decomposition to gas and carbon (Fig. III) proceeds so rapidly in the case of the 100 cc. rate as to cause a marked falling off in the percentage of synthetic products. The gas and carbon formation being slower in the 200 cc. rate, its effect on the synthetic products is less marked and although the percentage of synthetics is greater at

Table I—Effect of Rate (Per cents on Basis of Total Benzene Used)

Temp. ° C.	Sp. Gr. Recovered Oils 100 cc. per hr.	200 cc. per hr.	300 cc. per hr.	Per cent Diphenyl and Tar 100 cc. per hr.	200 cc. per hr.	300 cc. per hr.	Per cent Diphenyl 100 cc. per hr.	200 cc. per hr.	300 cc. per hr.	Per cent Tar 100 cc. per hr.	200 cc. per hr.	300 cc. per hr.	Per cent Benzene Decomposed to Form Carbon and Gas 100 cc. per hr.	200 cc. per hr.	300 cc. per hr.
500	0.886	...	0.884	4.0	....	1.0	0.6	....	0.1	3.4	....	0.9	11.0	....	1.0
550	0.886	...	0.884	2.0	....	4.0	0.9	....	0.8	1.1	....	3.2	12.0	....	2.0
600	0.887	0.888	0.886	3.7	7.5	4.7	2.2	2.5	1.6	1.5	5.0	3.1	14.0	3.5	2.3
650	0.897	0.891	0.890	14.5	9.5	7.7	10.9	7.4	4.9	3.6	2.1	2.8	15.5	7.5	7.3
700	0.920	0.910	0.896	20.0	16.0	10.3	14.6	13.5	8.1	5.4	2.5	2.2	19.3	14.0	8.0
750	0.950	0.936	0.916	32.0	26.0	21.3	22.6	21.5	14.7	9.4	4.5	6.6	26.0	16.0	8.7
800	0.956	0.950	0.945	22.7	6.8	34.0	5.4	10.7	16.9	17.3	19.4	17.1	57.3	31.0	16.0

Table II—Effect of Catalysis (Per cents on Basis Total Benzene)

Temp. ° C.	Sp. Gr. Recovered Oil None	Cu	Fe	Nickel (*a*)	Per cent Diphenyl and Tar None	Cu	Fe	Nickel (*a*)	Nickel (*b*)	Per cent Diphenyl None	Cu	Fe	Nickel (*a*)	Nickel (*b*)	Per cent Residue Tar None	Cu	Fe	Nickel (*a*)	Per cent Gas and Carbon None	Cu	Fe	Nickel (*a*)	Nickel (*b*)
500	0.884	.....	0.884	0.884	1.0	....	1.9	...	...	0.1	..	0.8	...	0:0	0.9	..	1.1	...	1.0	....	4.0	15.0	36.0
550	0.884	0.884	0.884	.....	4.0	1.3	2.7	...	...	0.8	0.4	0.8	0.0	0.0	3.2	1.2	1.9	...	2.0	2.7	5.3	....	....
600	0.886	0.885	0.885	0.884	6.0	2.7	4.7	1.7	0.0	1.6	1.0	1.8	0.8	0.0	3.1	1.7	3.2	1.6	2.0	8.0	7.0	23.3	57.0
650	0.890	0.889	0.887	0.885	7.7	5.0	7.0	3.3	2.2	4.9	3.1	3.9	1.9	0.8	2.8	1.9	3.1	1.4	7.3	11.7	8.0	30.0	70.0
700	0.896	0.900	0.898	.....	10.3	11.3	12.0	...	5.8	8.1	9.8	7.6	...	1.9	2.2	1.5	4.4	...	8.5	18.7	12.0	....	79.2
750	0.916	0.926	0.902	0.884	21.3	23.3	11.0	5.0	0.0	14.7	18.1	5.6	0.5	0.0	6.6	5.2	5.4	4.3	10.7	24.0	38.0	65.0	100.0
800	0.945	0.936	0.906	.....	34.0	11.7	10.0	...	...	16.9	8.6	2.2	...	...	17.1	3.1	9.8	...	16.0	45.0	72.0	....	....

(*a*) 40-mesh Nickel (*b*) 50-mesh Nickel

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[1] See historical introduction.

800° than at 700°, the rate of increase is much smaller than in the previous 50° rise. Finally, in the 300 cc. rate, the amount of gas and carbon being much smaller than in either of the previous cases, its influence on the synthetics is scarcely noticeable, and their rate of increase is the same between 750 and 800° as between 700 and 750°.

If now we split the "synthetics" into their components and plot these separately (Figs. IV and V), we find that diphenyl decreases markedly above 750°, except in the case of the 300 cc. rate where there is a small increase. In any case, the rate of diphenyl formation is markedly diminished. To counterbalance this, we find that in all cases the rate of tar formation increases very markedly from 750 to 800°. It would then appear that the tar formation occurs at the expense of diphenyl and that the diphenylbenzenes and other condensation products are formed by the action of diphenyl on benzene.

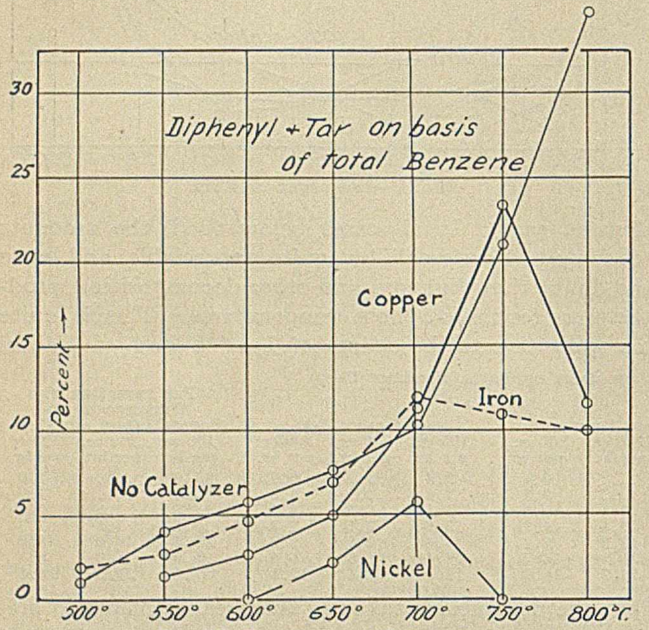

FIG. VI—INFLUENCE OF CATALYZERS

INFLUENCE OF CATALYZERS—The catalyzers studied were copper, iron and nickel. For the sake of uniformity, wire gauzes of the same mesh were used, except in the case of nickel when two different meshes were used. The rate in these cases was 300 cc. per hour.

The graph with "no catalyzer" is given for the sake of comparison. It is, of course, a question whether the finely divided carbon which forms abundantly at the higher temperatures is not itself a catalyzer. As, however, the amount formed on the sides of the tube was the same in all cases, its influence, so far as that amount is concerned, is negligible for purposes of comparison. As to whether a product of a reaction can be called a catalyzer, it must be borne in mind that at the higher temperature the speed of the reverse reaction, $6C + 3H_2 \longrightarrow C_6H_6$, is immeasurably small, and that the action of the finely divided carbon may be in the nature of a surface action, so important in cases of reactions in the gas phase. It must be also remembered that, not being a product of the reaction, $2C_6H_6 \longrightarrow C_{12}H_{10} + H_2$, it may act in this case as a true catalyzer.

The action of copper, iron and nickel as catalyzers is much the same as that observed by one of us[1] in connection with the decomposition of straight chain hydrocarbons. The action of the copper is almost nil up to 700° C. At 800°, however, a marked decrease in the diphenyl and tar formations takes place with consequent increase in the carbon and gas. There may be a question whether this decrease is due to specific catalytic action or merely to increased surface.

Whatever question there may be regarding the copper, there can be none regarding nickel and iron. These are true catalyzers for the reaction $C_6H_6 = 6C + 3H_2$ (see Fig. VII). Of course, the surface exposed has a marked effect on the action as may be gathered from the results obtained with two different meshes of nickel gauze.

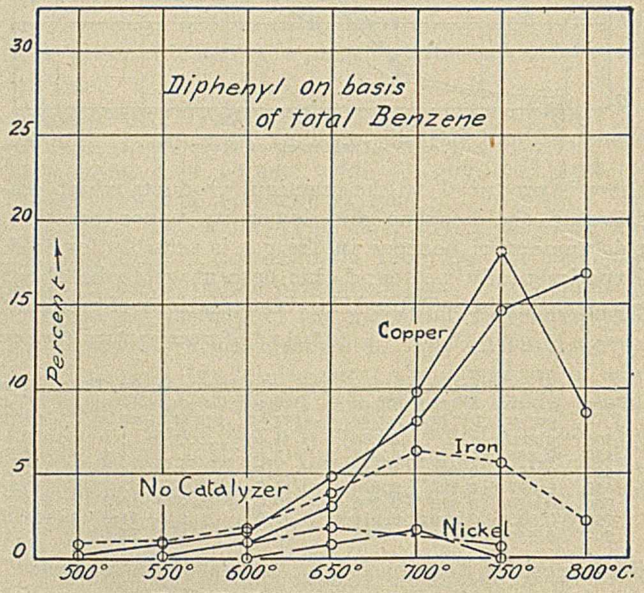

FIG. VII—INFLUENCE OF CATALYZERS

GASES—Analyses of the gases are given in Table III.

TABLE III—GAS FORMED AT 100 CC. PER HOUR RATE

Temp. ° C.	Liters per 100 Cc. Benzene Used: Total Gas	Liters per 100 Cc. Benzene Used: Hydrogen	Percentages of Total Gas: Unsaturated	Percentages of Total Gas: Hydrogen	Percentages of Total Gas: Residue
500	2.8	2.6	7.2	90.8	2.8
550	4.2	3.9	7.7	89.9	2.4
600	8.5	7.8	7.2	89.8	3.0
650	12.7	11.8	7.2	90.6	2.2
700	28.3	26.2	7.3	88.3	4.4
750	49.5	36.1	7.3	90.5	2.2
800	63.7	59.2	7.1	91.8	1.1

The per cent of "unsaturated" is so constant and corresponds so well to the amount of benzene vapor that it cannot be ascribed to any other cause.

Careful tests for acetylene with ammoniacal cuprous chloride proved absolutely negative. Of all investigators of the thermal decomposition of benzene, Berthelot is the only one to report acetylene,[2] and he was none too sure about its presence, owing to the interference of sulfur compounds in his benzene which generated H_2S.

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[1] *Loc. cit.* [2] See historical introduction.

It seems to us that if acetylene is formed by the thermal decomposition of benzene at atmospheric pressure, we should expect some of the condensation products that it forms with benzene, such as naphthalene, styrolene, anthracene, etc.,[1] whereas none of these products has been reported[2] and in fact, Berthelot positively declares they are not formed.

In the analysis of the gas, there always remained a residue after combustion of the hydrogen over copper oxide, which could not be exploded with oxygen. This residue, which amounted to about 2.5 per cent, was undoubtedly nitrogen. The very large volume of the system and the necessity of taking gas samples before the almost inevitable plugging of the tube with carbon, made it practically impossible to sweep out all the air from the apparatus with the hydrogen produced in the reaction.

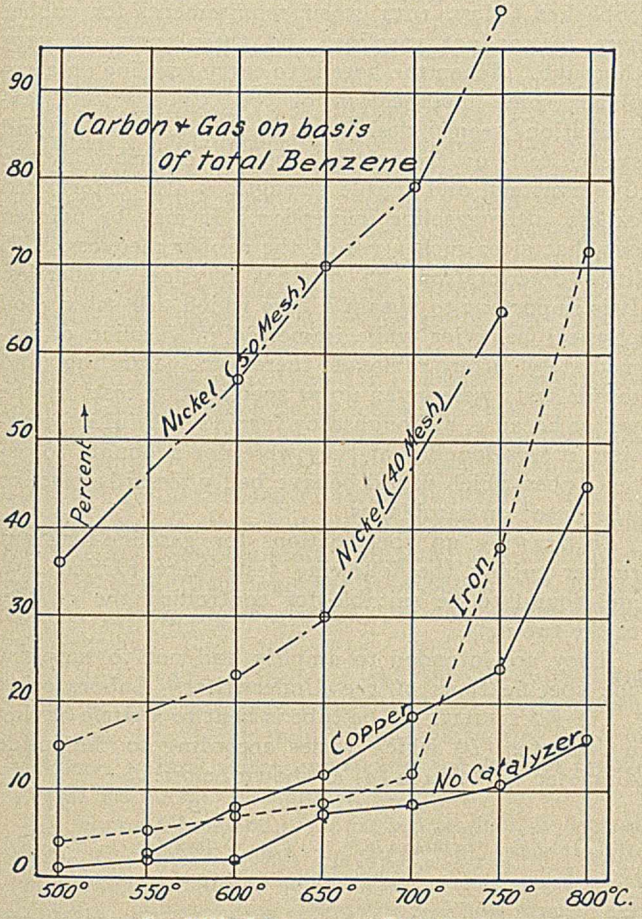

FIG. VIII—INFLUENCE OF CATALYZERS

TAR—The tarry compounds remaining after 275° were redistilled and extracted with alcohol, according to the method of Schmidt and Schultz.[3] We were able to obtain without difficulty the same compounds separated by those authors: *m*- and *p*-diphenylbenzenes melting at 86° and triphenylene 196°, this last giving a compound with picric acid. The amount of tar obtained from each separate run was so small that no quantitative relation of the influence of rate on the formation of its individual constituents could be obtained without the introduction of an enormous percentage error and for the present only the qualitative results can be reported.

CONCLUSIONS

From the above data, as well as from those of previous investigators, it seems settled that the decomposition of benzene at high temperatures (600–800°) takes place in accordance with the following reactions:

$$\left.\begin{array}{c}\text{Carbon}\\\text{and}\\\text{Hydrogen}\end{array}\right\} \longleftarrow \text{Benzene} \longrightarrow \text{Diphenyl} \longrightarrow \left\{\begin{array}{l}\text{Diphenylbenzenes}\\\text{(Condensation Products}\\\text{Containing 3 or}\\\text{more Benzene Rings)}\end{array}\right.$$

At temperatures below 750°, the reaction velocity of the diphenyl formation is greater than that of carbon and hydrogen. Above that temperature, the velocity of the carbon-hydrogen reaction becomes very great and decomposes the benzene before other condensation products can be formed.

It seems of interest to remark on the stability of the benzene ring and on its complete decomposition to carbon and hydrogen *without appreciable quantities of intermediate products*, such as acetylene, ethylene, ethane or methane at high temperatures. No conclusive evidence has thus far been brought forward to show that the ring is broken at high temperatures with formation of any products but carbon and hydrogen.

The remark of Rittman, Byron and Egloff[1] that diphenyl is not an equilibrium product but merely an intermediate one seems to be borne out by our results with this difference, however, that whereas those authors, as well as McKee,[2] believed the equilibrium to be Benzene ⟶ Diphenyl ⟶ Naphthalene; it is, in fact, Benzene ⟶ Diphenyl ⟶ Diphenylbenzenes.

There have been no catalyzers so far brought out that catalyze the formation of diphenyl. Those studied by Smith and Lewcock proved ineffective and those presented in this paper catalyze only the formation of carbon.

FORMATION OF NAPHTHALENE—Owing to the fact that this compound was reported present in the decomposition of benzene, by Rittman, Byron and Egloff, very careful tests both as to melting and boiling points and formation of picrate were made on the first fraction that came over on distilling the reaction products, after the undecomposed benzene had boiled off. The boiling point of naphthalene is 218°, whereas that of diphenyl is 254°. If any naphthalene were present, it would appear in the first fraction of the distillate which should come sensibly below the boiling point of diphenyl. The first fraction after the separation of the benzene did boil much below diphenyl and for that reason was separately collected, crystallized repeatedly and treated in alcohol solution with picric acid, according to the method given by Milliken.[3] In no case was a melting point higher than 70° obtained, using a standard short-stem thermometer; neither was the slightest precipitate of naphthalene picrate obtained, though the method was checked with satisfactory results both against pure naphthalene and

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[1] *Bull. Soc. Chim.*, **7**, 218, 278, 306.

[2] Except naphthalene by Rittman, Byron and Egloff (*v. i.*).

[3] *Ann.*, **203**, 118.

[1] THIS JOURNAL, **7** (1915), 1020.

[2] *J. Soc. Chem. Ind.*, **27** (1904), 403.

[3] "Identification of Pure Organic Compounds" (John Wiley & Sons).

mixtures of naphthalene and diphenyl in proportions from 1 : 1, to 1 of diphenyl : 0.01 of naphthalene.

As a further test the accumulated diphenyl from all experiments, amounting to about 1 kilogram, was distilled in a large flask and the first few cubic centimeters of distillate collected and submitted to the same tests with negative results.

The presence of naphthalene in Rittman, Byron and Egloff's product at atmospheric pressure can be ascribed by the writers only to the fact that those authors used commercial benzene, which doubtless contained toluene. This last on heating with benzene gives naphthalene as shown by Carnellay[1] by passing mixtures of benzene and toluene through a red hot tube.

The specific gravity of the benzene used by Rittman, Byron and Egloff at 15° was 0.879, whereas that of the one we used was 0.881 at 15.5°. The difference is small indeed but it tends to show the presence of some toluene (0.871 at 15.5°) in the material used by those authors.

SUMMARY

I—The thermal decomposition of benzene has been studied at temperatures varying from 500 to 800° C. and atmospheric pressure.

II—The chief products are diphenyl, diphenylbenzenes, carbon and gas. The formation of diphenyl begins at as low a temperature as 500°.

III—No acetylene was found in the gas, which consisted of hydrogen saturated with benzene vapor, and no naphthalene in the decomposition products, tending to show that the thermal decomposition of benzene at atmospheric pressure takes place with the formation of condensation products in which the benzene ring apparently remains intact, or with the formation of hydrogen and carbon.

IV—The effect of rate on the yields of diphenyl has been studied. The slower rates are more favorable to the formation of diphenyl. The optimum temperature is in the neighborhood of 750°. Above that temperature, diphenyl benzenes as well as carbon and hydrogen form readily.

V—The catalytic action of copper, iron and nickel has been studied. Iron and nickel favor the decomposition to carbon and hydrogen. The action of copper is not marked except above 750°, when the formation of carbon is accelerated.

Further work upon these topics is now in progress in this laboratory.

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RUBBER HOSE FOR USE ON AEROPLANES

By PERCY A. HOUSEMAN[2]

Received December 18, 1916

The enormous increase in the world's output of aeroplanes during the last three years has rendered important a systematic inspection of materials used in their construction.

One of the materials requiring detailed examination is rubber hose, which is held to be the most desirable material for conveying gasoline from the tank to the engine on aeroplanes.

It was found, at the time that a system of inspection for aeroplane materials was initiated in England, that the quality of the rubber being used was quite unsatisfactory. This was probably due in a large measure to the unfamiliarity of the rubber manufacturers with the properties required of gasoline-resistant rubber hose. They appear in some cases to have endeavored to adapt their regular types of material, such as steam- or water-hose, for use with gasoline, with results which were sometimes disastrous to the life of the aeroplane and to its pilot.

The Underwriters' Laboratories of Chicago have published (May, 1914) their requirements for rubber hose to conduct gasoline, and their tests are very thorough. When the hose is to carry gasoline on aeroplanes some modification of the Underwriters' examination seems desirable. Bursting, tensile, and stretch tests on the original hose are described by the Underwriters, and tensile strength is also determined 24 hrs. after gasoline immersion. It may be pointed out that after such a period the rubber recovers, with little deterioration, its original physical properties It is important to obtain a hose which will show good physical behavior while immersed in gasoline or immediately after removal therefrom. Bursting and tensile tests were given up as specification tests by the writer because, although they furnish helpful information, it was found that they were not adequate to detect tubes which would behave badly towards gasoline when used on aeroplanes.

In drawing up specifications for gasoline-resistant rubber tubing the following tests were carried out, and found to be suitable for controlling the quality of the tubing.

They are intended to amplify and not to supplant the specifications of the Underwriters' Laboratories.

(1) FLEXIBILITY—The tube is bent to a circle having a diameter (*D*) which varies according to the inside diameter of the tube (*d*) as shown below:

d	*D*
Up to 1/2 in.	8 times *d*
9/16 in. to 1 in.	10 times *d*
1 1/16 in. to 1 1/2 in.	12 times *d*
Above 1 1/2 in.	14 times *d*

The diameter of the tube so bent should not change at any point by more than 10 per cent from its original diameter.

A tube of poor flexibility will show a permanent weak spot if bent sharply a dozen times at the same place.

(2) IMMERSION IN GASOLINE—At first an immersion test of 200 hrs. in cold gasoline of about 0.720 sp. gr. was used. It was found that approximately the same effect can be attained in a shorter time by boiling in gasoline for 1 hr. under a reflux condenser, followed by 24 hrs.' standing in gasoline at room temperature. The approximate increase in weight and volume of the sample (about 3 in. long) is recorded for correlation with the results of the other tests. The decrease in bore at the narrowest part of the tube is also noted

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[1] *J. Chem. Soc.*, **37**, 712.

[2] Formerly Chief Examiner, Aeronautical Inspection Department Laboratories, London, England.

and should not exceed 25 per cent, otherwise the supply of gasoline to the engine may be seriously diminished, especially for tubes of less than $^1/_2$ in. internal diameter.

The adhesion of the rubber to the canvas fabric must remain good, and the "nerve" of the rubber must not be seriously impaired when examined immediately after the gasoline treatment.

This test for strength of adhesion of rubber to canvas, and for retention of "nerve" of the rubber is open to the objection of being too vague, but it was not found expedient to incorporate standardized tests for these properties, and in actual practice no difficulty was ever experienced in judging whether or not a sample passed the test. This test is also a rough guide to the amount of free sulfur present, crystals of sulfur being deposited from a tube containing an excessive amount.

(3) PERMEABILITY TO GASOLINE—A 14 in. length of the tube is held vertically and plugged with a glass stopper at the bottom. A glass tube is fitted to the top, and is filled with gasoline to a head of 12 in. above the top of the rubber tube, and then loosely stoppered. The length of rubber tube exposed to the action of the gasoline is 12 in. At first the gasoline is absorbed comparatively rapidly by the rubber. The level of the gasoline in the glass tube should not be allowed to fall more than 3 in., additions of gasoline from a known volume being made as necessary. The amount of gasoline which permeates through the walls of the rubber tube is noted during the first and second days, as a guide to the behavior of the sample. During the third 24 hrs., by which time the rate of permeation has become approximately constant, the amount of gasoline passing through the tube should not exceed 100 cc. per sq. ft. of original internal surface of the rubber tube.

(4) DRY HEAT—A piece of the tube is heated for 2 hrs. at 132° C. The rubber should remain elastic after this treatment, and should show no signs of stickiness or brittleness, nor should any surface cracks become visible on stretching the sample.

(5) COLD—The tube is immersed in carbon dioxide snow, which was found to render all tubes brittle while they remained cold. The rubber regains its elasticity on attaining room temperature again, and this test was, therefore, discontinued.

(6) BURSTING PRESSURE—Tests on bursting pressures were carried out before and after the permeability test, but were subsequently given up, as it was found that the quality of the tube could be sufficiently safeguarded by the other tests, and, moreover, the pressure to which the tube is subjected in actual service is very slight.

(7) ACETONE EXTRACT, FREE SULFUR, MINERAL SULFIDES, AND SULFUR OF VULCANIZATION are also determined, and furnish useful information in forming a judgment as to the quality of the specimen under examination. The free sulfur should not exceed 1 per cent of the weight of the finished tube (exclusive of the canvas). Excessive free sulfur will be carried by the gasoline into the cylinders of the engine where it may promote pitting.

(8) ASH—A portion of the rubber is incinerated very slowly, and the amount and composition of the ash determined.

(9) QUALITY OF CANVAS—Tests on the quality and strength of the fabric inserted in the tube were contemplated, but it was found expedient to leave to the judgment of the manufacturer the kind of fabric to be used, relying on the tests already enumerated to control the production of a satisfactory tubing.

When the examination of rubber hose for use with gasoline was commenced, great diversity in construction, composition and behavior was found. Some makers appear to have believed that vulcanized rubber is essentially non-resistant to the action of gasoline, and therefore put as little of it in the tubes as possible. Some tubes yielded as much as 75 percent ash, while others gave less than 40 per cent. As great a diversity was found in the composition of the ash. Barium sulfate, lead, zinc, calcium and magnesium were found in a great variety of proportions, each manufacturer carefully guarding his own "mixings" and considering them of vital importance for the production of a satisfactory tube. Some typical figures of ash analyses are appended. The figures for total ash are percentages of the finished tube, excluding the canvas.

TABLE I—TOTAL ASH AND ASH ANALYSES OF GASOLINE-RESISTANT RUBBER HOSE

DESCRIPTION OF TUBE	TOTAL ASH Per cent	PERCENTAGES OF TOTAL ASH				
		$BaSO_4$	PbO	ZnO	CaO	MgO
French No. 1	51	26	10	..	26	10
French No. 2	42	20	..	5	34	20
British 1-A	72	43	3	4	..	21
British 1-B	73	44	35	4	..	4
British 1-C	45	51	34	5	1	1
British 1-D	45	40	..	5	33	13
British 2-A	49	..	47	..	5	37
British 2-B	39	10	18	27	26	..
British 2-C	38	..	37	..	4	34
British 2-D	43	19	18	3	26	4
British 2-E	39	..	27	..	5	46
British 3-A	68	..	36	34	5	..
British 3-B	41	..	..	24	25	25
British 4-A	45	46	..	29	4	10
British 4-B	60	72	..	7	12	1
British 5-A	59	28	6	7	31	..
British 6-A	44	..	40	13	2	29
British 7-A	61	..	60	8	..	3

French No. 1 was not a very good tube. The rubber was somewhat harsh. The tube failed to pass the flexibility test, but was satisfactory for permeability. The adhesion between rubber and canvas at the end of the immersion test was fairly good, but the tube contained as much as 3 per cent free sulfur. The heat test caused obvious deterioration in the quality of the rubber. Barium sulfate and lime are the chief mineral ingredients.

French No. 2 was inferior to No. 1. The rubber was harsh, and its behavior varied along the length of the consignment, indicating probable uneven vulcanization. Mechanical defects, such as local pitting, were to be seen. The adhesion of rubber to canvas after immersion appeared at first sight to be very good, but this was due rather to the ease with which the rubber itself tore. Lime and magnesia are the most prominent minerals, with barium sulfate as a diluent. Rubber hose for use with gasoline on French aeroplanes is required to contain 45 per cent mineral matter with a margin of ±5 per cent, 50 per cent rubber with the same margin, and to have a density of 1.6 (±0.1).

British 1-A to 1-D, though all from the same maker, show wide variations in total ash and in the composition of the ash. The bad feature of both 1-A and 1-B was the weakness of the adhesion between rubber and canvas. Separation of the plies occurred spontaneously under gasoline. The other properties of these tubes were satisfactory. 1-D was a good tube.

British 2-A to 2-E, all made by one firm, show less variation in total ash, but much variation in the composition of the ash. 2-A and 2-B represent respectively outer and inner rubber layers of the same tube. The same applies to 2-C and 2-D. The inner layer of rubber proved to be of better quality for use with gasoline than the outer layer. The adhesion between rubber and canvas was bad. Tubes 2-A and B showed high constriction of the bore. All of these tubes contain a considerable quantity of lead, and 2-E is noticeably high in magnesia.

British 3-A and 3-B—3-A showed bad "adhesion;" 3-B very good adhesion, though the rubber was rather "short" after the immersion test.

British 4-A and 4-B—The product of this firm showed great variability in bore-constriction, but the flexibility, permeability, adhesion after immersion test, and quality of rubber after immersion test were all good.

British 6-A was a good tube. *British 7-A* was too harsh.

A large number of other tubes were examined, but most of them showed defects in one or more of the properties tested. Some manufacturers used a certain amount of reclaimed rubber or of rubber substitute, but it is believed that this is not desirable as regards the quality of the product, although it lowers the cost.

One firm made an excellent tube by the use of 45 per cent Para rubber. The mineral ingredients in this tube were lead, calcium and magnesium. This tube withstood the immersion test with hardly any deterioration in the "nerve" of the rubber, and the adhesion between rubber and canvas was scarcely affected. The bore constriction after immersion test was less than 25 per cent on a $^1/_2$-in. tube, and all of the other tests gave good results.

It is probably undesirable to use less than 40 per cent rubber.

In many cases it was customary to insert a spiral of brass or steel wire in the bore of the tube so as to improve its flexibility. This practice is unnecessary if the walls of the tube are made fairly thick, and in the case of the brass spiral constitutes a possible source for the entry of copper into the rubber.

It was found that a decided improvement in some of the properties of gasoline-resistant rubber hose could be achieved by changing the manner in which the canvas was inserted. The usual method was to friction the canvas with a very thin layer of the rubber mixing, so that in the finished tube there were virtually three plies, an inner layer of rubber, a middle layer of canvas, usually from 2 to 4 turns according to the size of the tube, and an outer layer of rubber. When a tube made in this manner is subjected to the immersion test the three layers expand at different rates, resulting often in spontaneous separation. The canvas layer expands hardly at all, and so the expansion of the inner layer of rubber is forced inwards, with consequent constriction of the bore. A better method of construction consists in spreading a definite layer of rubber on the canvas, so that in the finished tube the thickness of rubber between each turn of the canvas is at least twice as thick as the canvas itself. A cross-section of a tube made in this way shows the canvas to be distributed as a spiral through the whole thickness of the wall of the tube. Such a tube shows improved flexibility and better behavior under the immersion test, there being less tendency to separation between rubber and canvas and a smaller constriction of the bore. For tubes up to $^5/_8$ in. internal diameter, two turns of canvas are sufficient. Between $^{11}/_{16}$ in. and $1^1/_4$ in., three turns are desirable, and for tubes larger than $1^1/_4$ in. internal diameter 4 turns of canvas should be used. The larger sizes are used for oil or water.

The inner layer of rubber on all tubes for carrying gasoline should, of course, be seamless. A seam on the inner rubber would facilitate penetration of the gasoline to the canvas, which would then function as a wick for the distribution of gasoline throughout the wall of the tube.

A satisfactory material for protecting a cut end of tubing from absorption of gasoline may be made from a mixture of about 4 parts gelatin with 1 part glycerin, with the addition, if desired, of a small quantity of formaldehyde or potassium bichromate. Such a solution might even be run, while warm, through the whole length of the rubber tube, so as to form a protective film on the inner surface. Rubber hose for gasoline is, however, now being made in Great Britain of a quality sufficiently good to need no protective film, and there is, moreover, the possibility of portions of such a film becoming detached and causing partial choking of the tube. When the hose is not to be cut the ends may be best protected from absorption of gasoline by being capped.

In testing a large consignment, a sample should be taken from at least every 100 ft. in order to guard against lack of uniformity in quality, such as would be caused by uneven vulcanization or variability of the mixing.

In storing gasoline-resistant rubber hose the usual precautions should be taken for protection from strong light, and from extremes of temperature. As a matter of safety a tube should not be used which is more than 6 months old.

The testing of rubber hose for use with oil or hot water on aeroplanes is less important. Rubber hose for use with oil should withstand 8 hrs.' immersion in castor oil at 100° C. without serious injury to the quality of the rubber, and without any disintegration of the tube. The increase in weight after thoroughly wiping off the oil should be less than 5 per cent. Rubber hose for use with hot water should withstand boiling in water.

The writer had the privilege of being associated with Mr. W. E. Gibbs and Mr. N. W. Barritt in carrying out the work described in this and in the following paper.

HIGHLAND PARK, LLANERCH, PENNSYLVANIA

GLUE FOR USE ON AEROPLANES

By Percy A. Houseman[1]

Received December 18, 1916

There are many parts of an aeroplane that require the use of an adhesive material. Of these may be mentioned "airscrews" (the collective name for propellers and tractors), hollow spars, booms, ribs, plywood, etc. For some of the small parts, such as the ribs, which are subsequently covered by "doped" fabric, it is not necessary to use the best quality of glue. For other parts, however, it is of vital importance that only the strongest glue be used. This applies particularly to airscrews, which rotate at a very high speed. Airscrews are built up in laminae of walnut or mahogany, usually 7 in number, and each 1 in. thick. It is usual to glue two laminae together, and allow them to remain in clamps for a period of from 6 to 24 hrs. before gluing on the next lamina. The finished airscrew is shaped out after the total number of layers have been glued together and have been allowed to set. The glue is applied hot, and usually by at least two workmen, in order to cover the surface as quickly as possible. The temperature of the gluing room is kept above 70° F. It would, of course, be an economy to glue at one operation all of the laminae of an airscrew, but this is not possible when a cake glue is used, on account of the rapidity with which the hot solution sets. Attempts have been made to overcome this difficulty by the use of "liquid" glues, but these have usually proved unsatisfactory. One French liquid glue contained some hygroscopic material, and failed to set in 14 days. "Liquid" glues should be used only on work in which great strength under widely varying conditions of temperature and humidity is not of prime importance. Bone glue should never be used on aircraft work. The best results are obtained from skin or hide glues.

In working out a method for the examination of glue some attention was given to such chemical and physical tests as moisture, ash, nitrogen, strength of jelly, viscosity, percentage precipitable by alcohol (Stelling's test),[2] etc., but while the information furnished by these tests was of interest, it was not found possible to correlate definitely the results obtained, with the value of the glue for aeroplane work.

A method was therefore developed to test the strength of a glued joint under various conditions. Experiments were made with blocks of biscuit-ware, as recommended by Rideal in his book on "Glue and Glue Testing." Messrs. Doulton, of London, kindly made the necessary blocks, which had a base (*ab*) 1 in. square, similar in design to that shown in Fig. I.

Two such blocks were glued together under various conditions of strength of glue solution, temperature, method of application, pressure of clamping, etc. The blocks were pulled apart in a cement testing machine with automatic application of the load, but as uniform results could not be obtained, the stone blocks were abandoned. More uniform results were obtained with wood, which also has the advantage of giving results more nearly comparable with those obtained under actual service conditions. Pieces of carefully selected straight-grained walnut were used, and from them a number of different types of joints were prepared, and used to illustrate different kinds of stresses. The type of joint finally adopted is that shown in Fig. II. This joint gives by no means a true shear, as was easily seen by examining under polarized light a celluloid model made to scale. A stress more nearly approaching pure shear would probably be obtained with a joint like that shown in Fig. III, made up from pieces 9 in. × 2 in. × 1/4 in. but for the purpose of obtaining comparative results, that shown in Fig. II answers well and has the advantage of simplicity.

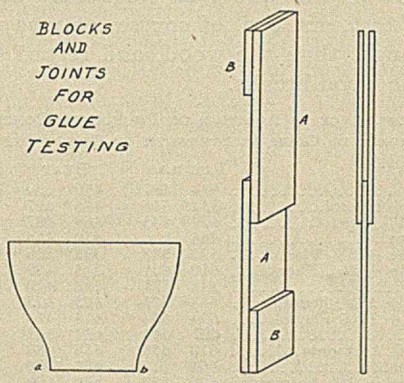

FIG. I FIG. II FIG. III

The wood is exposed for 24 hrs. to a temperature of 35° C. before making the joint. The test pieces (*A*) are 9 in. × 2 in. × 3/8 in. These were roughened by a toothed plane, as it was found that a roughened surface gives a stronger joint than a smooth one. The distance pieces (*B*) are 3 in. × 2 in. × 3/8 in. The area of the glued surface of the joint to be pulled apart is 4 sq. in. To prepare the glue, it is broken into small pieces and is soaked over night in the requisite amount of water. For the gelatine types of glue, 1 part by weight of glue to 2 parts by weight of water gives a desirable concentration, while for "Scotch" glues 1 part of glue to 1.25 parts of water gives the best results. For other types of glue the water required usually falls within these limits. The soaked glue is dissolved by warming to 60° C., and the solution is applied at that temperature. The joints are clamped under moderate pressure for 48 hrs., and are tested after a further 24 hrs. For each sample of glue, the following three tests, each in duplicate, are carried out on the joints prepared as described above.

(1) REGULAR TEST—The joints are pulled apart in a Buckton and Wicksteed or in a Riehlé (Philadelphia) Testing Machine and the breaking strain per sq. in. of glued surface is recorded. The experimental variation is less than ±10 per cent, most of which may be ascribed to unavoidable variations in the wood.

(2) HEAT TEST—The joints are subjected to dry heat in an electrically heated oven for 2 days at 45° C., and then pulled apart, and the breaking strain recorded.

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[2] *Chem.-Ztg.*, **20**, 461.

(3) IMMERSION TEST—The joints are completely immersed in water at 20° C. for 12 hrs., and are then pulled apart, and the breaking strain recorded.

Tests (2) and (3) are intended to throw light on the behavior of an airscrew under the extreme conditions of a tropical climate and high humidity. Tests were also made with moist heat, and on immersion followed by dry heat, but were discontinued. The last named test was found to be too drastic, all glues giving very low results.

The whole procedure outlined above is an arbitrary one, and for this reason it is necessary rigidly to standardize and adhere to the technique of the method, in order to obtain comparable results. When the break occurs in the wood, as frequently happens in the regular test, one can, of course, only say that the glue is stronger than the wood, and record the figure at which the wood breaks.

TABLE I—INFLUENCE OF ADDITION OF PHENOL OR CONCENTRATED AMMONIA TO GLUE ON STRENGTH OF GLUED JOINT

GLUE TESTS:	REGULAR		HEAT		IMMERSION	
Gelatin A	644	627	459	...	504	...
Gelatin A + 5% Phenol	532*	616	476*	627	621	...
Gelatin A + 10% Phenol	677*	845	369	487	560	660
"Propeller" Glue	464	...	470	464	540	504
"Propeller" Glue + 5% Phenol	526	593	395*	506	553	560
"Propeller" Glue + 10% Phenol	610	632	315	429	560	565
"Scotch" Glue	548	571	448	470	448	470
"Scotch" Glue + 5% Phenol	688*	723	425	425	532	548
"Scotch" Glue + 10% Phenol	694	694	414	453	436	476
Gelatin A	627	644	459	565	504	549
Gelatin A + 2% Ammonia	610	655	616	688	800	875
"Propeller" Glue	464	..	464	470	540	504
"Propeller" Glue + 2% Ammonia	520	532	580	609	648	783

The figures represent breaking strain in lbs. per sq. in. of glued surface of the standardized joint. Breaks in the wood are indicated thus *.

Addition of phenol to the glue improves the regular test. The influence on heat tests and on immersion tests is not marked, but the tendency is to raise them slightly. The addition of 5 per cent phenol to a 1 : 2 gelatine solution, depressed the setting point of that solution from about 26 to 18° C., while 10 per cent phenol caused the solution to be still viscous at 5° C. The addition of 5 per cent phenol to glue solutions to be used on aeroplane work is, therefore, to be recommended, both because of its tendency to increase the strength of the joint, and also on account of its action in depressing the setting point.

Ammonia causes the glue to set more rapidly. It was found to have the unexpected effect of raising the figures for heat and immersion tests, while leaving regular tests little affected.

The Germans appear to have used a casein glue on some of their aircraft. An analysis of a Swiss glue of this type showed its composition to be about 66 per cent casein and 23 per cent mineral matter. The latter was composed of soda, silica, lime and alumina. About 1 per cent of petroleum was present in the powder. This casein glue is prepared for use by rubbing up with cold water. It requires about 3 days for the joint to set, but has the advantage that all the laminae of an airscrew can be glued together at once.

The following test figures were obtained on joints made with the Swiss casein glue:

Regular		Dry Heat		Moist Heat		Immersion	
551	655	526	661	448	465	672	862

The immersion test is particularly high.

Casein glues are very generally used for cementing together the "veneers" on ply-wood which finds extended use on the fuselage and other parts of the aeroplane. One English firm uses a mixture of casein, lime, and blood, which yields a cement very resistant to water. A three-ply board made with such a cement will withstand an immersion test in water at 50° C. for 12 hours without any separation of the plies, though the strength of this cement on a "regular" test is inferior to that of a hide glue.

Another firm of ply-wood manufacturers uses lime and casein only, in the proportion approximately of 4 parts by weight of lime to 7 parts by weight of casein. Casein and borax form a good mixture, but are, of course, more expensive than casein and lime. Casein glues cannot be kept more than a few hours after mixing with water, so that a batch when mixed must be completely used, or the residue wasted.

When a new glue is intended for use on airscrews, the tests described above should be supplemented by a practical test of spinning a trial airscrew made with the new glue.

HIGHLAND PARK, LLANERCH, PA.

A STUDY OF CERTAIN FERMENTS WITH A VIEW TO DETERMINING A METHOD FOR THE DIFFERENTIATION OF PASTEURIZED MILK FROM RAW MILK

I. REDUCTASES

By RICHARD EDWIN LEE AND MELVIN GUY MELLON

Received May 1, 1916

INTRODUCTORY

The enthusiasm and skill with which many of the problems relating to the distribution, composition and action of a class of substances known as *enzymes* or *ferments* have been attacked in recent years have contributed much data of importance to the biological chemist and sanitarian.

Some of these ferments are so widely distributed in living tissues of members of both the animal and vegetable kingdoms that it has been suggested by one well-known investigator "that the properties of *these substances might almost be turned to account as a general chemical test for vital activity*." While this may seem like an exaggeration of their significance and although the precise rôle of these substances in the life of the cell has not yet been determined, it is undoubtedly true that they are concerned in a great many of the most important biochemical processes with which we are familiar. And furthermore, regardless of the fact that very few, if any, of these substances have been isolated in a pure condition,[1] they have, without doubt, as have other compounds, a definite chemical composition; and through the exercise of definite chemical affinities, they are able to produce alterations in other compounds.

Holding to this view, Traube[2] formulated his theory of fermentation, for example, upon two distinct chemical propositions: *first*, that the ferments are defi-

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[1] It would probably be more accurate to say that we do not know whether a specific enzyme has, or has not been prepared in the pure state.

[2] *Theorie der Fermentwirkungen*, Berlin, **1858**; *Ueber Aktivirung des Sauerstoffs.*, **15**, 659–675.

nite chemical compounds elaborated from protein as a result of the combined action of heat, water, and oxygen, and are present not only in the lower organisms but also in the tissues of the higher forms, where they are responsible for biochemical processes; *second*, that the ferments are powerful reducing agents and oxygen carriers, capable, in the capacity of chemical go-betweens (*Vermittler*), of effecting the transfer not only of free oxygen to easily oxidizable substances, but also the transfer of combined oxygen from one compound to another.

In accordance with this theory, he was led to divide ferments into three classes:[1]

(*a*) *Verwesungsfermente*[2]—those combined loosely with oxygen, forming unstable compounds which give up their oxygen to other substances less readily oxidized.

(*b*) *Reductionsfermente*—those which combine with the oxygen of water, the hydrogen going to effect the reduction of some passive body.

(*c*) *Höchste Fäulnissfermente*—those which cause putrefactions in which hydrogen is set free.

Although there is not complete agreement among investigators as to the exact mechanism by which the alterations are effected, there is very general belief that they act catalytically, and, therefore, partake of the nature of ferments; that is, enzymes may be regarded as organic catalysts.

As is well known, they are very unstable, being generally destroyed by an exposure to a temperature outside of relatively narrow limits; and inasmuch as they have optimum, maximum, and minimum temperatures, and thermal death points, they resemble microorganisms.

Usually action ceases at 0° C.; the optimum for most types lies between 30 and 50° C., they are soon destroyed at temperatures above 70° C., and almost instantaneously by boiling water. Likewise they are remarkably sensitive to the action of mineral acids such as HCl and various poisons[3] such as HCN, SO_2, $HgCl_2$, $C_2H_5NH_2$ and $CHCl_3$.

It is in virtue, however, of these facts which have been pointed out, *viz.*, the wide distribution of these enzymes in the animal and vegetable kingdoms and their sensitiveness to various physical and chemical agents, that they have become of great importance to the biological chemist and sanitarian, as enabling them by means of specific tests for these enzymes to form correct conclusions regarding the character and condition of certain foodstuffs; *i. e.*, these tests have enabled the chemist to say whether the food is *raw* or has been *heated*.

Among the first of these enzymes to be discovered and to have its properties studied is the group now known as the *oxidases*. They are among the most widely distributed of all the ferments. These, together with another group known as the *reductases*, are of particular interest to us in the consideration of the problem presented in this paper, owing to the presence of the former (oxidases) in milk, and the *probable bacterial origin* of the reductases.

For a number of years it has been a most interesting question as to whether these enzyme reactions could be made the basis of methods for differentiating old milk from new milk, and pasteurized milk from raw milk. Regardless of the controversy which has arisen, a number of investigators have proposed tests in which the reactive properties of these enzymes have been utilized with a view to formulating methods for ascertaining the "sanitary condition" of milk. These investigations seem to be entirely justified when we recall the following well-known facts: (1) Normal fresh milk has the property of decomposing hydrogen peroxide into free oxygen gas and water; (2) ordinary milk possesses the power of decoloring, within certain limits of time, various coloring substances by reduction or removal of oxygen. Although the exact nature of these reactions and the source of the substances in milk influencing them have not been clearly established, there is much evidence which indicates that they are of an enzymic nature.

It is scarcely necessary to point out that there is much uncertainty at the present time as to the accuracy and significance of these proposed tests. There is no question, however, as to the need of them.

Inasmuch as it has often become necessary to pasteurize milk to be sold to the public, because it has not been produced under the required sanitary conditions, the need of a test which will quickly and easily show whether a given sample of milk has been heated or not, is at once obvious. In the effort to meet this want a considerable number of methods have been formulated in the last few years. Unfortunately, most of those proposed are not characterized by exactness or simplicity. However, there seem to be a few methods which have received neither the use nor the study to which they are apparently entitled.

It was this view of the situation which led the authors of this paper to the examination of various methods which have been proposed for the differentiating of raw milk from pasteurized milk with regard to determining their relative accuracy.

The methods which have been proposed may be conveniently divided into two main groups:[1]

(*1*) *Methods based upon changes which the protein in milk undergoes when the latter is heated.*

(*2*) *Methods based upon reactions influenced by the presence of certain chemical ferments in milk.*

An examination of the literature dealing with this subject reveals the fact that only those methods which are included in the second group have proven at all satisfactory. And it will be noted that these are the methods which are based upon the action exerted by the presence of certain enzymes.

In this investigation we have been concerned with but three groups of these chemical ferments: (1) a *peroxidase*, which causes hydrogen peroxide to react

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[1] Kastle, *Bull.* **59**, Hygienic Laboratory.

[2] Traube in his later writings used the term *Oxydationsfermente* as preferable to the term Verwesungsfermente. This term is employed to signify those ferments which possess the power of taking up free oxygen and carrying it to other passive substances, thereby accomplishing the oxidation of the latter.

[3] For a more complete list see article by Harris and Creighton, *J. Biol. Chem.*, **22** (1915), 535.

[1] Barthel, "Milk and Dairy Products," p. 97.

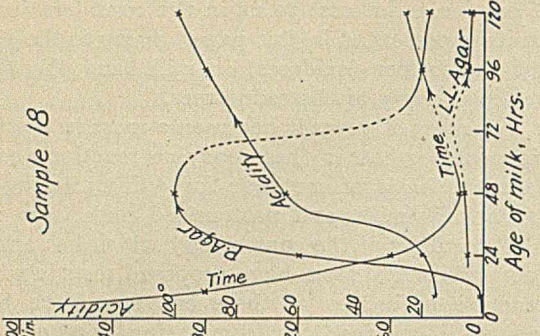

FIG. 5

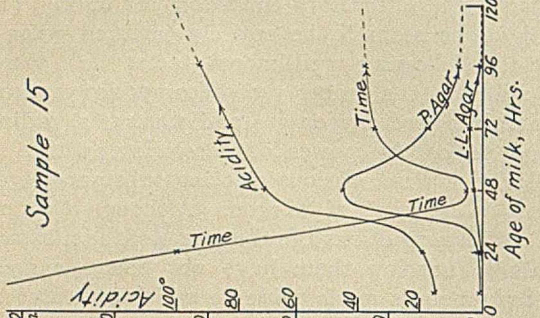

FIG. 4

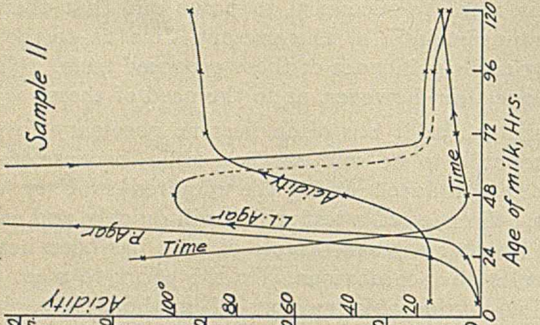

FIG. 3

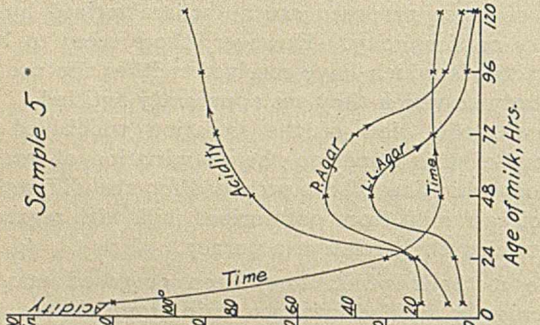

FIG. 2

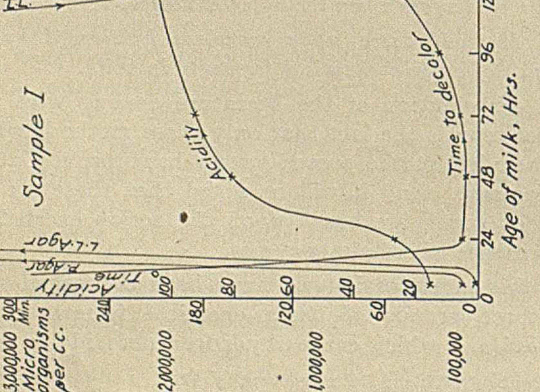

FIG. 1

with certain (oxidase) reagents, thereby producing change of colors; (2) a *catalase*, which decomposes hydrogen peroxide (with the liberation of oxygen) but is incapable of effecting the oxidation of oxidase reagents by means of the peroxide; (3) the *reductases*, which combine with the oxygen of the water, the liberated hydrogen effecting the reduction of a passive body like methylene blue with attendant decoloration.

Owing to the fact that the peroxidases and catalases are to be taken up in another paper, they will not be considered further at this time as this paper is concerned only with the nature, source, and action of the enzyme which influences the reactions upon which are based the reductase methods.

REDUCTASES IN RELATION TO PROBLEM

The reductases (*Reductionsfermente*) are usually defined as those ferments which combine with the oxygen of water, the hydrogen going to effect the reduction of a passive body like methylene blue.

The reductase test is based upon the fact, first noticed by Duclaux,[1] that ordinary normal cow's milk has the power of converting certain coloring matters, as indigo-carmine, into the corresponding leuco-compound by reduction. He also showed that this property of milk depends upon the microörganisms which it contains.

Neisser and Wechsberg[2] proposed the use of methylene blue as a reagent for testing the quality of milk. H. Smidt,[3] P. Th. Müller,[4] and Barthel[5] also worked on this method and came to the conclusion that there existed a distinct parallel between the number of organisms in the milk and the time required, under certain conditions, for a solution of methylene blue to be decolorized. According to Barthel[6] the reductase test gives approximately the relative number of bacteria in the milk. Van Slyke[7] seems to agree with this as he maintains that this reducing property appears to depend upon the presence of microörganisms in milk since the larger the number of bacteria, the shorter the time required to produce decoloration.

There seems to be some dispute, however, among other investigators as to the exact origin of the reductase. Konning,[8] Seligman,[9] and Grimmer[10] are of the opinion that the reductases are produced by bacteria. However, Seligman states that possibly some reductases may exist as enzymes in milk. Romer and Sames[11] are opposed to the enzyme nature of reductase, and state that it is produced by the destruction of the cells of the mammary glands during milking, as the first milkings have but slight reducing properties and the last milkings are highly reducing.

Sames[12] is not only opposed to the enzyme nature of

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[1] Le Lait, "Études chimiques et microbiologiques," Paris, **1887**.

[2] *Analyst*, **26** (1901), 148.

[3] *Münch. Med. Wochschr.*, **1900**, No. 37.

[4] *Hyg. Rundschau*, **14** (1904), 1–137.

[5] *Arch. Hyg.*, **56** (1906), 108.

[6] *Z. Nahr. Genussm.*, **15** (1908), 385; "Milk and Dairy Products," p. 128.

[7] "Modern Methods of Testing Milk and Milk Products," p. 158.

[8] *Milchwirtschaft Zentr.*, **4**, 156.

[9] *Z. Hyg.*, **58**, 1.

[10] *Milchwirtschaft Zentr.*, **6**, 243.

[11] *Z. Nahr. Genussm.*, **20**, 1.

[12] *Milchwirtschaft Zentr.*, **6**, 462.

TABLE I

Sample No.	Age Hrs.	Degree of Acidity	Time to Decolorize Methylene Blue	BACTERIAL COUNT(a) Plain Agar	BACTERIAL COUNT(a) L. L. Agar
1	4	16.5	No Decol.	90,000	30,000
	24	27	10 Min.	10,000,000	7,000,000
	48	82	7 Min.	450,000,000	300,000,000
	72	93	12 Min.	10,000,000	8,000,000
	96	100	25 Min.	4,000,000	2,000,000
	120	105	50 Min.	....	....
2	4	16	No Decol.	500,000	400,000
	24	26	30 Min.	8,000,000	5,000,000
	48	43	25 Min.	10,000,000	7,000,000
	72	65	15 Min.	1,000,000	600,000
	96	...	....	....	....
	120	85	50 Min.	1,000,000	1,000,000
3	8	19	No Decol.	150,000	....
	24	21	Several Hrs.	160,000	40,000
	48	25	Several Hrs.	6,000,000	4,000,000
	72	...	....	....	....
	96	95	35 Min.	3,000,000	2,000,000
	120	103	45 Min.	1,000,000	800,000
4	3	15	No Decol.	20,000	10,000
	24	21	28 Min.	80,000	50,000
	48	...	....	....	....
	72	78	35 Min.	2,000,000	1,000,000
	96	87	55 Min.	2,000,000	1,000,000
	120	95	75 Min.	100,000	60,000
5	4	18	4 Hrs.	200,000	100,000
	24	22	1 Hr.	400,000	150,000
	48	76	25 Min.	1,000,000	700,000
	72	87	30 Min.	800,000	300,000
	96	92	30 Min.	220,000	75,000
	120	97	35 Min.	180,000	50,000
6	8	19	5 Hrs.	20,000	15,000
	24	20	4 Hrs.	160,000	40,000
	48	72	10 Min.	4,000,000	750,000
	72	88	18 Min.	800,000	100,000
	96	99	60 Min.	600,000	....
	120	...	....	....	....
7	4	19	Slightly 6 Hrs.	20,000	10,000
	24	22	2 Hrs.	100,000,000	75,000,000
	48	74	6 Min.	1,000,000	50,000
	72	79	40 Min.	750,000	40,000
	96	...	....	....	....
	120	97	30 Min.	500,000	60,000
8	4	16	No Decol.	10,000	4,000
	24	17	35 Min.	600,000	150,000
	48	75	10 Min.	10,000,000	500,000
	72	...	....	....	....
	96	90	15 Min.	1,000,000	400,000
	120	96	12 Min.	1,000,000	500,000
9	4	15	150 Min.	10,000	....
	24	18	90 Min.	100,000	40,000
	48	...	....	....	....
	72	76	10 Min.	1,000,000	80,000
	96	88	30 Min.	200,000	60,000
	120	90	35 Min.	120,000	50,000
10	8	19	No Decol.	10,000	....
	24	...	....	....	....
	48	59	4 Min.	1,350,000	100,000
	72	95	10 Min.	1,300,000	80,000
	96	102	14 Min.	500,000	80,000
	120	107	18 Min.	300,000	10,000
11	4	16	No Decol.	15,000	4,000
	24	16.5	Several Hrs.	20,000	10,000
	48	43	8 Min.	5,000,000	2,000,000
	72	95	15 Min.	370,000	....
	96	97	20 Min.	350,000	300,000
	120	100	30 Min.	250,000	200,000
12	8	17	No Decol.	9,000	3,000
	24	18	65 Min.	400,000	150,000
	48	44	4 Min.	1,500,000	1,000,000
	72	90	15 Min.	500,000	350,000
	96	97	14 Min.	400,000	150,000
	120	...	....	....	....
13	4	17	No Decol.	15,000	6,000
	24	20	40 Min.	90,000	10,000
	48	64	10 Min.	8,000,000	3,000,000
	72	84	18 Min.	2,000,000	1,000,000
	96	...	....	....	....
	120	...	....	....	....
14	8	17	No Decol.	13,000	1,700
	24	18	25 Min.	1,500,000	30,000
	48	61	4 Min.	5,000,000	60,000
	72	90	30 Min.	1,500,000	....
	96	93	60 Min.	50,000	5,000
	120	96	60 Min.	30,000	....
15	8	15	Slightly, 3 Hrs.	8,000	....
	24	19	Partly, 3 Hrs.	20,000	3,000
	48	72	10 Min.	900,000	50,000
	72	83	70 Min.	350,000	70,000
	96	93	75 Min.	150,000	10,000
	120	...	....	....	....
16	4	19	Partly, 3 Hrs.	8,000	1,000
	24	22	25 Min.	20,000	3,000
	48	86	20 Min.	100,000	20,000
	72	96	30 Min.	20,000	16,000
	96	...	....	....	....
	120	102	35 Min.	10,000	3,000
17	4	19.5	Partly, 3 Hrs.	10,000	1,000
	24	23	20 Min.	100,000	3,500
	48	86	18 Min.	130,000	70,000
	72	96	15 Min.	100,000	55,000
	96	...	....	....	....
	120	100	45 Min.	10,000	2,000
18	8	16	Slightly, 150 Min.	5,000	....
	24	19	60 Min.	1,200,000	100,000
	48	64	15 Min.	2,000,000	120,000
	72	...	....	....	....
	96	89	40 Min.	400,000	100,000
	120	98	50 Min.	350,000	80,000
19	8	16.5	150 Min.	5,000	....
	24	17	120 Min.	75,000	20,000
	48	82	40 Min.	100,000	25,000
	72	...	....	....	....
	96	95	60 Min.	80,000	50,000
	120	103	60 Min.	30,000	10,000
20	4	17	Slightly, 3 Hrs.	30,000	8,000
	24	33	15 Min.	400,000	40,000
	48	...	....	....	....
	72	100	15 Min.	140,000	20,000
	96	107	30 Min.	100,000	10,000
	120	98	60 Min.	20,000	....

(a) "Standard Methods" as formulated by the American Public Health Association for the bacterial examination of milk were employed in making all bacterial counts.

reductase but insists that Seligman's assumption that the reduction is due to bacteria is too far-reaching. Salus[1] believes that reductase is a product of cell transformation. Oppenheimer[2] is of the opinion that the reductase is in no way related to the bacteria and that it is merely difficult to distinguish from bacterial reductases.

However, on the basis of the probable bacterial origin of reductase, there have been two tests proposed for its detection:

(1) *Schardinger's M. Reductase Test*,[3] which is carried out by adding 1 cc. of Schardinger's reagent M. (*viz.*, 5 cc. of a saturated alcoholic solution of methylene blue and 195 cc. of water) to 20 cc. of milk in a test tube and placing it in a water bath at 45 to 50° C. With this reagent a number of hours is required to produce decoloration.

(2) *Schardinger's F. M. Reductase Test*,[4] which is carried out by adding 1 cc. of Schardinger's F. M. reagent (*viz.*, 5 cc. of a saturated alcoholic solution of methylene blue, 5 cc. of 40 per cent formaldehyde, and 190 cc. of water) to 20 cc. of milk in a test tube, placing it in a water bath at 45 to 50° C., and covering the contents of the tube with a layer of liquid petroleum to prevent the access of air. The formaldehyde serves to produce an acceleration in the time of reduction. Lythgoe[1] states that raw milk will decolor this reagent in less than 20 min. and pasteurized milk will take a longer time.

The reaction depends upon the supposed presence of a specific enzyme in milk called aldehyde-reductase, which is more or less quickly destroyed at a temperature above 70° C.; when in milk heated above 80° C., its destruction is complete.[2] Barthel[3] states that the enzyme is destroyed more or less quickly at temperatures above 70° C.; and that milk heated to 80° C. does not discharge the color at all; or milk heated to 75° C. for a few minutes or pasteurized for 15 minutes at 70° C., discharges the color in 30 minutes.

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[1] *Arch. Hyg.*, **75**, 371.

[2] *Arb. Kgl. Inst. Experim. Therap. zu Frankfort a/M*, **1908**, 75.

[3] *Z. Nahr. Genussm.*, **2** (1906), 377.

[4] THIS JOURNAL, **5** (1913), 922–927.

[1] THIS JOURNAL, **5** (1913), 922–927.

[2] Van Slyke, "Modern Methods of Testing Milk and Milk Products," p. 163.

[3] "Milk and Dairy Products," p. 128.

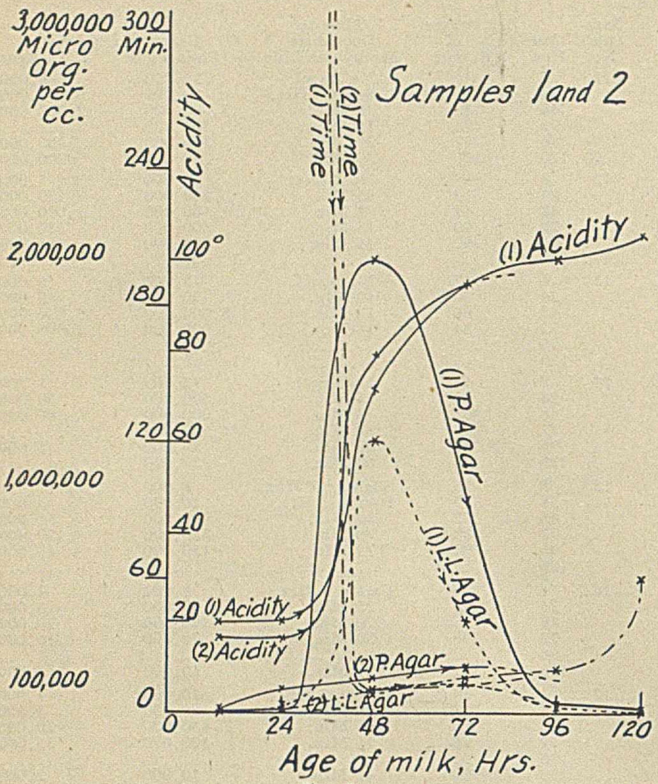

FIG. 6

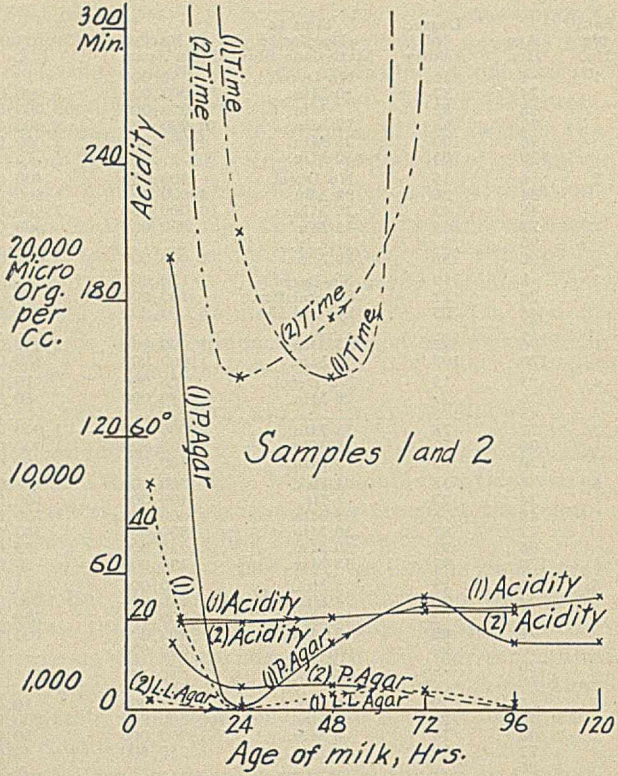

FIG. 7

By means of these reagents it is possible, according to Lythgoe,[1] to get a good idea of the temperature to which the milk has been heated, and also how long it has been heated, since heating the milk destroys the enzyme. Thus, he maintains, this method affords a very good means of distinguishing between raw and pasteurized milk.

As stated previously, there seems to be a difference of opinion as to the origin of the reductase; likewise investigators are far from any agreement regarding any relationship which may exist between the time of methylene blue reduction and the number of bacteria present. Angelici[2] states that there is absolutely no parallelism between the two. Fred,[3] however, holds to the view that most, but not all, milk bacteria reduce methylene blue; and that milk reducing methylene blue in from 15 minutes to an hour contains from 15 to 50 millions of bacteria per cc., and milk requiring 7 hours or more contains less than one million bacteria per cc.

Barthel[4] states that fresh milk containing 10,000 bacteria per cc. decolorized the methylene blue solution in 11 hrs.; and the same milk four days old containing 17 millions of bacteria per cc. decolored the solution in 14 min. He further[5] maintains that when the reduction takes place in less than one hour, the milk has more than 10 million bacteria per cc., and when the time required is from 1 to 3 hrs., the number of bacteria present is from 4 to 10 millions per cc. As a conclusion he asserts that when the reduction requires less than 1 hour, the milk is bacterially too impure for food; and that good commercial milk should require not less than 3 hours for decoloration.

As a result of the foregoing discussion, therefore, we may conclude that there exists a considerable difference of opinion: (1) as to whether the reductase is of bacterial origin or of animal metabolism; and (2) as to the relationship existing between the time of methylene blue reduction and the number of bacteria present.

EXPERIMENTAL

The following experimental work was carried on with a view to determining by means of the Schardinger F. M. test:

1—The relationship existing between the number of bacteria and the time required to decolorize the methylene blue solution.

2—The influence of time and temperature of pasteurization on milk in its relation to Schardinger's reagent, F. M.

RELATIONSHIP BETWEEN NUMBER OF BACTERIA AND TIME REQUIRED TO DECOLORIZE METHYLENE BLUE

Twenty samples of milk were tested as follows: (1) the acidity was determined by titration with $N/10$ NaOH, 0.1 cc. of the solution being equivalent to 1° of acidity; (2) the time required to decolor methylene blue solution was observed; (3) bacterial counts were made at the time of each test both on plain agar and on lactose litmus agar. Each sample was tested daily for a period of five days, during which time the milk was allowed to remain at the temperature of the laboratory. The results of this work appear in Table I.

The full significance of this data becomes more easily

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[1] THIS JOURNAL, **5** (1913), 922–927.

[2] *Clin. Vat.*, **34**, 388.

[3] *Centr. Bakt. Parasitenk., II Abt.*, **35**, 491.

[4] *Z. Nahr. Genussm.*, **15**, 385.

[5] *Ibid.*, **21**, 513.

apparent when it is presented graphically. In Figs. 1 to 5, graphs have been drawn of 5 of the representative samples of the above series, using separate curves to show the increase in degrees of acidity, the time of decoloration of methylene blue, the plain agar bacterial count, and the lactose litmus agar bacterial count. The dotted portion of the curves indicates the probable course covering the period during which no tests were made, as, for example, on Sundays.

The age of the milk in hours is plotted as abscissas. There are three sets of ordinates: first, the column on the left by which both the plain agar and the lactose litmus agar counts are plotted; second, the middle column expressed in minutes, by which the time of decoloration is plotted; and third, the column on the right expressed in degrees, by which the degree of acidity is plotted. This gives four curves for each sample.

From the data presented in the preceding table and by means of graphs the following conclusions have been formulated:

(1) An increase of acidity occurs with increase of age. In the periods examined this increase was greatest in the majority of cases in the period between 24 and 48 hrs.

(2) Normal fresh milk of good quality does not reduce Schardinger's F. M. reagent in less than 20 min.—the shortest time observed being much longer. When the decoloration was effected in 10 min. or less time, the milk was found to contain at least 1,000,000 microörganisms per cc.

(3) Up to a certain point an increase in the number of bacteria in *a given sample* is accompanied by a corresponding decrease in the time required by it to decolor the reagent. At this point the maximum bacterial count and the minimum time required for decoloration coincide.

This relationship seems to point to the conclusion that the reductase is of bacterial origin. The tables will show, however, if data for *different* samples are compared, that no absolute parallelism exists between the time required for decoloring the reagent and the *number* of bacteria present. This is in agreement with results obtained by Angelici.[1]

(4) As the acidity increases beyond this point of coincidence the number of bacteria decreases and the time required for decoloration increases.

(5) The final decrease in the number of bacteria and the increase in the time of decoloration are probably due to the production of acid by acid-forming bacteria, the acid thus produced probably tending to remove the effect produced by the aldehyde-reductase and to make the medium unfit for the further growth of certain bacteria.

The foregoing conclusions are in accord with the data obtained in this laboratory over two years ago by F. W. Fabian[2] working on a similar problem.

In this connection it is noted that it is a matter of record that Lythgoe[3] found that normal fresh milk reduced Schardinger's F. M. reagent in less than 20 min. The authors are unable at this time to account for this discrepancy in the time element, unless it can be attributed to a difference in the standard of milk which is to be regarded as "normal."

Table II is quoted from the report of Mr. Fabian's work to which reference has just been made.

TABLE II (*Results by Mr. Fabian*)

Sample No.	Minutes Required to Decolorize M.-Blue	Bacterial Count on Plain Agar
10	3	17,000,000
7	3	35,000,000
5	6	12,000,000
14	7.5	44,000,000
11	9	1,900,000
2	13	810,000
1	14	720,000
12	15	370,000
4	15	600,000
3	17	560,000
6	19	300,000
13	20	300,000
8	27	220,000
9	34	490,000
15	32	360,000
19	37	300,000
20	42	240,000
16	45	300,000
18	59	120,000
17	95	55,000
25	120	80,000
22	150	110,000
24	155	90,000
23	180	40,000
21	184	20,000

Twenty-five different samples of raw milk were tested with Schardinger's reagent, F. M. A bacterial count was also made of each sample.

EFFECT OF TIME AND TEMPERATURE OF PASTEURIZATION ON MILK IN ITS RELATION TO SCHARDINGER'S REAGENT

Four separate portions of each of three different samples of milk were heated gradually—a rise of 2° C. per min.—in a water bath to 60, 65, 70 and 75° C., and then maintained at these respective temperatures for 30 min. Portions were removed every 10 min. and tested with the reagent. Bacterial counts were made of each sample tested at the various intervals of time. Milk 10 hrs. old was used, as fresh milk 4 hrs. old produced no decoloration of the reagent. The results obtained are given in Table III.

TABLE III

Sample No.	Pasteurization Temp. ° C.	Pasteurization Time Min.	Time Required to Decolorize Min.	Bacterial Count on Agar Plain	Bacterial Count on Agar L. L.
1	60	0	30	40,000	12,000
		10	70	12,000	6,500
		20	95	6,000	3,500
		30	150	2,000	1,200
	65	0	60	40,000	11,000
		10	100	10,000	4,000
		20	120	400	None
		30	160	200	None
	70	0	65	35,000	11,000
		10	No decolor.	200	None
		20	No decolor.	None	None
		30	No decolor.	None	None
	75	0	65	36,000	10,000
		10	No decolor.	300	None
		20	No decolor.	None	None
		30	No decolor.	None	None
2	60	0	28	70,000	25,000
		10	65	19,000	9,000
		20	87	8,000	5,000
		30	135	4,000	3,000
	65	0	55	65,000	31,000
		10	90	15,000	8,000
		20	120	1,000	200
		30	155	300	None
	70	0	56	44,000	23,000
		10	No decolor.	700	35
		20	No decolor.	None	None
		30	No decolor.	None	None
	75	0	55	30,000	18,000
		10	No decolor.	200	None
		20	No decolor.	None	None
		30	No decolor.	None	None
3	75	0	48	35,000	21,000
		10	No decolor.	150	None

These data indicate that both the temperature and the duration of the pasteurization process affect milk

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[1] *Clin. Vat.*, **34**, 388.

[2] Working in this laboratory in 1912 in collaboration with the senior author.

[3] THIS JOURNAL, **5** (1913), 922–927.

with reference to the time required by the latter to decolorize methylene blue. In general, as either factor is increased the time required for decoloration is increased. Furthermore, the authors found as the result of a larger number of tests than are recorded here that milk heated to a temperature of 70° C. for 10 min. failed to decolor the reagent in several hours. In this latter respect the behavior of samples of milk pasteurized under the stated conditions was identical with that of freshly drawn milk of good grade.

Mr. Fabian found that milk pasteurized at 80° C. for 1 min. behaved towards the reagent in the same manner as milk pasteurized at 75° C. for 3 min. or at 70° C. for 10 min., and that in no case was the reagent decolored in several hours. Table IV is quoted from Mr. Fabian's report. Samples of raw milk, eight hours old, were used in making the tests indicated.

Table IV (*Results by Mr. Fabian*)

Temp. (° C.) of Pasteurization	Duration of Pasteurization	Minutes Required to Decolorize Duplicates	
60	20	20	19
60	15	16	18
60	10	13	17
60	5	7	10
60	0	3	7
70	20	+	+
	10	+	+
	5	40	42
	0	3	4
75	10	+	+
	5	+	+
	0	4	4
80	5	+	+
	3	+	+
	2	+	+
	1	+	+
	0	3	7

+ Signifies that no decolorization occurred in several hours.

FURTHER EVIDENCE AS TO THE ORIGIN OF REDUCTASE

With a view to obtaining more evidence in regard to the origin of reductase in milk, 5 samples of the latter were pasteurized at 70° C. for 10 min. and then set aside. The samples, in the usual paper-disk-covered bottles, were allowed to "age" at the usual laboratory temperatures. They were tested at intervals of 24 hrs. with the Schardinger reagent and bacterial counts made.

The data obtained by testing the first two samples are presented graphically in Fig. 6.

Table V

No.	Age Hrs.	Acidity Degrees	Time to Decolorize	Bacterial Count on Agar Plain	Bacterial Count on Agar L. L.
1	8	20	No decol.	500	300
	24	20.5	No decol.	5,000	.....
	48	72	8 min.	2,000,000	1,200,000
	72	95	15 min.	1,000,000	400,000
	96	100	18 min.	40,000	20,000
	120	106	60 min.	30,000	10,000
2	4	17	No decol.	2,500	500
	24	17	No decol.	100,000	5,000
	48	78	10 min.	150,000	100,000
	72	95	12 min.	200,000	125,000
3	4	16	No decol.	1,000	300
	24	18	No decol.	10,000	4,000
	48	76	25 min.	100,000	30,000
	72	93	30 min.	60,000	25,000
4	4	19	No decol.	800	450
	24	20	No decol.	11,400	4,500
	48	74	14 min.	700,000	250,000
	72	98	16 min.	500,000	250,000
5	4	20	No decol.	400	300
	24	23	No decol.	8,000	5,000
	48	76	8 min.	1,000,000	800,000
	72	96	12 min.	800,000	300,000

The experiments reported in Table V yielded results which indicate that milk pasteurized at 70° C. for 10 min. will not decolor methylene blue solution at the expiration of 24 hrs. but will after being allowed to stand for 48 hrs. This points to the conclusion that reductase is not only destroyed by the pasteurization process but that it is of bacterial origin, the presumption being that no decoloration of the reagent takes place until the bacteria have again multiplied sufficiently.

Mr. Fabian in his work for a similar purpose collected a number of samples of raw milk and after making the bacterial count of each subjected them to a similar set of tests, with the results given in Table VI.

Table VI (*Results by Mr. Fabian*)

No.	Age Hrs.	Time Required to Decolorize	Bacterial Count on Agar Plain	Bacterial Count on Agar L. L.
1.........	3 (raw)	Several hrs.	300,000	110,000
	24	Several hrs.	.....	....
	48	92 min.	.....	....
	72	17 min.	.....	....
	96	2 min.	.....	....
	120	4 min.	.....	....
2.........	3 (raw)	Several hrs.	220,000	110,000
	24	Several hrs.	.....	....
	48	70 min.	.....	....
	72	6 min.	.....	....
	96	3 min.	.....	....
	120	6 min.	.....	....
3	3 (raw)	Several hrs.	310,000	100,000
	24	Several hrs.	.....	....
	48	35 min.	7,000,000	304,000,000
	72	6 min.	.....	....
	92	7 min.	.....	....
	120	8 min.	.....	....
4.........	3 (raw)	Several hrs.	150,000	200,000
	24	Several hrs.	.....	....
	48	10 min.	.....	....
	72	6 min.	.....	....
	96	9 min.	.....	....

The conclusions to be made here are obviously the same as those formulated in the preceding paragraph.

EFFECT OF THE PRESENCE OF FORMALDEHYDE ON MILK WITH REFERENCE TO THE TIME REQUIRED TO DECOLORIZE METHYLENE BLUE

The following work was undertaken in order to ascertain if a so-called "preservative" like formaldehyde influences the action of milk in its relation to the Schardinger reagent. Five different samples of milk, each 8 hours old, were examined as follows: Each sample was tested as regards its acidity, time required to decolor the reagent, and bacterial count; then each sample was treated with formaldehyde (0.5 cc. per pint of milk) and the enumerated tests repeated at intervals of 24 hours. The results are given in Table VII.

Table VII

No.	Age Hrs.	Acidity Degrees	Time to Decolorize	Bacterial Count on Agar Plain	Bacterial Count on Agar L. L.
1	8	20	No decolorization	20,000	10,000
	24	20.5	Slight, 3 hrs.	200	100
	48	21	Slight, 3 hrs.	3,000	700
	72	22	No decolorization	5,000	800
	96	23	No decolorization	3,000	28
	120	23	No decolorization	3,000	None
2	8	19	No decolorization	5,000	1,500
	24	19	Slight, 2 hrs.	1,000	35
	72	20	Slight, 5 hrs.	1,200	None
	96	21	No decolorization	....	....
	120	21	No decolorization	100	None
3	8	17	No decolorization	15,000	7,000
	24	19	Slight, 5 hrs.	8,000	1,100
	72	20	No decolorization	3,000	600
	96	22	No decolorization	1,300	45
	120	22	No decolorization	1,400	None
4	8	20	Slight, 3 hrs.	40,000	17,000
	24	23	Slight, 7 hrs.	3,000	450
	48	23.5	No decolorization	3,000	250
	72	23.5	No decolorization	1,800	40
	96	24	No decolorization	2,000	None
5	8	16.5	Slight, 4 hrs.	27,000	6,500
	24	18	Slight, 4 hrs.	4,000	600
	48	19	No decolorization	5,500	375
	72	21	No decolorization	6,000	80
	96	21	No decolorization	4,800	None

CONCLUSIONS

The relationships indicated, if not proved, by this rather limited series of experiments are extremely interesting. For example:

(1) The germicidal properties of formaldehyde in relation to microörganisms found in milk are shown in a general way.

(2) Unless it be proven that reductase is formed *within* the milk by purely chemical changes, this series, considered in relation to the foregoing series of tests, points to the conclusion that reductase is of bacterial origin, as the time required for decoloring the reagent was not reduced by allowing the milk to "age," owing presumably to the fact that bacterial growth in the samples of milk was inhibited by the formaldehyde.

(3) The partial decoloration which occurred at first was probably effected by the reductase present in the milk before the formaldehyde was added. The final loss of power of these same samples to effect the same reaction suggests that the formaldehyde may interact with the reductase or counteract its influence in some way. The fact that both of these substances are strong reducing agents does not tend to render the problem more easy of solution.

Since the completion of this work the report of the investigation of Harris and Creighton[1] on the influence of certain poisons on reductase has appeared. Although the list of poisons reported by them as either destroying the reductase or retarding its action does not include formaldehyde, the latter may act in a similar manner. This, however, will be a matter for future investigation.

GENERAL SUMMARY

I—A brief outline has been made of the classification, distribution and reactions of certain enzymes; the possibility of making their sensitiveness to various physical and chemical agents the basis of methods for determining the sanitary condition of certain foodstuffs has been considered.

II—A survey has been made of the work done concerning the source, nature and action of reductase in its relation to certain methods which have been proposed for the differentiation of pasteurized milk from raw milk.

III—The experimental investigation undertaken by the authors of this paper has been described. As the result of this work certain conclusions have been formulated. They are as follows:

(1) Methylene blue as it occurs in Schardinger's reagent, F. M., is not decolored by:

(*a*) Normal fresh milk in less than 20 min. When decoloration was effected in 10 minutes or less time the milk was found to contain 1,000,000 or more, microorganisms per cc.

(*b*) Milk pasteurized at 70° C. for 10 min. unless approximately 48 hrs. have elapsed since the milk was pasteurized; or until the bacteria have had time to multiply sufficiently.

(*c*) Old milk in which the "preservative," formaldehyde, has inhibited the growth of bacteria.

(2) Schardinger's reagent, F. M., is as a rule decolored by normal milk allowed to "age" under ordinary conditions of temperature for 24 to 48 hrs.

(3) Pasteurization increases the time required for the decoloration of the reagent.

(4) In general, no proportionality exists between the time required for the decoloration of the reagent and the number of bacteria in milk. In a given sample, however, a general relation seems to exist between the two up to a given point of acidity.

(5) Inasmuch as there is no absolute parallelism between *number* of bacteria present in milk and the *time* required to decolor the reagent but that the relationship seems to exist in a given sample of milk, it would indicate that reductase is of bacterial origin but that not all bacteria found in milk produce this enzyme. (This latter conclusion is in accord with the views of Fred.[2])

(6) It seems probable that formaldehyde either gradually retards the action of the reductase or destroys it. This is a matter, however, for more careful investigation in the future.

It will be noted that although the conclusions formulated in this paper are not in accord with the entire body of conclusions of any previous worker in this field, yet many of them are in close agreement with certain conclusions of a number of investigators.

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A STUDY OF THE VOLUMETRIC OR PEMBERTON METHOD FOR DETERMINING PHOSPHORIC ACID, WITH SOME EXPERIMENTS SHOWING THE INFLUENCE OF TEMPERATURE AND THE SULFURIC ACID RADICAL ON RESULTS[3]

By Philip McG. Shuey

Received October 20, 1916

There has been a great deal written and said of the volumetric method for determining phosphoric acid, but still many chemists have trouble in its use and manipulation. It has been found by most workers who employ this method that a number of years of careful and patient experience is necessary to master it, and owing to the length of time necessary to acquire this, many chemists have discarded it altogether. The writer has had more than 10 years of practical and constant experience in determining phosphoric acid by this method, both with a large fertilizer concern, and in the phosphate fields of Florida, and possibly some points already mentioned can be emphasized in this paper.

On account of the extreme delicacy of the method, and in order to show how it may be rendered accurate and reliable, it might be of interest to include some experiments showing some of the principal causes that bring about disturbances in results. The problem is most interesting, and while no pretense is made that this article will cover the entire field, it is hoped that it will at least serve the purpose of aiding

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[1] Harris and Creighton, *J. Biol. Chem.*, **22** (1915), 535.

[2] *Centr. Bakt. Parasitenke, II Abt.*, **35**, 491.

[3] Presented at 53rd Meeting of American Chemical Society, New York City, September 25 to 30, 1916.

TABLE I—RESULTS BY VARIOUS METHODS OF TREATMENT

1—By dissolving in nitric acid and a few drops of hydrochloric acid.

2—By adding an equal weight of 50° Bé. sulfuric acid, as in the manufacture of acid phosphate, and then making solution like (1).

3—By adding twice the quantity of sulfuric acid, as is usually employed in the manufacture of acid phosphate.

4—By solution in a mixture of 10 cc. sulfuric and 15 cc. nitric acid.

5—By increasing the sulfuric to 25 cc.

6—By making solution according to (2), and then adding barium chloride to remove sulfuric acid.

7 and 8—Solutions corresponding to (1) and (2), respectively, only using a standard that has been used in the writer's laboratory for the past 5 years, and which contains much less iron and alumina than the A. C. S. Standard, but which, by coincidence, contains practically the same amount of phosphoric acid.

	CUBIC CENTIMETERS STANDARD SOLUTION SODIUM HYDROXIDE REQUIRED						CORRECTIVE FACTORS					
No.	5° C.	20° C.	30° C.	40° C.	50° C.	65° C.	5° C.	20° C.	30° C.	40° C.	50° C.	65° C.
1	30.08	30.15	30.25 30.10 Av. 30.17	30.22 30.30 Av. 30.31	30.65 30.65 Av. 30.65	31.15 31.30 Av. 31.22	1.0023	1.00	0.99905	0.99472	0.9837	0.96573
2	30.20	30.0	30.20 30.40 Av. 30.30	30.70 30.75 Av. 30.72	31.10 30.95 Av. 31.02	32.15 32.10 32.20 32.20 Av. 32.16	0.998	1.005	0.99505	0.98144	0.97195	0.9375
2B	.....	.....	......	......	31.30 31.45 Av. 31.37						0.9611	
3	.....	.....	......	......	31.25 31.25 Av. 31.25	32.75 32.80 Av. 32.77	.....	.....	.....	.....	0.9648	0.92005
4	30.20	30.20	30.50 30.70 Av. 30.60	31.15 31.08 Av. 31.11	31.40 31.50 Av. 31.45	31.40 31.50 Av. 31.45	0.99802	0.99802	0.98529	0.96914	0.95866	0.95866
5	30.10	30.10	30.40 30.55 Av. 30.47	30.95 31.08 Av. 31.01	31.25 31.28 Av. 31.26	31.45 31.15 Av. 31.30	1.00166	1.00166	0.9895	0.9722	0.9648	0.96326
6	.....	.....	30.35	30.45	30.50	31.00	.....	.....	0.9934	0.99011	0.98852	0.97258
7	.....	.....	......	......	30.35 30.20 Av. 30.27	30.80 30.80 30.95 Av. 30.85	.....	.....	.....	.....	0.99108	0.97244
8	.....	.....	......	......	30.95 31.15 Av. 31.05	32.10 32.20 Av. 32.15	.....	.....	.....	.....	0.96618	0.93312

some chemists, and more particularly those starting out in making analyses of fertilizers, and of the materials which enter into their composition, and show that when properly handled the method is equally accurate, or more so, than the Standard Gravimetric. Dr. F. B. Carpenter, in his very able article, mentions both the advantages and disadvantages of the method, together with details which cause disturbances of results.[1]

As a means toward more accurate determinations, a number of modifications of the original method have been proposed. Briefly stated, their principal features are as follows:

1—Richardson's modification for analyzing acid phosphate, which depends upon the removal of sulfuric acid with barium chloride, after making solution in a mixture of nitric and hydrochloric acids.[2]

2—Separation of the phosphoric acid from sulfuric acid by precipitation with ammonium hydroxide, then, after filtering and washing, the phosphates are dissolved and precipitated in the usual way.

3—Fairchild's modification making the end-point sharper by the addition of barium chloride, after dissolving the precipitate of ammonium phosphomolybdate in an excess of standard alkali.[3]

It is conceded by those experienced in the method that the details which have the greatest influence on results are temperature and the amount of sulfuric acid radical present; and to show the effects of these important factors on the results, several series of experiments have been made which may be briefly described as follows: The sample of phosphate rock which was adopted by the Fertilizer Division of the Society as a standard for phosphoric acid was taken as a basis for the experiments.[4] The value of the standard adopted is 30.15 per cent, which was the average of a large number of determinations by the gravimetric method. After weighing out 1-g. portions and putting them into 200-cc. flasks, which had previously been carefully calibrated, solutions were made according to the descriptions given in Table I.

After making up solutions to mark, and filtering through dry filters, aliquot portions representing 0.1 g. were taken for analysis. After diluting with water the medium for precipitation was regulated in the usual way, by first adding ammonia until alkaline, and then clearing up by the addition of nitric acid. Before making precipitations from Solutions 4 and 5 10 g. of ammonium nitrate were added, as otherwise the precipitation would probably be incomplete in the presence of such a large quantity of sulfuric acid. As an experiment, 10 g. of ammonium nitrate were also added to (*2B*). In all other cases, however, no ammonium nitrate was added, other than that formed from the reaction between ammonia and nitric acid in getting the proper medium.

With the precipitant at 30° C., precipitation was made at various temperatures as follows:

At 5° C. by adding 50 cc. Molybdic solution, stirring 30 min.
At 20° C. by adding 50 cc. Molybdic solution, stirring 30 min.
At 30° C. by adding 45 cc. Molybdic solution, stirring 30 min.
At 40° C. by adding 35 cc. Molybdic solution, stirring 30 min.
At 50° C. by adding 35 cc. Molybdic solution, stirring 15 min.
At 65° C. by adding 35 cc. Molybdic solution, stirring 15 min.

Filtering and washing was done by the use of 11 cm. filter papers: this the writer regards as being more accurate than filtering under pressure, and when running a batch of 6 or more determinations at a time it is done about as rapidly. The precipitates were all washed free of acid as determined by the addition of a drop of $N/4$ alkali to the filtrate. It is noteworthy that in making these experiments only 2 or 3 of the duplicate determinations were run at the same time, and therefore the results are more truly checks than had all been duplicated together. Results found by precipitating at the low temperatures, 5 and 20° C., were not duplicated through lack of time, but as would be expected, the figures agree closely when making precipitation from the various solutions at these temperatures.

As the strength of the standard solutions was practically 0.3238 N, and as 0.1 g. of rock was taken for analysis, the number of cc. of solution required should

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[1] THIS JOURNAL, 2 (1910), 157.

[2] Sutton's "Volumetric Analysis, "Schimpf's "Volumetric Analysis," and *J. A. C. S.*, 29, 1314.

[3] THIS JOURNAL, 4 (1912), 520.

[4] "Details of Analysis for Standardization," THIS JOURNAL, 3 (1911),

very nearly correspond to the actual percentages, provided there were no disturbing elements to offset the results. In Table I is shown the number of cc. required when precipitation was made at the various temperatures and from the various solutions and the corrective factor for each cc.

It will be noticed what a great deviation there is in the number of cc. of the standard solution required to dissolve the various precipitates formed under the different conditions of temperature, and the varying amounts of sulfuric acid, and that according to the Official Volumetric Method[1] the number of cc. required corresponds to the percentage for anything from room temperature up to 65°, without making any allowance whatever for correction.

While in the Official Method it is not recommended that sulfuric acid be used in making solutions of the material, no distinction, however, is made in the mode of precipitation, whether or not the sulfuric acid radical is present. It is noteworthy that at a temperature of 65° C., much higher results are found on acid phosphate dissolved in nitric acid than when phosphate rock was dissolved in a mixture of sulfuric acid and nitric acid.

By reference to the table under Treatment 2, it will be noticed that the number of cc. of standard alkali required to dissolve the yellow precipitate, when precipitation was made at the various temperatures, varies all the way from 30 to 32.16 cc., a maximum variation of 2.16 cc., which would correspond to 2.16 per cent when not making correction.

If we consider that the addition of 1 g. of sulfuric acid to 1 g. of rock gives 2 g. of acid phosphate, and that the aliquot taken represents 0.2 g., the maximum variation caused by changes in temperature is 1.08 per cent, without correction, and when precipitating at 65° in determining the phosphoric acid in acid phosphate, results will often be 1 per cent higher than they should be.

It was found in making the experiments that there was much difficulty in making results agree when precipitating at 50 and 65°, while at 30 and 40° there was not the least trouble in this respect, the results being extremely regular.

The deviation in analysis of phosphate rock caused by changes in temperature, as shown under (1), is about half of what it is after the addition of sulfuric acid (after the manner of making acid phosphate), the maximum variation being 1.14 cc.

Experiment 3 shows the variation at 50 and 65° after adding double the amount of sulfuric acid, as is usually employed in making acid phosphate. This addition gave a result 2.62 per cent too high, and 0.61 per cent higher than results shown in (2), necessitating a corrective factor of 0.92005 per cc. when precipitation was made at 65°.

Experiment 4, in which solution was made by dissolving in a mixture of sulfuric and nitric acids, shows a variation at different temperatures of 1.25 cc., and with precipitation at 30, 40 and 50° C., the volume required was from 0.3 to 0.6 cc. greater than in the acid phosphate under (2), but at 65° this quantity was 0.71 cc. less.

It was found that by increasing the amount of sulfuric acid used in making solution to 25 cc., little, if any, difference was made in results.

Experiment 6 shows the analysis after removing the sulfuric acid radical with barium chloride. The results were not duplicated, but they agreed closely with those under (1), in which no sulfuric acid is added.

Experiments 7 and 8 were made to determine whether or not iron and aluminum had a tendency to affect results, the sample being very low in these metals, while the A. C. S. standard is very high. The results were concordant.

The results found at the various temperatures and from the various states of solution show how utterly impossible it is to do correct work when precipitation is made at from 40 to 50 or from 60 to 65°, as mentioned in the Official Method, unless correction is made by the use of a standard, which is run along with the batch under identically the same conditions, and then corrections made accordingly. If work is being done on acid phosphate, it is suggested that a control test be carried on at the same time by adding to a weighed quantity of standard phosphate rock the amount of sulfuric acid used in making the acid phosphate. It was also found by experiment that the sulfuric acid may be added after making solutions in nitric acid with the same results. This suggestion is intended particularly for those who precipitate phosphoric acid at temperatures higher than 30° C. It is advisable, too, that a stirring machine be employed.

Should a sample of fertilizer under examination contain a large amount of organic matter like fish scrap, ground tankage or cottonseed meal, it is suggested that the method of solution be the addition of a mixture of 10 cc. sulfuric acid and 15 cc. nitric acid, boil on a hot plate until black, and then oxidizing the organic matter by the addition of potassium nitrate. Whenever employing this method allow the flask to cool down with the hot plate, otherwise it will crack; then boil with about 100 cc. of water. A portion of a standard sample of phosphate rock is dissolved and treated in the same manner, and the value per cc. found and correction made. It is advisable when precipitating from a sulfuric acid solution to add at least 5 g. of ammonium nitrate.

It has been found also that the age of the molybdic solution may seriously affect results. If a solution is very old and shows a tendency of separating out molybdic acid, it should be discarded and not even mixed with a fresh solution. By keeping the solution in a dark bottle and in a cool place it will be preserved longer. A precipitating vessel that is most convenient is a 250 cc. Soxhlet fat extraction flask fitted with a No. 9 rubber stopper; after adding an excess of standard alkali, the stopper is inserted, and the flask shaken until the yellow precipitate is dissolved. The end-point is sensitive to a drop, and therefore Fairchild's modification is unnecessary.

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[1] Bureau of Chemistry, *Bull.* **107** (1912).

In conclusion it may be stated that with a knowledge of the method and with strict attention to detail, very accurate and reliable results may be obtained, and the fact that it is extremely delicate is a point in its favor. Accuracy, however, will come only with practice.

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THERMOCLINE STUDIES AT KENSICO RESERVOIR[1]

By FRANK E. HALE AND JOHN E. DOWD

Received September 30, 1916

The new and enlarged Kensico reservoir is the storage reservoir for the new Catskill water supply nearest to New York City. Owing to the progress made on the dam, the reservoir was filled in the winter of 1915–16. Close watch was kept of the quality of the water in order to utilize it at the earliest possible moment. During construction the water of the Bronx watershed had been held back by the Bronx and Rye Dykes and the Bronx supply fed from Rye Dyke. As soon as the quality of the water permitted, change of draught was made to the new dam and filling continued over the Dykes in order to conserve in the Catskill system as much of the winter and spring flow as possible.

The problem was interesting in that it is not the usual procedure to use water from a reservoir without long standing and possibly blowing of bottom water after stagnation.

TREATMENT OF RESERVOIR BOTTOM

Soil stripped from certain designated portions was used for filling areas of shallow flowage. Swampy areas were covered with sand and gravel to a depth of 12 in. or more. The bottom and a margin of about 30 ft. outside the flow-line were cleared of all buildings, fences, trees, bushes, logs, stumps, high grass, tussocks or clumps of roots of bushes or grass, weeds and rubbish. Stone walls within the 30-ft. margin and to a depth of 20 ft. below the flow-line were removed. Designated areas within the 30-ft. margin and the reservoir bottom to a depth of 35 ft. below the flow-line were grubbed of stumps and roots. Material was burned, excrement removed, and chloride of lime used.

TABLE I—QUALITY OF WATER AT VARIOUS DEPTHS, KENSICO RESERVOIR

		PHYSICAL EXAMINATION				CHEMICAL ANALYSIS (Parts per Million)												EXAMINATION Bact'l				Mic'l
						NITROGEN AS										OXYGEN			*Bacillus coli*			
DATE	PLACE OF COLLECTION	Temp. ° F.	Turbidity P. P. M. SiO_2	Color P. P. M. Pt.	Odor	Albuminoid Ammonia	Free Ammonia	Nitrites	Nitrates	Total Solids	Chlorine	Hardness	Alkalinity	Iron	Free CO_2	Per cent Saturation	P. P. M. Dissolved	Bacteria per cc. 24 Hrs. at 37° C.	in 0.1 cc.	in 1.0 cc.	in 10 cc.	Total Microscopic Organisms per Cc.
Dec. 22, 1915	Surface	34	8	20	1*v*	0.116	0.038	0.002	0.15	51	2.2	25	14	0.70	0.9	91.9	13.08	15	0	0	0	15
	50 ft. Depth	34.7	11	21	2*v* + *m*	0.106	0.024	0.002	0.15	50	1.5	25	14	0.60	0.9	90.0	12.67	37	0	0	+	15
	82 ft. Bottom																					
Jan. 7, 1916	Surface	34	5	16	2*v*	0.088	0.016	0.002	0.15	48	1.0	25	13	0.40	0.4	93	13.25	11	0	0	0	20
	25 ft. Depth	34.5	5	16	2*v*	0.088	0.020	0.002	0.10	51	1.2	20	13	0.50	0.4	..	...	11	0	0	0	100
	50 ft. Depth	35	4	16	2*v*	0.090	0.030	0.002	0.20	59	1.4	20	13	0.50	0.4	92	13.25	19	0	0	0	0
	117 ft. Bottom																					

The time of filling the reservoir was well chosen, late fall, since circulation continues all winter and anything approaching the stagnation of summer is avoided. Water first flowed in from the Ashokan tunnel on November 22, 1915, and continued steadily until January 15, 1916, when the water was 123 ft. deep. Filling was resumed February 21, 1916, and continued to full reservoir level which was reached May 23, 1916.

The water entering was of low turbidity and free from *B. coli* in 10 cc., having seen long storage at Ashokan reservoir. The water as it entered the reservoir stirred up the mud of the bottom with the result that the whole volume of water in Kensico reservoir was muddy and showed *B. coli* in many of the tests in 0.1 cc. The turbidity contained fine silt which settled very slowly. The turbidity was still 30 p. p. m. at the end of a month and naturally cleared more slowly in the deeper water. *B. coli* results improved with subsidence of turbidity and time of standing, tests in only 10 cc. being obtained at the end of 3 weeks and at the end of 6 weeks being negative in 10 cc.

Special inspections were started by the Laboratory Division of the Department of Water Supply, Gas and Electricity, and special samples were taken on December 22, 1915. Eight samples taken at different points along the side of the reservoir had an average of only 36 bacteria per cc. (agar 37° C.) and no *B. coli* in 10 cc. within 24 hrs., lactose bile test. In 3 days' time the tests in 10 cc. were positive in $^3/_4$ of the samples. One only gave a test in 1 cc. These results proved the presence of attenuated *B. coli* only, its source being the disturbed mud of the reservoir.

A path was broken through the ice to a point several hundred feet back of the intake at the dam and samples taken from a row boat at the surface and at 50 ft. depth, the total depth of water being 82 ft. These samples were taken, as were all similar samples later, by the method employed for collecting dissolved oxygen samples, *i. e.*, allowing a larger bottle to fill through a small bottle so that the analysis of the water in the small bottle represents the actual conditions at the depth sampled. These samples were given complete analysis, physical, chemical, bacteriological, and microscopical. Dissolved oxygen and free carbonic acid were also determined at the reservoir. The results are shown in Table I.

The temperature, oxygen-free carbonic acid and other determinations proved the water to be of uniform character throughout. Microscopic organisms were practically absent, oxygen was abundant, 90

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[1] Presented at the 53rd Meeting, American Chemical Society, New York City, September 25 to 30, 1916.

per cent of saturation at 50 ft. depth, free carbonic acid very low, and the *B. coli* present only in attenuated form in the 50-ft. sample. The turbidity, which accounted also for the slight excess of iron, was still just sufficient to have caused complaint if turned into service.

On January 7, 1916, a second inspection was made in the same way (see Table I). The shore samples were of similar character, averaging 38 bacteria per cc., and only attenuated *B. coli* appearing in 10 cc. in 4 out of 7 samples.

Samples were again taken from a boat at surface, 25 ft. and 50 ft. depths, the total depth being 117 ft. Owing to the difficulty of winter sampling from a row boat, samples were not taken at a greater depth than 50 ft.: in fact some samples froze and burst the bottles while standing in the boat. The results were similar to the previous analyses.

The water had improved in showing less turbidity, about 5 p. p. m., no *B. coli* in any sample, still lower carbonic acid, and oxygen 92 per cent of saturation at 50 ft. The temperature, oxygen, free carbonic acid, and microscopic organisms for both inspections are plotted in Chart No. 1 and show the absence of striation or any thermocline, all lines being vertical.

CHART No 1 WINTER CIRCULATION

Quality of Kensico Reservoir Water at Various Depths

As the water rose difficulty was experienced with the pipe line bringing water from Rye Dyke and it became necessary to supplement at the new dam. Service from Rye Dyke was soon discontinued and all draught taken at the new dam, the point of draught being 50 ft. off the bottom, the lowest available. Filling of the reservoirs, which was stopped January 15, was continued February 21, and the Dykes flooded until the reservoir was practically full with a depth of 155 ft. on May 23, 1916.

Previous experience with Croton Lake having indicated that there would be no stagnation until summer, special sampling was discontinued until spring. Regular samples were taken 3 times weekly of surface and effluent at the dam and these remained of excellent quality.

Common reference is made to winter stagnation in reservoirs. It is the opinion of the writers that under usual conditions there is no winter stagnation. In our experience with Croton Lake and with Kensico Reservoir the water circulates and overturns all winter long even to a temperature below that of greatest density. The following table of temperatures taken by thermophone by the Board of Water Supply substantiates this point:

Table II—Temperature of Water at Various Depths, Kensico Reservoir

Depths	February 8, 1916		Depths	April 5, 1916	
Surface........	32.7° F.	0.4° C.	Surface	35.8	2.1
7 ft..........	33.9	1.1	14 ft.	36.0	2.2
22 ft..........	34.0	1.1	34 ft.	36.1	2.3
62 ft..........	34.2	1.2	89 ft.	36.3	2.4
102 ft..........	34.8	1.6	129 ft.	36.4	2.4
122 ft. (bottom)	..	...	149 ft.	..	...

It will be noted that the colder temperatures are at the surface, that on February 8, there was only a difference of 1.2° C. between top and bottom temperatures taken, and on April 5, only 0.4° C. difference, and that all the temperatures on April 5 are higher than those on February 8, proving circulation from top to bottom. The probable explanation of this circulation is that water cooled below 4° C. becomes lighter and when it again increases in temperature grows heavier up to 4° C. Any disturbance as by wind then causes an overturning which temperatures show is profound. Such appears to be the case all winter. Only in the summer does true stagnation take place. The fact that Kensico was filling most of the winter really has no bearing on the results in that the same phenomenon has been noticed at Croton Lake and also there was no water running in from January 15 to February 21, a period of 5 weeks. Again the water entered at the northern end and sampling was at the southern end.

The temperatures obtained on the different dates are shown in Table III.

COMPLETE ANALYSES

On May 22, 1916, the first of a very complete set of analyses was started. Temperatures were taken by a thermophone of the Board of Water Supply, operated by Mr. Glazer. The instrument was of the galvanometer type and readings could be made accurately to 0.1° F. The instrument had been compared with standard thermometers and found to be correct. Temperatures were read at every 5 ft. depth down to 100 ft., then at every 10 ft. depth. When the thermocline developed later its exact position was determined by readings 1 ft. apart. Samples for other determinations were taken at frequent intervals, including especially just above and just below the thermocline. Samples have also been taken from the effluent pipe each time, which have demonstrated that the draught is actually at the depth intended.

TABLE III

May 22, 1916					June 29, 1916			July 28, 1916			August 31, 1916		
Depth Ft.	Temperatures Thermophone		Temperatures Bottle		Depth Ft.	Temperatures Thermophone		Depth Ft.	Temperatures Thermophone		Depth Ft.	Temperatures Thermophone	
1	55.1° F.	—12.8° C.	55.8° F.	—13.2° C.	1/2	75.1° F.	23.9° C.	1/2	78.3° F.	25.7° C.	1/2	75.6° F.	24.2° C.
5	55.0°	—12.8°	....	....	5	73.2°	22.9°	5	78.2°	25.7°	5	75.6°	24.2°
10	54.3°	—12.4°	....	....	10	72.9°	22.7°	10	77.9°	25.5°	10	75.6°	24.2°
15	54.0°	—12.2°	....	....	15	72.4°	22.4°	15	77.8°	25.4°	15	75.2°	24.0°
20	52.9°	—11.6°	....	....	16	71.5°	21.9°	20	77.6°	25.3°	20	74.0°	23.3°
..	....	....	....	....	17	66.4°	19.1°	21	77.2°	25.1°	21	73.7°	23.2°
..	....	....	....	....	17 1/2	64.3°	17.9°	22	76.6°	24.8°	22	73.5°	23.1°
..	....	....	....	....	20	62.4°	16.9°	23	62.3°	16.8°	23	72.1°	22.3°
..	....	....	....	....	..	....	....	24	61.4°	16.3°	24	68.5°	20.3°
25	51.2°	—10.7°	54.0°	—12.2°	25	56.1°	13.4°	25	60.4°	15.8°	25	65.7°	18.7°
30	49.6°	— 9.8°	....	....	30	52.9°	11.6°	30	56.0°	13.3°	30	58.0°	14.4°
35	47.9°	— 8.8°	....	....	35	51.8°	11.0°	35	53.6°	12.0°	35	55.5°	13.1°
40	47.0°	— 8.3°	....	....	40	50.5°	10.3°	40	51.9°	11.4°	40	53.2°	11.8°
45	46.2°	— 7.9°	....	....	45	48.6°	9.2°	45	50.3°	10.2°	45	51.9°	11.1°
50	45.3°	— 7.4°	46.8°	—8.2°	50	47.0°	8.3°	50	48.9°	9.4°	50	50.5°	10.3°
55	44.5°	— 6.9°	....	....	55	45.3°	7.4°	55	47.5°	8.6°	55	48.6°	9.2°
60	44.0°	— 6.7°	....	....	60	44.4°	6.9°	60	45.9°	7.7°	60	47.4°	8.6°
65	43.7°	— 6.5°	....	....	65	43.7°	6.5°	65	45.0°	7.2°	65	46.3°	7.9°
70	43.6°	— 6.4°	....	....	70	43.4°	6.3°	70	44.1°	6.7°	70	45.3°	7.4°
75	43.4°	— 6.3°	....	....	75	43.2°	6.2°	75	43.6°	6.4°	75	44.5°	6.9°
80	43.3°	— 6.3°	....	....	80	43.0°	6.1°	80	43.5°	6.4°	80	44.2°	6.8°
85	43.2°	— 6.2°	....	....	85	42.9°	6.1°	85	43.3°	6.3°	85	43.8°	6.6°
90	43.2°	— 6.2°	....	....	90	42.7°	5.9°	90	43.1°	6.2°	90	43.4°	6.3°
95	43.2°	— 6.2°	....	....	95	42.5°	5.8°	95	43.0°	6.1°	95	43.1°	6.2°
100	43.1°	— 6.2°	45.0°	—7.2°	100	42.4°	5.8°	100	42.8°	6.0°	100	42.9°	6.1°
105	(Effluent)		43.2°	—6.2°	105	42.3°	5.7°	105	42.7°	5.9°	105	42.8°	6.0°
110	42.6°	— 5.9°	....	....	110	42.15°	5.6°	110	42.5°	5.8°	110	42.8°	6.0°
..	....	....	....	....	115	42.05°	5.6°	115	42.4°	5.8°	...	....	....
120	42.1°	— 5.6°	....	....	120	41.95°	5.5°	120	42.3°	5.7°	120	42.6°	5.9°
..	....	....	....	....	125	41.95°	5.5°	125	42.2°	5.7°	...	....	....
130	41.8°	— 5.4°	....	....	130	41.9°	5.5°	130	42.1°	5.6°	130	42.4°	5.8°
..	....	....	....	....	135	41.85°	5.5°	135	42.0°	5.6°	...	....	....
140	41.7°	— 5.4°	....	....	140	41.8	5.4°	140	42.0°	5.6°	140	42.5°	5.9°
..	....	....	....	....	145	41.8°	5.4°	145	42.0°	5.6°	...	....	....
150	41.7°	— 5.4°	44.0°	—6.7°	150	41.8°	5.4°	150	43.0°	6.1°	150	43.4°	6.3°
..	....	....	....	....	...	....	....	155	43.8°	6.6°	155	44.4°	6.9°
..	....	....	....	....	...	....	....	160	43.8°	6.6°	...	....	....

The analyses made May 22 are shown in Table IV. Chart No. 2 shows the temperatures, oxygen, free carbonic acid, and microscopic organisms. It is evident from the chart that a thermocline had begun to form at about 20 ft. depth. Oxygen was abundant at all depths and microscopic organisms at a minimum.

Comparison of the small bottle temperatures with the thermophone proved that the samples came from the depth intended. Some change of temperature in the deep samples is occasioned while drawing up through the warmer water. This difference becomes greater as the surface temperatures become higher. The tubes were so arranged that the bottles took 2 min. to fill, and it took only about one-half minute to lower to the depth desired.

The analyses show the water to be of remarkably uniform character from top to bottom.

On June 29, 1916, samples were again taken. The results, shown in Table IV and on Chart No. 3, indicate that marked changes have taken place. A distinct thermocline has formed at 16 ft. depth with great increase of temperature of the surface water. Microscopic organisms have increased above the thermocline. Free carbonic acid has increased below the thermocline

TABLE IV—QUALITY OF WATER AT VARIOUS DEPTHS AT KENSICO RESERVOIR

SAMPLE		PHYSICAL EXAMINATION			CHEMICAL ANALYSIS (Parts per Million)													BACTERIOLOGICAL EXAMINATION				MICROSCOPICAL EXAMINATION No. of Standard Units per Cc.				
					NITROGEN AS														*Bacillus coli*					IMPORTANT GENERA		
DATE (1916)	Place of Collection (Several Hundred feet Back of Dam)	Turbidity P. P. M. SiO_2	Color P. P. M. Pt.	Odor	Albuminoid Ammonia	Free Ammonia	Nitrites	Nitrates	Total Solids	Loss on Ignition	Fixed Solids	Chlorine	Hardness	Alkalinity	Iron	Free CO_2	Dissolved Oxygen	Bacteria per Cc. 24 Hrs. at 37° C.	in 0.1 Cc.	in 1.0 Cc.	in 10 Cc.	Total Microscopic Organisms	Amorphous Matter	*Synedra*	*Asterionella*	*Aphanizomenon*
5/22	Surface	3	13	0	0.180	0.020	0.004	0.00	48	14	34	1.3	20	13	0.20	0.8	11.2	7	0	0	+	225	270	70	45	....
	25 ft.	2	12	0	0.170	0.025	0.002	0.00	48	14	34	1.3	20	13	0.05	1.5	10.8	12	0	0	0	150	220	55	35	....
	50 ft.	2	12	0	0.110	0.025	0.002	0.05	48	14	34	1.3	20	13	....	1.5	10.8	17	0	0	0	90	190	30	15	....
	100 ft.	2	12	0	0.060	0.030	0.002	0.00	48	14	34	1.3	20	13	0.25	1.5	11.2	1	0	0	0	85	270	40	30	....
	150 ft.	2	12	0	0.120	0.025	0.004	0.05	48	14	34	1.3	30	13	0.25	2.3	11.2	14	0	0	0	75	200	35	25	....
	105 ft. (*Effluent*)	2	12	0	0.065	0.020	0.002	0.05	48	14	34	1.3	20	13	0.25	2.3	11.5	2	0	0	0	65	180	15	40	....
6/29	Surface	2	12	1*v*	0.195	0.000	0.000	0.00	46	18	28	1.4	23	18	0.10	0.2	9.5	6	0	0	0	2950	250	110	..	2700
	16 ft.	2	15	1*v*	0.155	0.005	0.000	0.00	49	21	28	1.6	23	18	0.15	1.1	9.2	16	0	0	0	900	350	120	..	610
	24 ft.	2	11	1*v*	0.170	0.000	0.000	0.05	40	16	24	1.5	23	18	0.15	3.0	8.6	5	0	0	0	330	360	170	..	110
	50 ft.	1	11	1*v*	0.065	0.050	0.002	0.10	41	14	27	1.4	22	16	0.15	4.6	9.5	13	0	0	0	190	360	80	..	40
	79 ft.	1	11	1*v*	0.065	0.100	0.004	0.05	42	16	26	1.3	20	15	0.20	3.4	10.2	9	0	0	0	130	290	90	..	10
	105 ft. (*Effluent*)	1	11	1*v*	0.075	0.100	0.006	0.10	47	16	31	1.4	21	17	0.25	3.4	10.6	9	0	0	0	80	240	50	..	....
	150 ft.	1	15	1*v*	0.120	0.080	0.006	0.05	46	17	29	1.4	21	17	0.20	3.8	9.4	3900	0	0	0	140	280	40	..	80
7/28	Surface	3	12	0	0.190	0.000	0.002	0.05	...	..	..	1.8	26	16	....	0.38	7.78	30	0	+	+	4020	320	...	..	3900
	20 ft.	3	14	0	0.215	0.020	0.002	0.05	50	18	32	1.8	23	16	0.30	2.66	7.78	52	0	0	+	3770	220	...	..	3700
	25 ft.	2	11	0	0.185	0.110	0.002	0.05	49	17	32	1.5	26	16	0.30	4.56	6.04	12	0	0	0	1870	360	...	..	1800
	50 ft.	1	10	0	0.135	0.030	0.002	0.05	...	..	..	1.5	23	14	....	4.56	7.45	15	0	0	0	520	320	...	..	460
	75 ft.	1	9	0	0.150	0.020	0.006	0.05	46	20	26	1.5	26	14	0.35	4.56	8.61	6	0	0	+	190	370	...	..	180
	105 ft.	3	13	0	0.190	0.005	0.008	0.10	42	14	28	1.5	23	12	0.60	4.56	8.78	2	0	0	0	100	675	...	..	30
	125 ft.	1	11	0	0.145	0.015	0.008	0.10	...	..	..	1.5	25	14	....	4.56	8.45	15	0	0	0	150	270	...	..	120
	150 ft.	6	160	3*v*	0.150	0.060	0.018	0.15	...	..	..	1.8	..	34	....	15.20	1.90	13	0	0	+	510	2400	...	..	460
8/31	Surface	2	9	1*e*	0.115	0.005	0.002	0.15	49	..	..	2.0	25	18	0.15	1.1	7.40	100	0	0	+	125	480	...	..	....
	20 ft.	2	10	1*e*	0.110	0.010	0.002	0.10	49	..	..	1.5	25	19	0.15	2.1	6.67	175	0	0	0	130	820	...	..	....
	30 ft.	2	6	1*e*	0.095	0.005	0.002	0.10	48	..	..	1.5	26	18	0.15	9.3	2.20	64	0	0	0	80	1050	...	..	....
	50 ft.	1	6	1*e*	0.075	0.005	0.002	0.10	43	..	..	1.5	26	18	0.15	7.0	5.20	83	0	0	0	50	750	...	..	....
	75 ft.	1	6	1*e*	0.080	0.005	0.002	0.10	51	..	..	1.5	23	13	0.10	6.1	7.24	115	0	0	0	115	520	...	..	....
	105 ft. (*Effluent*)	1	7	1*e*	0.040	0.005	0.002	0.10	58	..	..	1.5	18	14	0.30	6.5	7.20	4	0	0	+	60	570	...	..	....
	125 ft.	1	7	1*e*	0.055	0.005	0.002	0.10	45	..	..	1.5	21	19	0.15	6.1	7.32	540	0	0	0	40	570	...	..	....
	150 ft.	12	440	1*e*	0.190	0.685	0.002	0.15	100	..	..	1.6	33	28	11.20	21.5	0.57	32	0	0	0	30	2500	...	..	....

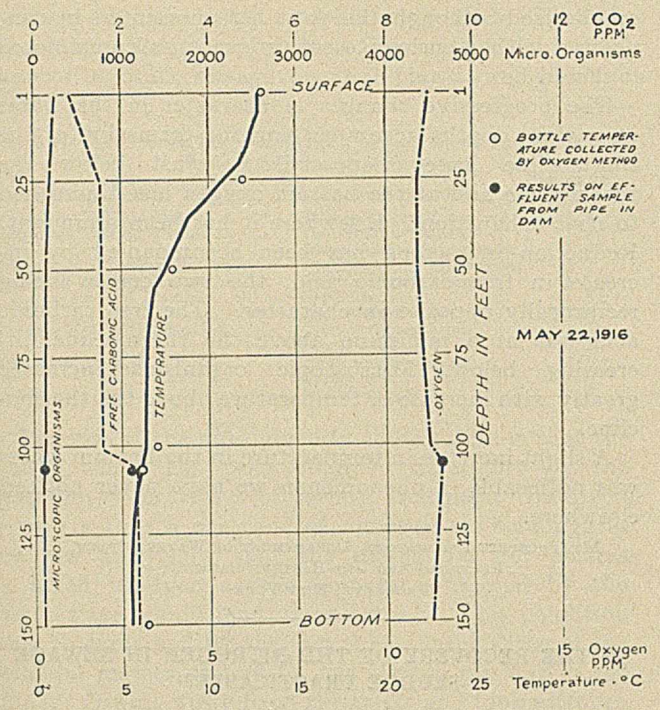

CHART No 2 THERMOCLINE FORMING AT ABOUT 20 FEET

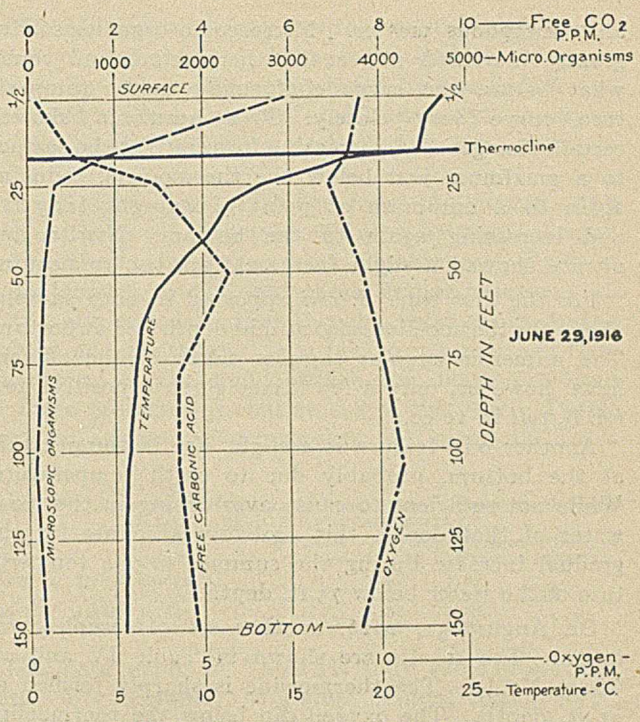

CHART No 3 THERMOCLINE FORMED AT 16 FEET

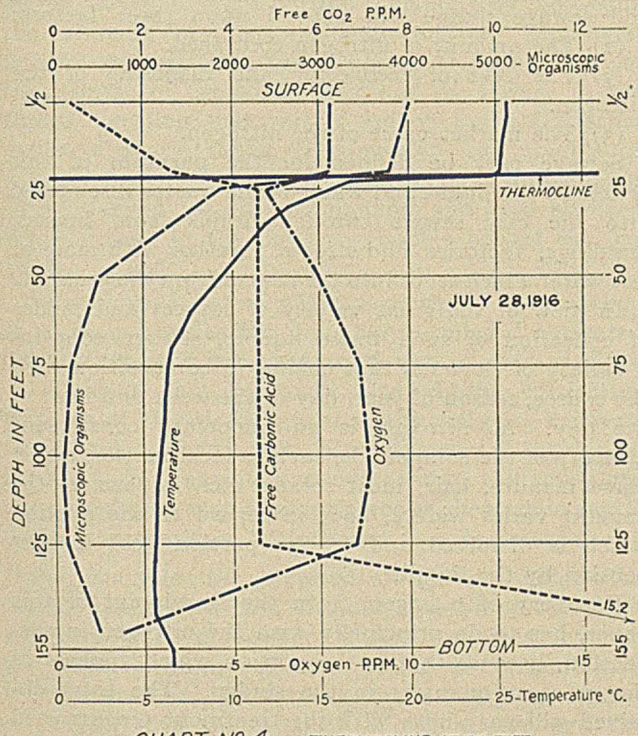

CHART No 4 THERMOCLINE AT 22 FEET

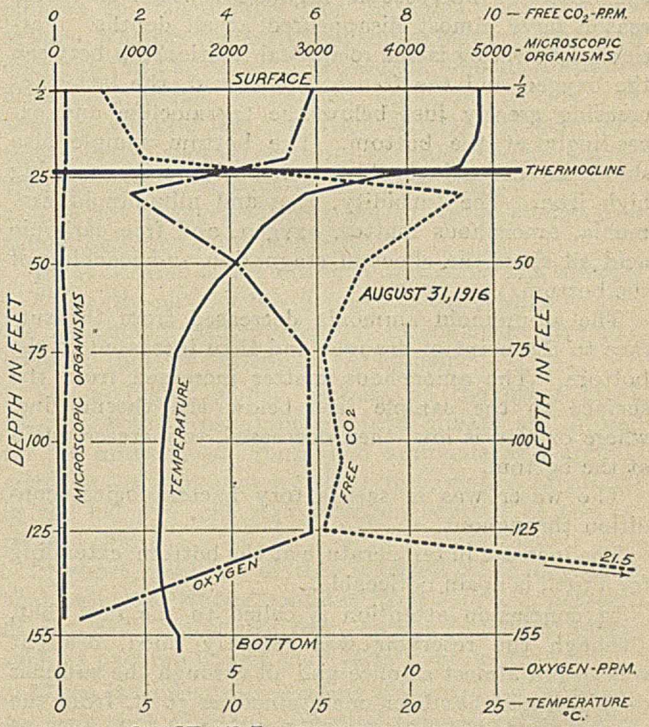

CHART No. 5 THERMOCLINE AT 23 FEET

Quality of Kensico Reservoir Water at Various Depths

and oxygen has begun to decrease just below the thermocline and at the bottom. There was, however, an abundance of oxygen at all depths. The albuminoid ammonia decreased with the microscopic organisms from top to bottom. The reverse was true of free ammonia, nitrite, and free carbonic acid. The bottom samples alone showed high bacteria.

The next set of samples was taken July 28, 1916. The results are shown in Table IV and on Chart No. 4. The thermocline is very sharply defined at 22 ft. depth. Between 22 ft. and 23 ft. there was a difference of 8° C., whereas for each foot above and below these points there was only fractions of a degree difference. Other changes were more sharply marked. The oxygen curve dips deeper below the thermocline and is nearly exhausted at the bottom. The free carbonic acid has greatly increased at the bottom accompanied by high color, free ammonia, nitrite, and amorphous matter. Microscopic organisms have greatly increased above the thermocline and somewhat below, the curve conforming to the temperature curve very closely. Free ammonia showed certain changes also, increasing from zero at the surface to a maximum just below the thermocline, reducing again to a minimum at point of draught (105 ft.) and increasing again to the bottom. Nitrite and nitrate showed a slight increase from top to bottom.

For the first time *B. coli* appeared in both samples above the thermocline, also at mid depth and at bottom. The numerous regular samples taken of the effluent have, however, only a few times given a positive test for *B. coli* in 10 cc.

Another odd feature is a slight rise in temperature at the bottom, probably due to earth temperature. While not sufficient to cause overturning in the quiet water of that depth, this probably accounts for the gradual increase during the summer in the temperature of the water below 75 ft. depth.

On August 31, 1916, another set of samples was taken. The results are shown in Table IV and on Chart No. 5. The thermocline is sharply formed at 23 ft. depth. The oxygen dip below the thermocline and at the bottom is striking. This is accompanied by heavy amorphous matter at both points due to the death of microscopic organisms which for some reason have almost disappeared at all depths. Particularly striking is the reciprocal relationship between the oxygen and the free carbonic acid, the latter increasing greatly just below the thermocline and exceedingly at the bottom. The bottom sample also shows an exceedingly high color with accompanying high iron. The turbidity, free and albuminoid ammonia, amorphous matter, oxygen, and free carbonic acid all show the effect of stagnation and leaching of the bottom.

The albuminoid ammonia decreased from the surface to the point of draught and then increased to the bottom. The amorphous matter increased from the surface to the sample just below the thermocline, where oxygen is low, then decreased, to increase again at the bottom.

The water was in satisfactory bacteriological condition throughout.

The increase in temperature at the bottom, extending for 15 ft., is again noticeable.

In conclusion attention is called to the fact that, although the reservoir was recently filled, draught was begun almost at once and all through the summer deep draught has been maintained at 50 ft. from the bottom. The water obtained has been clear, cold (43° F.), free from *B. coli* and low in bacteria. Microscopic organisms have been avoided, although heavy growths have occurred at the surface of a type producing on decay disagreeable pig-pen odors. The water has also contained abundant oxygen. The draught of 27 to 30 m. g. d. has had no effect whatever on the water in the Reservoir. Similar results with larger draught have been obtained at Croton Lake for several years.

The fact of continuous winter circulation is also emphasized although the data here presented in connection with Kensico Reservoir is not as complete as it should be.

The progressive changes in character of the water at various depths accompanying the formation of the thermocline have been striking. Just below the thermocline and at the bottom oxygen has diminished to near exhaustion. Elsewhere it has been abundant. Reduction in oxygen has been accompanied by increase in free carbonic acid, the two curves being reciprocally opposite in character. The free carbonic acid was at a minimum above the thermocline, increasing below. Microscopic organisms increased greatly with increase of temperature above the thermocline.

A slight increase in temperature in the bottom water was noticeable, a phenomenon we have never noticed elsewhere.

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IS THE RECOVERY OF THE NITROGEN IN SEWAGE SLUDGE PRACTICABLE?[1]

By William R. Copeland

The answer to the question as to whether it is or is not practicable to recover the nitrogen in sewage and sewage sludge will depend upon three factors:

(1) The amount of nitrogen contained.

(2) The cost of recovering and disposing of the nitrogen.

(3) The market value of the nitrogen.

Sewage may be defined for the purposes of this article as the liquid and water-borne wastes discharged into the city sewers through drains from houses, buildings, factories and streets, together with more or less water which seeps into the sewers from the ground.

In view of the great variety of sources and modes of collection of such waste liquors, sewage contains a variety of elements that change in composition with the source, season of year, day of the week and hour of the day. As nitrogen is an important constituent in many of the compounds, such as fecal matter, urine, horse manure, hair, meat scraps, etc., in sewage, the amount varies widely, both in regard to the portion which is dissolved and to the portion held in suspension by the liquid.

Recovery of nitrogen, from the standpoint of this paper, has to do principally with the nitrogen in suspension, because that is the portion which appears in the greatest quantity in the sludge. The total obtained will vary both with the treatment process used and with the volume contained by the raw sewage. To illustrate these points the following data are taken from Metcalf and Eddy's "American Sewerage Practice," Volume 3:

Table I—Composition of Dry Sewage Sludge

Source of Sample	Sludge Obtained from	Per cent Nitrogen
Frankfort-am-Main............	Plain sedimentation	2.85
Columbus, Ohio................	Septic tank	1.40
Essen..........................	Imhoff tank	1.22
Philadelphia..................	Imhoff tank	1.20
Worcester, Mass...............	Chemical precipitation	2.77

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[1] Presented at the 53rd Meeting of the American Chemical Society, New York City, September 25–30, 1916.

Some additional data compiled by J. R. McClintock, Consulting Engineer, of New York, from published reports of other sewage disposal plants, are given in Table II.

TABLE II—ADDITIONAL DATA UPON THE COMPOSITION OF SEWAGE SLUDGE (Basis of 10 Per cent Moisture)

SOURCE OF SAMPLE	SLUDGE OBTAINED FROM	PER CENT NITROGEN
Brooklyn (Williamsburg).........	Dickson (Yeast) process	1.4
Columbus Testing Station........	Grit chamber sludge	1.2
	Plain sedimentation tank	1.6
Philadelphia Testing Station......	Plain sedimentation tank	1.2
Cleveland Testing Station........	Plain sedimentation	1.4
	Septic tank	1.3
	Imhoff tank	1.2
Gloversville Testing Station......	Plain sedimentation	2.3
	Septic tank	2.2
Worcester M. & E. Vol. III.......	Plain sedimentation	2.7
	Septic tank	2.7
Atlanta........................	Imhoff tank	1.5

The gist of the data given in these tables is that the sludge which has been obtained heretofore by the best known processes of sewage treatment contained from 1.2 to 3.0 per cent of nitrogen. These figures are low and show that the sludge did not possess as much nitrogen as the amount contained by the raw sewage would lead us to expect. This condition may be explained by the fact that a large share of the colloidal matter carried by the sewage ran out in the effluent flowing away from the tanks and took nitrogen with it; or in the case of chemical precipitation works the lime added drove nitrogen off in the form of ammonia and diluted the portion remaining by increasing the amount of inert mineral matter. Moreover, various authors state that from 10 to 60 per cent of the volume of the solids deposited by sewage in the sludge digestion chambers of Imhoff tanks and other forms of septic tanks, is converted into soluble or gaseous form. Much of the albuminoid ammonia is thus changed into free ammonia and free nitrogen which escape in the liquor or bubble out at the gas vents.

Within the last two years, however, a new method of sewage purification by the so-called "Activated Sludge" process has been tried out in various cities of America and England. One of the distinctive features of this process is that the colloidal and suspended matters of the sewage are collected in the sludge. If this is not reaerated or overaerated the solids are not liquefied to such a large degree as they are in septic tanks, and therefore the nitrogen does not escape.

For example, the digested sludge accumulates in Imhoff tanks at a rate of from 1 to 10 cu. yds. per 1,000,000 gals. of sewage treated; whereas, by the activated sludge process 20 to 80 cu. yds. or more may be deposited in the settling tanks, varying widely, of course, with the strength of the sewage and the water content of the sludge.

TABLE III—ANALYSES OF MILWAUKEE CITY SEWAGE BEFORE AND AFTER TREATMENT BY IMHOFF TANK AND BY ACTIVATED SLUDGE
Results in Parts per Million

Month 1915	SAMPLE	Suspended Matter	Nitrogen as AMMONIA Free	Nitrogen as AMMONIA Albuminoid	Nitrogen as Organic N	Nitrogen as Nitrite	Nitrogen as Nitrate
Aug.	Sewage............	253	14.6	7.88	29	0.15	0.13
	EFFLUENT:						
	Imhoff............	105	16.2	6.10	27	0.19	0.13
	Activated sludge....	14	3.8	3.19	6	0.29	6.00
Sept.	Sewage............	300	13.5	8.81	29	0.25	0.14
	EFFLUENT:						
	Imhoff............	116	15.4	7.10	27	0.12	0.09
	Activated sludge....	8	5.7	2.22	9	0.24	5.01

The Milwaukee sewage testing station carried on a series of experiments during the summer of 1915 where the city sewage was treated by the Imhoff and activated sludge processes simultaneously. Analyses of the sewage effluents and sludges are given in Table III.

Samples of digested sludge from the Imhoff tank and of the fresh activated sludge were also collected and analyzed in August and September. While it is not correct to say that these sludges represent all of the raw sewage passed through these tanks during August and September, it is fair to assume that they are typical of the sludge which was being produced by those processes at that season of the year. Therefore, the analyses of the sludges are given in Table IV.

TABLE IV—ANALYSES OF SAMPLES OF IMHOFF AND ACTIVATED SLUDGES OBTAINED FROM MILWAUKEE SEWAGE

Date 1915	SAMPLE	Nitrogen Reported as NH_3 on a Basis of Sludge Dried to 10 Per cent Moisture		
Aug.	Imhoff sludge..................	2.87	3.82	..
	Activated sludge...............	5.71	4.97	7.04
Sept.	Imhoff sludge..................	3.88	8.69	..
	Activated sludge...............	8.69	9.00	..

The data given in Table III show some interesting facts. For example, the Imhoff effluent contained on an average more than 100 pts. per m. of suspended matter, whereas the effluent from the activated sludge process contained only about 10 p. p. m.; the Imhoff effluent contained more free ammonia than the raw sewage, whereas the activated sludge effluent contained only one-third as much. The Imhoff effluent contained almost as much albuminoid ammonia as the raw sewage, whereas the activated sludge effluent contained only about one-third as much. The Imhoff effluent contained almost as much organic nitrogen as the raw sewage, whereas the activated sludge contained only one-third as much.

What became of the nitrogen carried by the sewage? Evidently most of the nitrogen in the sewage treated by the Imhoff tank passed out in the suspended and colloidal matters carried by the effluent.

The activated sludge process, on the other hand, converted the free ammonia into nitrate and stored up the undissolved albuminoid ammonia and organic nitrogen, as indicated by the large amount of nitrate in the effluent and high nitrogen content of the activated sludge.

In short, analyses of this material when dry show that activated sludge contains from 4 to 4$^1/_2$ per cent of nitrogen, and sludge from certain industrial plants such as packing houses may carry even more.

When it comes to recovering this nitrogen, however, we meet with a serious difficulty, because as the sludge gathers in the settling tanks it contains from 98 to 99 per cent of moisture and the bulk of this water must be removed before the dry material can be sold for fertilizer.

Several methods of dewatering the sludge have been tried, such as settling, passing the mixture through centrifugal machines, pressing and drying.

The best information now available points to a combination of settling and decantation as a preliminary process. By this means the water will be cut down from about 99 to 96 per cent. On passing the concentrated residue through a press the moisture can be cut down to 75 per cent. The press cake can be dewatered in a dryer to 10 per cent moisture or less.

More than thirty samples of activated sludge have been dewatered by sedimentation, decantation and pressing at Milwaukee.

It is an interesting and notable fact that two different types of press can handle the settled sludge without requiring the addition of lime. Many experts and manufacturers of presses have held heretofore that sewage sludge could not be pressed advantageously without lime because of the gummy or gelatinous nature of the colloids in the sludge; but the facts remain that the sludge is not as gummy as was expected and it presses fairly easily down to 75 per cent of moisture.

In order to try out the feasibility of further dewatering the sludge four samples of the press cake were sent to fertilizer plants and dried there on a commercial scale. Three of these tests were made in a steam jacketed (indirect heat) dryer and one in a semi-direct heat dryer.

In each case the tests proved to be successful from three standpoints:

1—The sludge dried readily to a satisfactory mechanical condition.

2—The processes did not require much power.

3—Little nitrogen, if any, was driven off or lost by drying.

From the mechanical standpoint, therefore, the recovery of nitrogen in sewage sludge is practicable.

With regard to the question of cost, however, the situation at the time of writing is not so clear. The pieces of apparatus used for settling the raw sludge and drying the press cake were not designed to handle activated sludge in the most economical manner, but were requisitioned as being the best commercial apparatus available at the time.

By comparing the behavior of activated sludge with such matters as packing house tankage I estimate that this sludge can be dewatered so that the recovery of the nitrogen in it will probably cost upon present evidence about $8.00 to $12.00 per ton of material containing 10 per cent of moisture, depending upon a variety of local factors. These figures are intended to cover interest charges, depreciation, repairs and renewals, and a liberal provision for labor and fuel, as well as the cost of resettling and decanting of the water of the original sludge, and expenses for handling, freighting, and marketing the finished product. Obviously, the total cost per ton will be somewhat more in the case of a small plant than for a large one. For a very large plant, where fuel and labor are relatively cheap, it is possible that further experience will reduce the cost below the lower limit in the range here given.

The dried samples of sludge were analyzed and the data obtained are given in Table V.

TABLE V—ANALYSES OF COMMERCIALLY DRIED ACTIVATED SLUDGE
Basis of 10 Per cent Moisture

		Per cent of					
Sample No.	Character of Dryer	Nitrogen as Ammonia			Available Phosphoric Acid		
1	Semi-Direct Heat	4.36			0.70		
2, 3 & 4	Indirect Heat	4.76	4.56	5.06	0.81	0.47	0.39
Average of 4 Samples		4.68			0.57		

These analyses may be supplemented by the following tests:

TABLE VI—ADDITIONAL ANALYSES OF ACTIVATED SLUDGE PRESS CAKE

Date of Collection	Per cent of Nitrogen Calculated to Ammonia (Basis of 10 Per cent Moisture)
May 3, 1916	5.74
June 20, 1916	4.65
June 13, 1916	4.88
June 14, 1916	4.92
June 16, 1916	5.01

The data obtained at Milwaukee as cited in Tables V and VI indicate that dry activated sludge (basis of 10 per cent moisture) will contain 4.6 to 5 per cent of nitrogen figured as ammonia and 0.6 to 0.7 per cent of available phosphoric acid. In addition to this our data show that the dry product contains about $^1/_4$ to $^1/_2$ per cent of potash and from 3 to 4 per cent of fatty material. At present prices the nitrogen is worth $2.50 per unit (or per cent). In normal times this nitrogen would be worth about $2.00 per unit. The phosphoric acid is worth about $0.50, and the potash may be worth something in the future, although the best that can be said of it at present is that it will assure for the fertilizer a more ready sale.

The fat present in the Milwaukee sludge is negligible. It would not pay to recover the fat nor will the fat injure the selling qualities of the dried sludge.

SUMMARY

Summing the whole situation up, then, we see that the dried sludge has a market value upon present figures of $9.00 to $15.00 per ton of material containing 10 per cent moisture. The total cost of getting this product and placing it on the market will probably run from $8.00 to $12.00 commercially per dry ton, depending upon local conditions. For large plants this cost may possibly be reduced as a result of further experience.

The activated sludge containing 4 per cent or more of nitrogen is much nearer a commercial possibility than the sludges obtained by the older methods of treatment, such as chemical precipitation, septic tanks, or the Imhoff process, which the data given in Table I indicate to contain only 1$^1/_2$ to 3 per cent of nitrogen.

In case the question arises as to the possibility of finding a market for the dried activated sludge, it should be added that raw materials containing nitrogen, phosphoric acid and potash are capable of being worked up readily as a base for making high-grade fertilizers, and as they are not very plentiful they are in good demand.

Presumably, however, large cities such as New York, Chicago, etc., by installing this activated sludge process, would produce so much raw material of this character that the product would have to be parcelled out among a number of manufacturers. It is even possible that the production might be sufficient to reduce the price.

However, the dried sludge is a good fertilizer just as it stands and contains enough value to pay for sale and distribution in quite a large local market.

The data given in the preceding pages indicate, therefore, that the recovery of the nitrogen in sewage sludge has at last been brought within the range of a commercially practicable problem.

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STORAGE RESERVOIRS AS A FACTOR IN THE PURIFICATION OF SURFACE WATERS[1]

By S. T. Powell

The impounding of surface waters in storage reservoirs has been practiced for years, but the primary object of such treatment has been the conservation of the supplies or the physical improvements to the water to be derived from sedimentation. Until within a few years past very little was known concerning the hygienic improvement that takes place in water retained in storage basins. Dr. Sedgwick[2] made note of this fact in a paper which he read before the New England Water Works Association. He pointed out that it was but fifteen years ago that he advanced the theory that it was in "stagnant" rather than in running water that the greatest bacteriological purification takes place. At that time this statement caused considerable discussion on account of this seemingly radical theory. Since that time so much has been learned concerning the chemical and bacterial efficiency of storage reservoirs that it is improbable that any sanitarian would attempt to disprove this general statement.

For a time a number of cities in this country depended wholly upon this method of purification but, as stated by Mr. George W. Fuller,[3] "this method is expensive and seldom tried at present." With our present knowledge of water treatment, aside from the economic standpoint, it is doubtful if the public would be content with this form of purification as a complete or sufficiently safe one. Considered merely as an adjunct to filtration or sterilization preliminary to such treatment, storage reservoirs are particularly efficient and the purification to be derived in this way far outweighs certain disadvantages that are at times encountered in the course of storage. It is in respect to a consideration of the value of stored water as a preliminary method of purification prior to ozone sterilization that it is dealt with in this paper.

During the past fifteen months the writer has been afforded an opportunity to study conditions in the Herring Run storage reservoirs used in connection with the ozone plant of the Baltimore County Water and Electric Company. The raw water supply is obtained from Herring Run, a small stream which flows through a rather thickly populated district in Baltimore County adjacent to Baltimore City.

Previous to ozonization the raw water is stored in two shallow reservoirs holding approximately eighty million (80,000,000) gallons, permitting about a 3-weeks storage period. These reservoirs are used in tandem, the water flowing from the first to the second basin through an outlet chamber with gates at different levels so as to draw the water from near the surface at all times. Since undertaking a study of conditions that exist in these reservoirs weekly samples of the raw water and of the effluent have been made. The results obtained, particularly the bacterial data, are of unusual interest, considering the fact that the reservoirs are quite shallow, averaging probably less than 10 ft. in depth, and that the period of storage does not exceed 3 weeks.

The physical and chemical improvement to the water passing through these basins has been quite marked at all seasons of the year, but these removals have in no sense been abnormal. There has been an average reduction in turbidity of 14.2 per cent during the period covered by these tests, with a maximum removal of 35.3 per cent during July, 1915. The efficiency of storage here in respect to the removal of turbidity has not been as great as at other places with the same detention period. This is due to the fact that during periods of high water, when the raw supply contains the greatest amount of suspended solids, the influent gates have been closed and the necessary daily pumpage has been drawn from storage. The removal of the color effected by these reservoirs has been marked, averaging 15.0 per cent, but contrary to expectation the greatest color reductions have been in the spring and fall and not during the summer months as has usually been noted by observers in studying the bleaching effect of sunlight upon stored water. The greatest bleaching effect is normally to be obtained during the warmest months of the year, on account of the more active oxidation of the organic coloring matter and by the direct decolorizing effect of the sunlight. Stearns,[1] in studying these conditions in ten reservoir supplies of Boston, reported color reduction of from 9 to 69.5 per cent for periods of from one to nine years. Low color reductions were claimed by Mr. Stearns to be due to "color absorbed from reservoir beds" and this in a measure offsets the normal decolorization due to storage.

The reason the color reduction has been less here in summer is believed to be due not entirely to the absorption of organic substances in the reservoir bottoms but to the fact that during the summer months the algae growths are always prolific. Many of these growths[2] are chlorophyll-bearing organisms and, due to disintegration, the chlorophyll is scattered throughout the water and this tends to lessen the bleaching effect of the sunlight. In addition to reduction in color and turbidity there has been consistent removal of organic matter from the water as shown in Table I.

TABLE I—SHOWING PERCENTAGE REMOVAL OF CHEMICAL CONSTITUENTS DUE TO STORAGE IN THE HERRING RUN RESERVOIR

CONSTITUENTS	PERCENTAGE REMOVAL
Color	15.0
Turbidity	14.2
Total Residue	6.5
Volatile Matter	9.9
Mineral Residue	5.4
Consumed Oxygen	20.5
Total Iron	20.9
Free Ammonia	10.1(*a*)
Albuminoid Ammonia	8.2(*a*)

(*a*) These determinations have not been made throughout the entire year.

The physical and chemical improvement to be gained by storage cannot be discounted, yet the hygienic betterment derived by the diminution of the

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[1] Presented at the 53rd Meeting of the American Chemical Society, New York City, September 25 to 30, 1916.

[2] Dr. Wm. T. Sedgwick, "Water Supply Sanitation in the Nineteenth and Twentieth Centuries," *N. E. W. W. Assoc.*, **1916**.

[3] Geo. W. Fuller, "The Purification of Water from Standpoints Other than the Hygienic Aspect," *Trans. 15th Congr. Hyg. and Demography*, **1912**.

[1] Ralph H. Stearns, "Decolorization of Water by Storage," *N. E. W. W. Assoc.*, **1916**.

[2] S. T. Powell, "The Effect of Ozone on Algae Growths," *A. W. W. Assoc.*, **1914**.

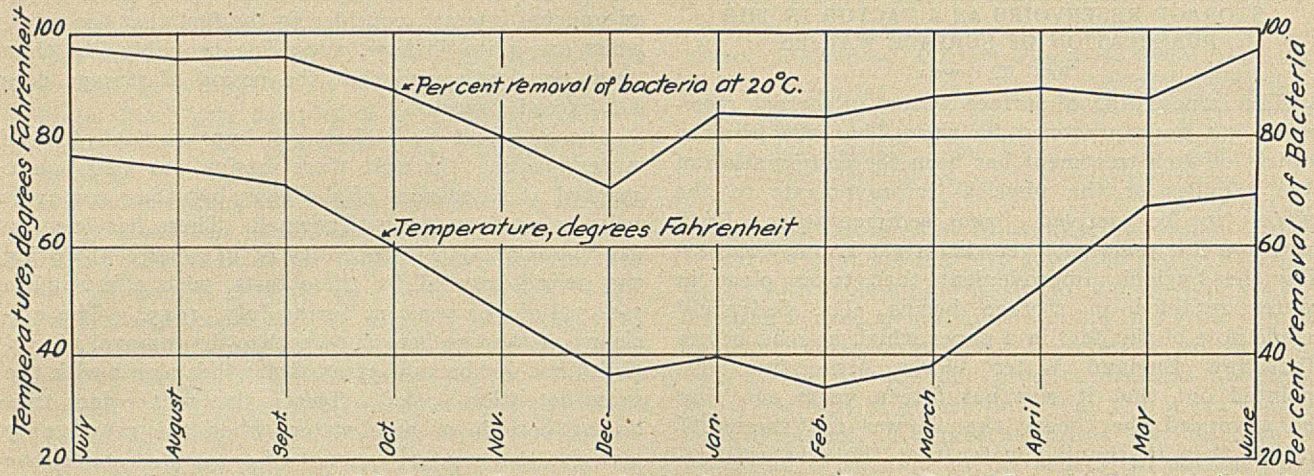

Fig. I—Percentage Removal of 20° C. Bacteria Effected by Storage Reservoir at Herring Run in Comparison with the Average Monthly Temperatures

bacterial count is of far greater value. The careful and exhaustive studies of Dr. A. C. Houston of the Metropolitan Water Board of London has clearly demonstrated the fact that by storage alone a very high percentage of the bacteria can be removed.

The bacterial reduction obtained in the Herring Run reservoirs has been quite high, but the efficiencies have varied with the seasons. There has been a direct relationship between the atmospheric temperature and the efficiency of these reservoirs in the elimination of the bacteria growing at 20° C. From Fig. I it will be seen that the greatest bacterial removal was during July, when the average temperature was the highest during the year. From then on there was a gradual and uniform falling off in the bacterial efficiency until January, when the sudden rise in temperature was followed immediately by an increased efficiency in the percentage removal of this type of bacterium. It will be noted also from Fig. II that the destruction of 38° bacteria appears to be less affected by temperature changes than that of the 20° organisms.

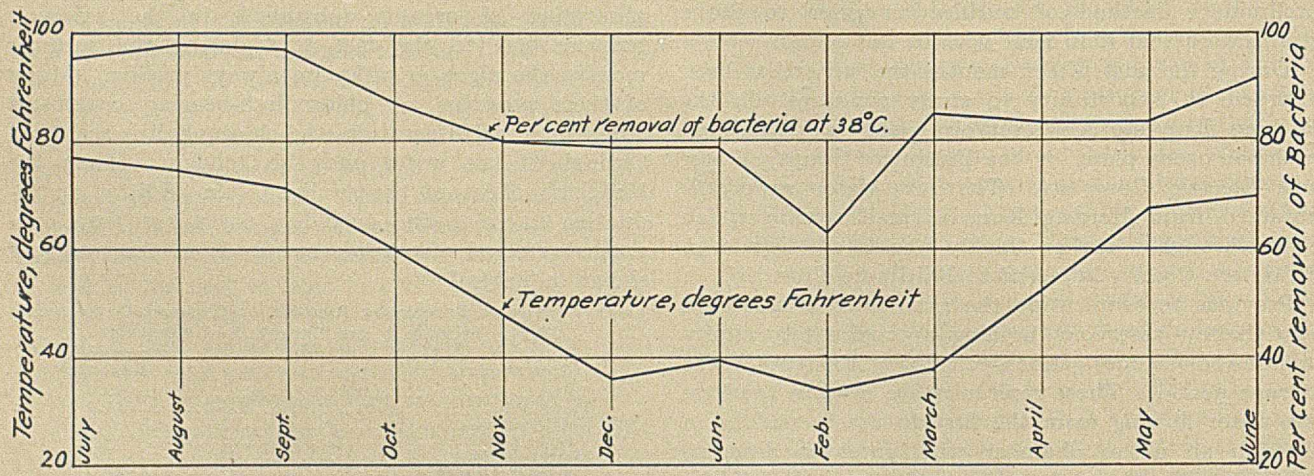

Fig. II—Percentage Removal of 38° C. Bacteria Effected by Storage Reservoir at Herring Run in Comparison with the Average Monthly Temperatures

It is interesting to note that during the summer months the percentage removal of blood temperature microbes was greater than 20° bacteria, but during the colder months the growth of these organisms was more persistent and the efficiency of the reservoirs in the removal of these types was considerably less than for the saprophytic bacteria. This condition has been noted by Houston,[1] Don and Chisholm[2] and others, and explained by the fact that in summer the active growth of the saprophytes creates an environment antagonistic to the life of the blood temperature germs. Recently the writer has made series of tests in the laboratory which tend to show that the rate of removal of the 38° bacteria, and particularly *B. coli* forms, is far more rapid in the presence of active growths of saprophytes than where such organisms are absent from the water.

Numerous theories have been advanced to account for the beneficial effect to surface waters brought about by storage. There is a general consensus of opinion, however, that the purification effected is due to no single cause but to the combined results of equalization, sedimentation and inanition or devitalization of the bacteria. The advisability of retaining surface waters in storage reservoirs to a condition of sterility in respect to the pathogenic bacteria the supplies may contain is an uncertain and questionable procedure

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[1] Dr. A. C. Houston, "The Purification of Water by Storage," *Trans. 15th Congr. Hyg. and Demography*, **1912**. *The Eighth Annual Report of the Metropolitan Water Board of London*, **1914**.

[2] Don and Chisholm, "Modern Methods of Water Purification," **1913**.

from an economic as well as practical viewpoint, but the bacterial reduction produced by comparatively short detention periods prior to final purification by means of filtration or sterilization with chemicals has much to appeal to the practical side of this question. The potent advantages in favor of such preliminary treatment are the reduction of all forms of bacterial life, but particularly the removal to a very large extent of the pathogenic germs, and the general physical and chemical improvements of the water ensuring more uniform control and economical operation of the final purification system, due to the equalizing effect that reservoirs of this type produce.

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LABORATORY AND PLANT

AN EXPERIMENT IN THE EDUCATION OF CHEMICAL ENGINEERS[1]

THE TWENTY-FIFTH ANNIVERSARY OF THE AUDUBON SUGAR SCHOOL

By Charles E. Coates

In these days of preparedness, the training of chemical engineers has taken on a consequence which is interesting both to the college and the country at large. The part which the chemist has played in modern development, we have known in a way for some years, of course, but we are appreciating now as never before, the vital and imperative importance to our nation of a body of men who cannot only discover chemical principles but can also apply them industrially.

At the same time, it has been generally acknowledged that college courses in Chemical Engineering have hitherto been lacking in some essential ingredient. Numerous efforts have been made to remedy this state of affairs. Among the most recent are the industrial fellowship system of the Mellon Institute and the plan lately outlined by the Massachusetts Institute of Technology, accounts of which have appeared in This Journal. The English journals are full of new schemes for the training of chemical engineers; indeed practically all the larger schools have changed such courses materially within the past few years. In view of this and inasmuch as experience, after all, is the only safe guide in the jungle of educational theory, it has been thought that a brief sketch of the origin and development of the Audubon Sugar School might not be untimely.

Few people realize how very largely the sugar industry of to-day is a chemical industry. A little over a century ago, when sugar was first made from beets, the root was low in sucrose and the process gave a poor yield of an inferior grade of sugar with an almost valueless molasses. The chemist and the agronomist, working together, slowly raised the sucrose content of the beet root until it was more than doubled; the chemist and engineer, working together, slowly improved the processes until a good yield of sugar was turned out, practically pure, and both the molasses and all the other by-products became sources of profit and not of loss. In consequence the net cost of beet sugar fell year by year until it became a serious competitor of cane sugar and, finally, it was offered at prices closely approaching the cost of cane sugar production.

The sugar planters of Louisiana, as a class, are certainly among the most intelligent agriculturalists in America. Seeing the increasing gravity of the situation, they decided to meet the competition of beet sugar by the same methods which made that competition possible. In the late eighties they called to Louisiana Dr. W. C. Stubbs and established, under his direction, the Sugar Experiment Station at Kenner, Louisiana, which was subsequently moved to Audubon Park, on the outskirts of New Orleans. This station was financed entirely by the planters of Louisiana. A complete sugar house was erected on a scale large enough to give commercial results, and altogether, perhaps $100,000 worth of equipment was obtained either by purchase or gift.

As soon as the work was fairly under way, it became evident that there were many leaks in the sugar industry as carried on in Louisiana and that these could be stopped by proper scientific control. But when the planters began to look for chemists and engineers, they were simply not to be obtained. Up to that time, the cane sugar industry throughout the whole world had been carried on largely by rule of thumb. Few men scientifically trained in sugar chemistry were to be found outside of Europe. In 1890, therefore, at a meeting of the Louisiana Sugar Planters' Association, it was decided to establish, in connection with the Sugar Experiment Station, a school for the training of experts in sugar work. This was placed under the direction of Dr. Stubbs and was opened in 1891 as the Audubon Sugar School. So far as I know, this was the first instance in America in which any industry established both laboratories for the scientific investigation of its problems and a school for the college training of men to put the theory into practice.

POST-GRADUATE CHARACTER OF WORK

As first outlined, the Audubon Sugar School was intended to appeal mainly to graduates of schools of engineering, and the course was distinctly post-graduate in character. The faculty was composed of some of the ablest men in the country, special stress being laid on research work. It soon became evident, however, that the number of college graduates who appreciated the opportunities in the sugar industry was quite small, and that the demand for training came mainly from men who had not received very much undergraduate training. Moreover, there were a number of applicants from tropical countries, whose preliminary studies had been of such a type as to make it impossible for them to take up, successfully, the advanced

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[1] Presented at the 53rd Meeting of the American Chemical Society, New York City, September 25 to 30, 1916.

scientific work offered in the Sugar School. At the outset, therefore, the greater number of students were special students, very un-uniform in educational training, which, of course, handicapped the school materially. The course was two years in length, classes were held at the Experiment Station, and during the sugar season the students did the actual work in the fields, in the laboratory, and in the sugar house.

The school was successful from the outset and, in a couple of years, more students were applying for admission than could well be accommodated. In the meantime the Sugar Experiment Station was taken over by the State of Louisiana as part of the Louisiana State University, and the Planters' Association withdrew its financial support. With limited funds, the increasing demands upon its staff along purely research lines, and the growing magnitude of its routine work, the Station found it impossible to handle students also. In 1896 the school was, accordingly, incorporated with the Louisiana State University, preserving the name by which it had become known. In 1908 its numerical importance was such that it was reorganized as a college of the University.

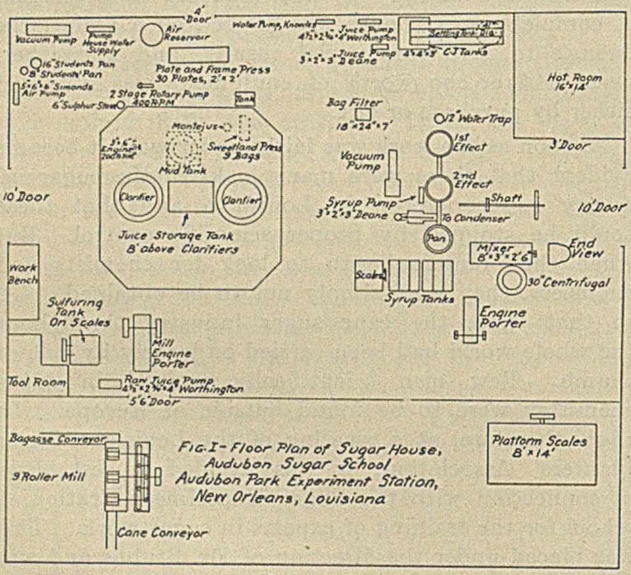

FIG. I—Floor Plan of Sugar House, Audubon Sugar School Audubon Park Experiment Station, New Orleans, Louisiana

From the first the writer and his colleagues were given a free hand by President Boyd in formulating the course of study, and changes were made year by year as experience or circumstances dictated. As the instruction was now given by the regular university staff, the students were, of necessity, ordinary college students, subject to the college entrance requirements. Moreover, as the chemical, mechanical, and agricultural subjects having to do with sugar technology had to be based upon chemistry, physics, mathematics and the biological sciences, it was necessary to require these subjects of all those taking up the purely sugar work. The enforcement of these two regulations worked, at the beginning, to eliminate a number of applicants whom the University would have been glad to welcome, if possible. They were, for the most part, men of maturity, from 25 to 40 years of age, who had had previous experience in sugar house work, and were anxious to supplement their experience with a certain amount of theory. For several years the University received these men as special students, but it soon became evident that, in spite of their laudable ambition, they were, in nine cases out of ten, merely wasting their time. They were taught certain things in a mechanical way, such, for instance, as how to polarize sugar, but they did not know the principles on which these things depended and their studies did not lead them anywhere. They were deceiving themselves in thinking they were studying sugar chemistry when they were merely becoming chemical mechanics. Only after it was too late did they recognize the necessity for the foundations and the futility of short cuts to learning. From the beginning, the writer counselled these men against their undertaking, but, as they were ordinarily both intelligent and self-confident, he could not keep them from following their own ideas. Finally, the advanced courses were closed to students of this type. We expected some criticism at first, but none came. The questions which were asked by certain men as to why they could not be admitted were readily answered to their complete satisfaction.

As men of this class present, collectively, a problem of a general nature, I may say here that I do not believe that it is possible to receive them in the same classes with the ordinary college student. The latter is presupposed to have a certain fairly uniform preparation for his work; the preparation of the former, on the other hand, is almost always inadequate and much has been forgotten of what had once been known. The college student, therefore, can be taught in the conventional way, but men of maturity must be taught each as a separate problem, with different difficulties to solve. Then, again, the college student is joyfully ignorant of practical experience and responsibilities, and the college teacher must bring these home to him as best he may; the practical man, on the other hand, has learned them in the school of hard knocks, and not infrequently comes better equipped than his teacher, so that what is good advice to one man is a platitude to the other. But the greatest difficulty in teaching the practical man lies in his unwillingness to fill in the gaps in his training. He probably knows no mathematics, and without this he cannot study to advantage college physics, without which problems in mechanics and machinery are unintelligible. The same holds along other lines.

The purpose of the school when first organized was to offer to the citizens of Louisiana the opportunity to secure such training as would qualify them to enter most advantageously the sugar industry of the state. The underlying idea, therefore, was to train men who would be competent to manage plantations which both grew cane and made sugar; that is to say, they were to be trained in agriculture, engineering and chemistry.

FOUR-YEAR COURSE CHANGED TO FIVE

The course, as formulated in 1897, was four years in length. During the last two years the students spent the sugar season at the Sugar Experiment Station at Audubon Park in practical sugar house work. It soon became clear, however, that a satisfactory foundation could not be given to high school graduates in two years, so, in 1899, the course was made five years in length, the first three years being devoted entirely to foundation subjects and all technology being avoided. During the fourth and fifth years the student was sent, as heretofore, to the sugar house at Audubon Park, returning at the end of the sugar season and taking up his work for the rest of the year. At the end of the fifth year the graduates received the degree of Bachelor of Science. Here, too, there was a little dissatisfaction. The Sugar School students thought that if the Engineering students received their B.S. degree at the end of the fourth year, so should they. At the end of the fifth year they could then receive another degree. There was a certain specious justice in this claim, but it was not granted. At the end of the fourth year the sugar school student would not be sufficiently trained. If he were to receive a degree then, however, he would be more than likely not to appreciate the deficiencies in his training. A degree is a *summum bonum*—an end in itself to most college students. These students were also anxious to get into practical work. Why work a year longer for a degree when they already had a degree? This argument would have been conclusive with many students and most parents. So the course was fixed at five years and the student got his B.S. degree in five years instead of four. This was done because the five years were necessary and those who did not like it were told that it was a rule of the school and could not be changed. The results justified the means and to-day the students take special pride in this particular feature of the course.

There was some fear, at first, on the part of the authorities, that a five years' course would drive away the desirable students, but such has not been the case. As a matter of fact, the Sugar School has had more students than it could well care for and they have been men of an exceptionally high class, which merely goes to prove again that, in matters educational, if a thing is well worth while the best men do not count the price, whether in time or money. So far as the writer knows, this was the first five years' course in Chemical Engineering ever offered in this country.

From the beginning, there was a strong demand for the graduates of the Sugar School. Ordinarily they were placed six months before they graduated and, as they made good without any exceptions, the requests became year by year more pressing. Most of the larger sugar houses began to put in laboratories and chemical control slowly displaced the old rule of thumb. About 1901, the demand for chemists became so great that two or three of the best fifth-year men were allowed to omit the second year of the practical course at Audubon Park. Instead they were sent to a sugar factory where they were paid the regular salary of an assistant chemist and worked through the season under strictly commercial conditions, returning to the University when the season was over. It was immediately apparent that these men had gained something which gave them a marked advantage over those students who were taking the routine fifth-year course at Audubon Park, but it was a little hard to tell wherein this advantage lay. Perhaps each man had benefited in a different way. To one it gave self-confidence, to another an appreciation of actual working conditions, to a third a knowledge of men as distinguished from boys; to all, a certain sense of responsibility and a maturer point of view.

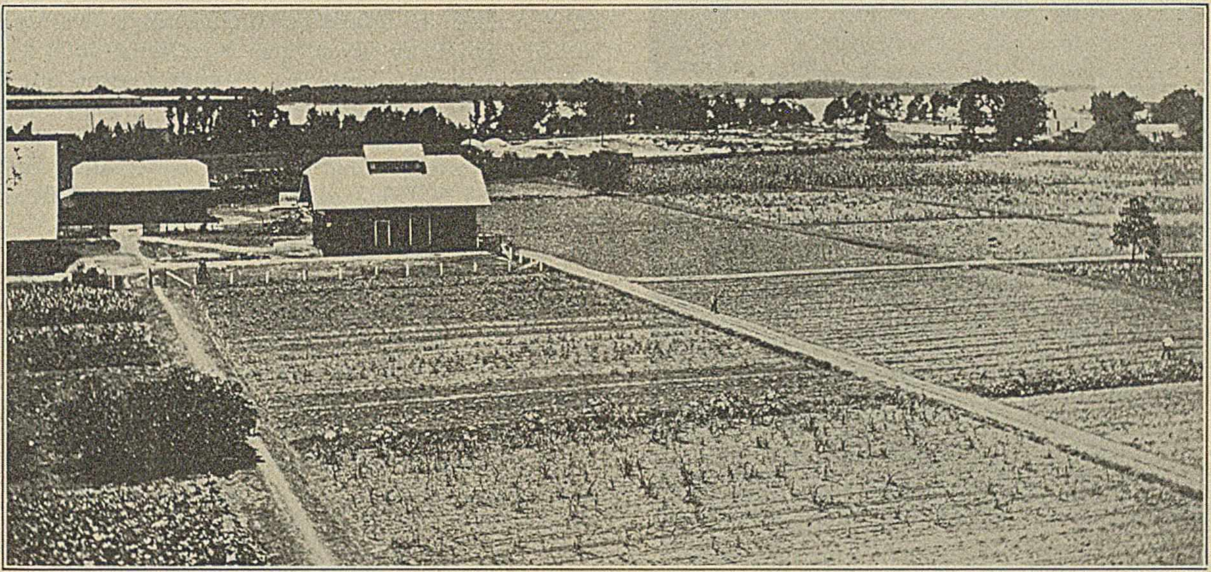

Fig. II—General View of Plats at Experiment Station, Audubon Sugar School

FACTORY WORK IN FIFTH YEAR

The fifth-year practical course had been formulated and carried out at Audubon Park and in the laboratory with great care. It contained many things which the student, by going to the factory, would not get, and which it was desirable he should get, so the actual factory practice was permitted with some degree of reluctance and a little fear that we were making a concession to a popular demand. But its undoubted advantage, largely psychological, over the routine course was so marked that in 1903 the sending out of the fifth-year students became a part of the established policy of the School and has remained so ever since. The planters met the movement more than half way and have given the students every possible assistance. These young men receive the same salary as other assistant chemists and for more than ten years there has not been one who failed to receive employment. An incidental but most important result has been the strengthening of the relationship between the sugar planters of Louisiana and the Louisiana State University. The students bring back to the University an intimate knowledge of the actual conditions in the various sugar houses and of the practical problems which are continually presenting themselves. The planters, on the other hand, discuss these conditions and these problems with the various officials of the Sugar School, sometimes personally, sometimes by correspondence, but always with perfect freedom.

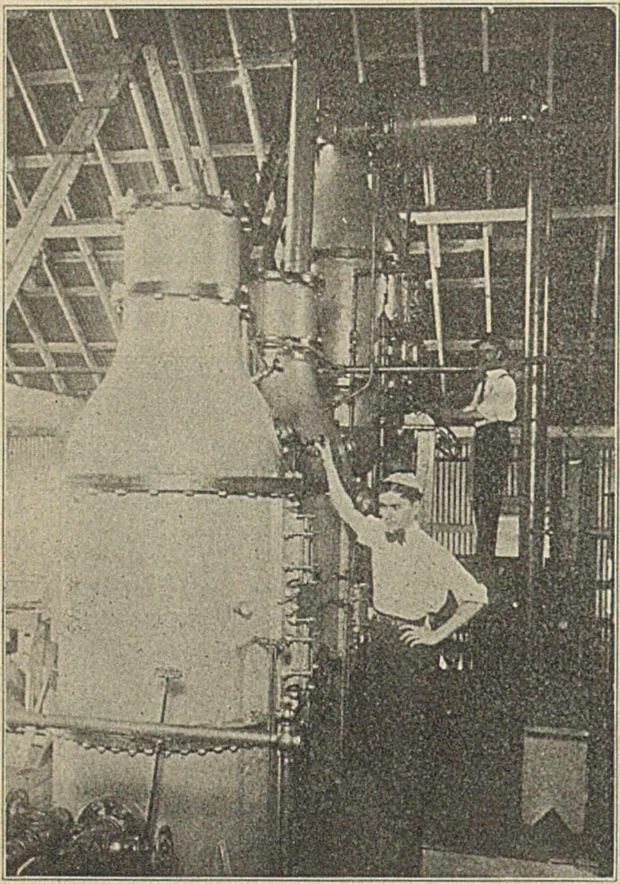

Fig. III—Evaporators and Pan in Sugar House

In order to get a certain breadth of view as to the Louisiana cane sugar industry it has been the custom of the writer to visit the various plantations during the sugar season. After a good many years of personal experience, the writer has come to the definite conclusion that this personal contact between the students and teachers in the School of Chemical Engineering, on the one hand, and the chemical plant, together with its responsible officials, on the other hand, is absolutely necessary if the school is to attain even reasonable efficiency. In each industry this contact may be obtained in a different way. In the Audubon Sugar School the practical method has just been outlined.

As these students are absent from the University in the fourth and fifth years for eight to ten weeks of the first term during the sugar season, they cannot be taught in the same classes with other students during the eight or ten weeks when they are present. They are, therefore, taught in different sections from the other students during the first term, the second term, of course, presenting no difficulties. This method placed some extra labor on the teaching staff, but it was the only logical way and has worked well in practice. There seems to be no reason why it could not be applied more generally to the articulation of courses in chemical engineering with the various industries studied. In this connection, the writer might say that he is convinced that, in the fifth year of a course in Chemical Engineering, the student should get away from generalizations and try to master reasonably well the details of some one particular industry. The confidence in his own ability which a student gains by thus narrowing his field of study, stays with him should he, by chance, find his opportunity in some other line of chemical industry.

INTRODUCTION OF AGRICULTURAL AND ELECTRICAL COURSES

As soon as the Sugar School was fairly under way, students began to come from all parts of the world and as, at the time, it was easier to secure a position as a sugar chemist than as a sugar agriculturalist, there was a tendency on the part of the student to stress Chemistry and Engineering at the expense of Agriculture. This tendency was encouraged by the unsatisfactory state of agricultural teaching twenty years ago. As the old professor of agriculture slowly began to resolve into his component parts and the professors of Agronomy, Soil Physics, Animal Industry and the like took his place, there was a notable tightening up along all lines of agricultural pedagogy. Full-term courses were offered where two or three weeks had sufficed and the increased efficiency of agricultural teaching began to appeal to students generally. But the Sugar School students found themselves in need of a very special type of tropical and subtropical agriculture, where the conditions were altogether unlike those in ordinary American agronomy. To meet this demand, it was decided in 1907 to offer such courses in Sugar Agriculture in the last three years of the Sugar School, these applying specifically to the conditions on cane plantations in Louisiana. At about the same time, Congress made it possible for the Experiment Stations to do experimental work in Mechanical Engineering. In Louisiana, this work was placed in charge of Professor E. W. Kerr, as professor of Mechanical Engineering in the Audubon Sugar School, and was concentrated on the specific problems in the sugar houses of Louisiana, such, for instance, as evaporation, bagasse burning, boiler efficiency and the like. As new fields in Sugar Agriculture and Sugar Mechanics began to develop, it became evident that even five years was not sufficient time to give students satisfactory courses in these and in Sugar Chemistry as well, so, in 1912, a course was formulated in Sugar Agriculture with Professor A. F. Kidder in charge of the special work in agriculture, the course including Chemistry and Agriculture, being distinct from Sugar Engineering which included Chemistry and Engineering. The practical work on the plantations and at Audubon Park was the same for each course. The student chooses one course or the other at the beginning of his junior year, and as there is an increased number of openings for scientific agriculturalists in sugar countries, this division has its fair share of students. It is possible that students under exceptional circumstance might find it desirable to specialize in Sugar Agriculture and Engineering, leaving out most of the work in Chemistry. Though no demand for this has yet arisen, the courses are so formulated that the demand can be met without any difficulty.

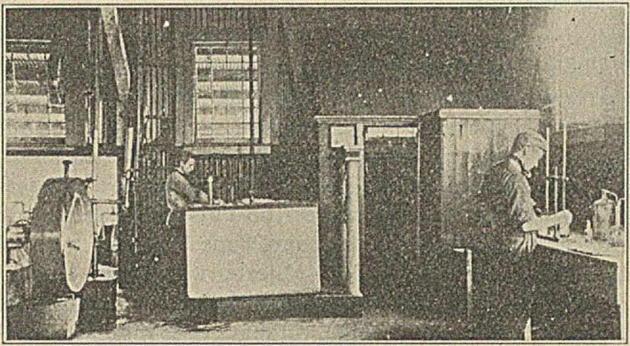

Fig. IV—Students Keeping Chemical Control in the Factory at the Audubon Sugar School

It is fair to infer from our experience in this respect that after a school of Chemical Engineering has been mainly associated with some given industry for a term of years, it would become necessary to arrange that the students have suitable latitude in elective subjects for the last year of the course. For instance, during the last year or two, many of the larger sugar mills have been changing over from the steam drive to the electric drive and it is generally believed that electrically driven machinery will largely supplant steam driven machinery in the near future. For this reason, there has arisen lately a demand for more Electrical Engineering in the sugar course, which demand we are now prepared to meet by offering as electives, special courses in that subject.

ADMISSION OF COLLEGE GRADUATES

As the value of scientifically trained men became recognized by the sugar industry throughout the world, students came to Louisiana from practically all of the sugar-producing countries. Japan, China, the Philippines, Mauritius, Tahiti, Hawaii, South Africa, France, Spain, Italy, Germany, Sweden, Norway, England and every one of the South and Central American countries have sent students to the Sugar School. In many cases these were already college graduates, and there was some difficulty in articulating their previous training with the regular Sugar Course. The first three years of the Sugar School, however, are devoted to pure science, and technology is avoided as far as possible. Students get Mathematics through Calculus, Inorganic, Organic, and Analytical Chemistry two years each of Physics, Mechanical Drawing, Mechanical Engineering, and one year of Electrical Engineering, together with English and some foreign language. As these subjects are covered in the Chemical Engineering courses at Cornell, Boston Tech., Illinois and other standard institutions, we decided to credit the first three years' work done in such institutions for the first three years of the Sugar School, without endeavoring to make a substitution of subject for subject. The last two years of the Sugar School, therefore, were made, so far as possible, of graduate nature, open to students who had had three or four years of college training and who were prepared to take the courses offered. In this class there have been graduates of various universities both in the United States and abroad. These have been matriculated as graduate students, candidates for the degree of M.S. Their courses have ranged from one to two years in length, depending upon the nature of the preliminary training. This system of articulation of a highly technical course with an undergraduate degree has been in use now for about 12 or 15 years and has worked out admirably because of the elasticity in electives permissible to the graduate student.

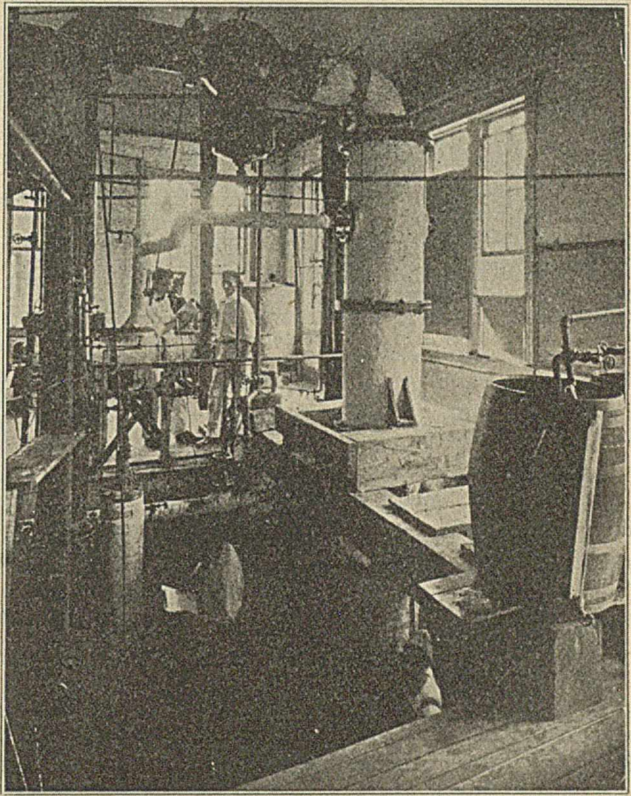

Fig. V—Apparatus for Experimental Study of Evaporation Mechanical Laboratory, Louisiana State University

There has been a decided tendency on the part of the graduates in Mechanical, Electrical and Chemical Engineering to apply for graduate courses in the Sugar School. We have arranged courses for such students and have found that they can cover nearly twice as much ground in a year as can the average undergraduate. A number of these men have gone into practical work with uniform success. In other words, the attitude of the Sugar School towards graduate students is something like this: For the mature man who is a college graduate and wants to take up this kind of work, it is fair to assume that he knows what he wants, so he is treated not as a boy but as a man and, in electing his course, he is allowed every latitude compatible with common sense. For instance, these courses hitherto have included the practical course at Audubon Park and some sugar house experience, but both these requirements would be waived in the case of the man who was already familiar with sugar house processes.

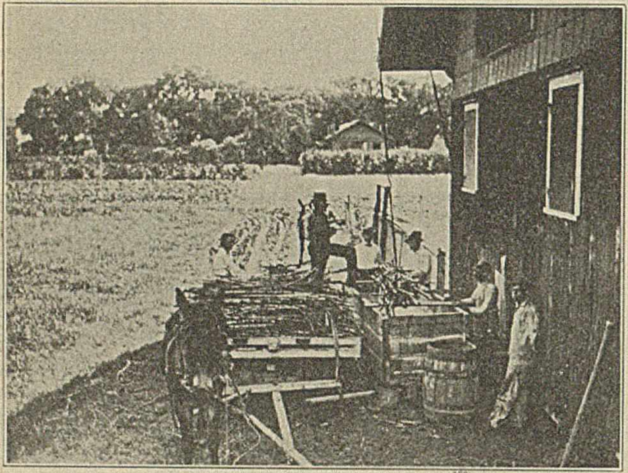

Fig. VI—Dipping Cane in Whale-oil Solution
Experiment in Control of Sugar-cane Mealy-bug

As at present organized, then, the course of the Audubon Sugar School is five years in length and leads to the degree of B.S. The first three years are given to general scientific training similar in type to that given in most standard schools of Chemical Engineering. The technical work is given entirely in the last two years, which, therefore, include most of its distinctive features. As the method of articulating the practical and the theoretical is the result of a number of years of experiment and experience, it might not be amiss to give it in detail. At the beginning of the fourth and fifth years, the student reports to the university about the 20th of September. He stays there until the opening of the sugar season, the date of which depends somewhat upon crop conditions, but ordinarily ranges between the 18th and the 25th of October. This gives him one full academic month at the university. The sugar season in Louisiana lasts until from the 10th to the 25th of December, some smaller estates finishing earlier and a few larger ones, somewhat later. The university assumes that they all close before the end of the Christmas holidays at which date the student must again report to his classes. This gives him one academic month before the mid-term examinations in February. He is therefore present at the university during the first and last month of the first term and is working at the sugar house during the second and third months, allowing a margin of about a week for overlapping, due to crop conditions.

FOURTH-YEAR WORK

The subjects taken by these students while at the university during these two months are of two types: The first type is strictly technical and special, as for example sugar house control, sugar machine design and sugar chemistry. Lectures in these subjects stop when the student leaves the university and begin when he returns. The second type includes general engineering and chemical subjects which are elected by other students, such as thermodynamics and machine design. The Sugar School students take half the usual number of such subjects for twice the usual number of hours per week, which requires extra sections. During the second term they report with the regular college classes in all subjects. This increases the work of the instructors for the first and fourth month and lessens it for the second and third, but as the number of class hours involved is not large, the method has worked well in practice. Laboratory subjects present, of course, no special difficulties.

During the first month of the fourth and fifth years all the students concentrate mainly on the technical chemistry and engineering of sugar house practice. As considerable planting is done during this period, they also visit the plantations under the direction of the professor of Agronomy, as occasion presents itself. The whole sugar squad is under the general charge of a special instructor in sugar technology who is generally one of the superintendents of one of the larger tropical sugar houses and is thus in immediate touch with the industry in its most recent developments. He accompanies the fourth-year sugar squad to the Sugar Experiment Station, Audubon Park, New Orleans, and remains with them during the sugar season, at the close of which period he leaves for his regular work in Cuba or elsewhere.

When these fourth-year students reach Audubon Park, they have been drilled in the routine analytical processes of sugar house laboratories and in the general mechanical principles of sugar house machinery. At Audubon Park, the university has a sugar house, cane fields, chemical laboratories—both control and research—bacteriological and entomological laboratories and a full equipment of all apparatus necessary for the investigation of any ordinary problem, chemical, mechanical or agricultural which might arise in connection with the cane sugar industry, the whole representing an investment of something over $100,000. Under the direction of an instructor, the student squad is brought into personal contact with each of these various lines of activity, and, to the same end, the squad is visited once a week by the Dean of the Sugar School, the professor of Mechanical Engineering or the professor of Agronomy. The United States Government maintains at the Park a department for the investigation of insects injurious to cane, and the students must keep up with the progress of these investigations. Immediately after reaching the Park, the students are put to work planting cane. This fall planting is finished in three or four days and is done by the students themselves in the most approved manner under the supervision of the director of the Sugar Experiment Station. At the end of this time the field hands begin to cut cane and deliver it to the sugar house. Thereupon the sugar squad is divided into ten sections which are assigned each to a specific station. The sugar house has a nine-roller mill grinding somewhat less than one ton of cane per hour, the juice being discharged into a cane weigher. This is Station I and the work is done by one division of the squad. From the weighing tank, the juice passes to the sulfuring and liming tanks, which make up Station II, thence to the open clarifiers, Station III, thence to the settling tanks and filter presses, Station IV, thence to the double effects, Station V. The syrup from the double effect passes to the vacuum pans, Station VI, and the grained massecuite passes to the mixer and centrifugal, Station VII. There are also bag filters, plate presses and a Sweetland press through which the juices are run for experimental purposes; these make up Station VIII. There are around the house a number of small engines and pumps; the care of these make up Station IX. To each of these stations, a small squad of students is detailed for two or three days so that every man makes the round of the stations about twice. The chemical control is Station X and rotates with the others. Samples are taken of the cane, the juice, the press cake, the bagasse, the syrup, the massecuite and the molasses and the requisite analyses made. A very elaborate system of chemical control has been instituted in as great detail as in the 2000-ton houses, specially printed blanks being provided for this purpose, the whole system being practically identical with that of the larger Cuban and Porto Rican sugar corporations. The laboratory is provided with an adding machine and also one for multiplying and dividing, so that the students may become familiar with these important labor-saving devices. Complete daily and weekly reports are made out and special stress is laid on the arithmetical side of sugar house control. The importance of this phase of chemical engineering is sometimes overlooked. It not only helps make the chemist a more valuable employee, but it also helps him to realize what he is doing and why.

From the engineering standpoint, in addition to the foregoing stations, certain squads make detailed reports on the efficiency of the various pumps, the mills and the evaporating apparatus.

From the agricultural standpoint other squads study the result of the field experiments at Audubon Park for the last twenty-five years, and learn the practical methods employed in agricultural research as applied to sugar cane.

During the fourth-year season, the squad is sent, two at a time, to the state sugar factory at Angola, La., a 1500-ton house, thoroughly equipped for making either white or 96 test sugar. Here they help in carrying out sugar house control on the large scale and under competent direction.

FIFTH-YEAR WORK

At the end of their first season, therefore, the students are fairly familiar with the technique of every part of the sugar house, though of course they are not skilled artisans. They are able to make out a complete report on the chemical control of the sugar house and, to some extent, on the chemical efficiency of the process. In the case of the students in sugar agriculture, they can also make out a report on the condition of the cane fields and their various agricultural requirements, such as fertilizers, drainage and the like. Most of the work on the purely theoretical side of both sugar chemistry and sugar engineering is given to the students on their return to the university, to which end a special equipment has been provided. For instance, there has been installed an elaborate apparatus for the experimental investigation of evaporation which has made possible a considerable quantity of research work along this line.

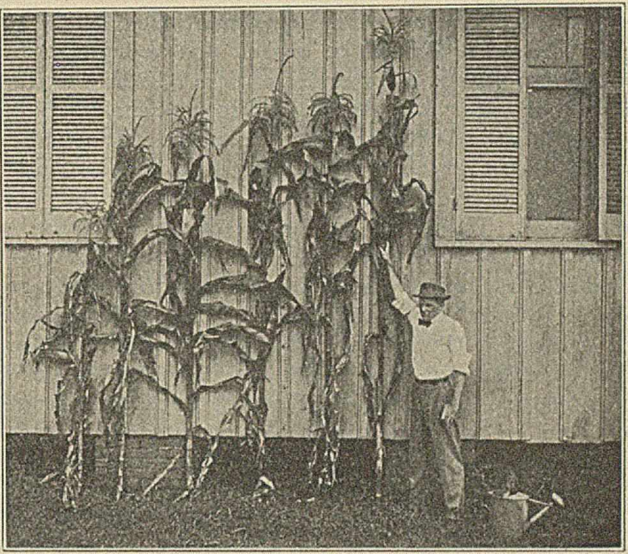

Fig. VII—Showing Results of Fertilizer Experiments

The fifth-year students, also, put in the first month at the university, concentrating on the details of various phases of sugar technology and paying special attention to speed and accuracy in their analytical work. They likewise study the principles underlying the various instruments they are to use in the chemical and mechanical control of the sugar house—as for example, the polariscope and the indicator card. When the season opens they go into actual sugar house practice at various factories over the state and stay through the sugar season. These students are treated simply as employees, are given no special favors and expect none. They draw the same salary as any other sugar chemist and hold their positions only on their merit. The Dean of the Sugar School makes an annual inspection of these factories during the sugar season and thus learns both what the students are doing and what the management expects them to do. After their return to the university at the end of the sugar season, they devote the rest of the year to the various subjects outlined in their courses.

The fourth and fifth years of the sugar school, therefore, are quite special in their nature and are open to graduates and senior students of standard schools of engineering. The student of the graduate type is classed according to his preliminary training and allowed to elect such subjects as he may be able to carry out profitably, the utmost latitude being given him.

The Audubon Sugar School is now twenty-five years old. The number of students during the past five years has been 124, 94, 65, 70, 75. The School graduates each year from 10 to 25 students. These young men have made good without exception. They are scattered all over the sugar world and occupy many of the most important positions in the sugar industry, which facts are taken to indicate that the school is founded upon correct pedagogic principles.

CODE OF ETHICS

Just one thing more might be mentioned in closing. It is somewhat difficult to discuss this and yet its extreme importance is beyond question. From the time a student enters the Audubon Sugar School until he leaves, it is the writer's custom to call frequent attention to the fact that no student can hope to learn much chemistry or mechanics or anything else of that sort at college. He merely learns where the literature is, what the problems are and how to study them for himself personally. One thing, however, he can learn at college and that is the standard of character necessary for success in Chemical Engineering. These men are not expected to stay engineers or chemists; such positions are only stepping-stones. Each man should hope to be, at some time, a superintendent or administrator and if positions of this type are to be won by merit, that merit must include absolute personal integrity. Any lapse from the highest possible code of honor will destroy the usefulness of a chemist or a superintendent. Absolute truthfulness in work and in reports, loyalty, willingness to coöperate—these things are essential to the highest success in the sugar business.

This is the code of the students in the Sugar School, insisted upon by themselves from the time they enter the university. Lapses are treated with the rude but efficient justice of student self-government and, by the time a man graduates, these standards are ground into him and are a part of his professional character. It is a matter of record in the Sugar School that in all the years of its history, there has not yet been one of its alumni to prove recreant to its personal standards, during the after years of his actual contact with the business world. The graduates of the Sugar School are more or less well-trained in the sugar industry, fair scientists or excellent as the case may be, but in all instances they are honorable men, trustworthy and loyal. They have had this record for a quarter of a century without a break. This is the one point in which the Audubon Sugar School feels it has a right to be proud.

Audubon Sugar School
Louisiana State University
Baton Rouge

THE CONCENTRATION OF SULFURIC ACID

By E. H. Armstrong

Received December 26, 1916

Owing to the unusual demand for munitions and as sulfuric acid is largely used in the manufacture of these products, there has been created a great demand for high strength sulfuric acid running from 93 to 97 per cent H_2SO_4.

In the old days the high strength sulfuric acid required was made very largely in iron and platinum stills. There are a number of other methods used for concentrating sulfuric acid but as all these give a small output and as the demand for the last year required a large tonnage, the tower method, in a large number of cases, has been resorted to by a great many chemical companies; in other cases the acid is first passed down a tower where it gets a preliminary concentration, bringing it up to 62 to 63° Bé. and thence through cast-iron pans that set in a furnace, one above the other; by the time it gets to the last pan, which is directly over the fire, it has attained the concentration of from 93 per cent to 98 per cent H_2SO_4. In this case the gases of combustion from the furnaces pass under the pans to the tower, at which point they become mixed with the vapors from the pan; the mixed gases pass through the tower and thence through a system of scrubbers to the atmosphere.

There is quite a difference in the methods pursued in building the towers, and also the arrangements of the scrubbers for the recovery of the distillates. But the principle of concentrating in towers is the same, as practically all the engineers engaged in constructing the plants use quartz for the packing and an oil flame for generating the heat.

The writer has had considerable experience recently in supervising the operation of some concentrators. There was very little known in the South, previous to the last year, about concentrating acid to such high strength; this being true, it was largely a question of experimenting to find the best method of operating.

CHEMICAL DISINTEGRATION OF QUARTZ PACKING

One of the first conditions that the writer observed was that an apparent obstruction would develop in the towers after a week to ten days' operation, necessitating shutting the plant down and washing the tower, after which the plant would usually run very satisfactorily for another week or so. During the above-mentioned washouts, the writer observed a very heavy non-gritty substance coming from the tower. It was then concluded that this substance must be silica and as silica could only come from a chemical disintegration of the quartz in the tower packing, the writer became convinced that the quartz was undergoing a chemical disintegration, most especially as there was a considerable quantity of aluminum in the acid passing over the tower.

This was finally proven to my entire satisfaction by the fact that after some weeks' operation, the plant would show all symptoms of the tower being too open and, in one case, it was found that more than one-half of the quartz originally in the tower had gone in solution and passed out. In others it was found that channels had formed through the packing, owing to the dissolution of the quartz. In view of the above, there can hardly be any disputing the fact that under the conditions prevailing in the concentrating tower there is a chemical disintegration of the packing. Before the writer had acquired the above-mentioned evidence, the question was taken up with a number of very able men, but in no case did they subscribe to the theory that there could be a chemical disintegration of the packing.

On three different occasions, one of our towers became so open that it would not concentrate beyond 63° Bé. and in each case the tower was got back to as good condition or better than it was when first built, and in one special instance the plant was brought up from 9 tons of 66° Bé. in 24 hrs. to 29.9 tons in 24 hrs. The actual time the plant was stopped to make the above stated change did not extend over 2$^1/_2$ hrs. The condition was remedied by simply removing the lute on top of tower and introducing a piece of ordinary light cast-iron drain pipe through the opening in tower top and passing small pieces of broken quartz through the pipe into tower. The end of the pipe was moved about as desired, thereby making it possible to place the quartz in any part of the tower. During a period of several months there was put into this tower as much quartz as was originally used to pack it, yet at the end of this period the tower did not contain any more quartz than it did when it was first started. As there was no quartz removed from the tower at any time it is quite evident that the packing was being removed by the action of heat and acid.

At one time, after the tower had been cooled off, an examination by means of an electric light let down in the tower showed that on one side the packing was gone until there was very little left over the arches. On that particular occasion it took 40 kegs of broken quartz to fill in the crevices in the tower so as to bring that side of the packing up level with the rest. One party, who was operating a plant built similar to ours, advised that he usually washed his tower out with water about four times, after which he had to shut it down and repack the tower. This man's experience bears out the theory advanced by the writer, that there was a chemical disintegration of the packing under the conditions prevailing in the concentrating tower.

PLAN AND OPERATION OF A TOWER CONCENTRATING PLANT

There is a series of symptoms present that if properly followed out will generally lead one to a proper understanding of the trouble. In order to make this plain, I will briefly describe a general lay-out of a tower concentrating plant. There is a small brick furnace into which the oil is sprayed by steam. From this furnace there is a flue leading into the side of concentrating tower. This tower has a brick lining and brick arches and is packed with about 4 ft. of small quartz, leaving about 5 ft. of space between top of tower and top of packing. The acid is fed to the tower by a syphon-and-boot arrangement so that there is about $^1/_2$ cu. ft. sprayed over the packing about once every 50 seconds. After the boot has become nearly empty the syphon gets air, which stops it from flowing; the boot in the meantime is being refilled from a supply tank overhead. When the boot fills to a certain point the syphon automatically starts emptying same, so we have an alternating spray. This is done to give the heat in the tower a chance to recover and the tower is supposed to concentrate better with this arrangement than when fed continuously.

The vapors and mists of acid pass from the tower into the scrubbers through an 18-in. flue, this flue being divided so that one-half of the gas goes into each scrubber. These scrubbers are merely enclosed tanks packed with fine gravel. The gravel packing is supported on brick and coke in the bottom of scrubbers, the brick being so arranged that tunnels or passageways are provided for the gas to pass out through a 12-in. flue in the bottom and thence to the auxiliary scrubber packed with coke. The draught is created in the flues by either a fan or steam jets and as each plant has a certain draught pressure that gives the best results it is generally tried to keep the draught as near this pressure as possible.

In the flue between the furnace and tower there is a pyrometer tube placed, connected by wires to a dial which gives a continuous record of the temperature of the gases entering the tower. In the flue leaving the tower near the top an ordinary glass U-tube containing water indicates the suction inside the flue. There is also placed at this point a Fahrenheit thermometer, so that by observing the temperature of gas entering tower and noticing the temperature and suction in top flue, one can get a pretty good line on the working of the plant. For instance, a tower doing proper work will usually show about 1200 to 1400° F. for the gas entering, and about 280 to 290° F. with about $^5/_8$ in. suction in the flue leaving the top of the tower. When the tower begins to become foul there will be observed an increase in the temperature of gas entering the tower and an increase in the suction pressure in the flue leaving top of tower. Also there will be observed a decrease in the temperature of the gas leaving the tower and when this temperature falls to about 250° F. it will be found that very little 66° Bé. acid is being made.

This condition is corrected by shutting down the tower and running weak acid down same until the packing becomes comparatively cool, after which it should be thoroughly washed with water running over the packing for at least 12 hrs. When the tower is again started it will be found that the temperature of gas entering it will be about 200° F. lower and the temperature of gas leaving it will be 40 to 50° higher with the suction pressure in flue reduced to about one-half to five-eighths of an inch. It is absolutely necessary to maintain a strong suction, either by steam jets or a fan, so that all vapor and distillates will be quickly taken from the tower as rapidly as formed, otherwise they would condense and dilute the 66° acid, thereby undoing the work already performed.

On the other hand, when the tower packing becomes too open so that the hot gases and acid are not split up into minute quantities the acid will pass through without attaining a strength greater than 63 to 64° Bé. and the gases will pass out of the tower entirely too hot, going as high as 350 to 360° F.; also the suction of the flue leaving the tower will drop to almost nothing, while the temperature of the gas entering the tower will decrease from 200 to 300° F.

The above-described conditions were the ones that were corrected by introducing broken quartz through the lute at the top of the tower.

DIFFICULTY WITH AN OPEN BRICK LINING BETWEEN THE PACKING AND LEAD

The writer had a very peculiar experience on one occasion. The tower showed all symptoms of being too open. It was shut down and the top removed but the packing appeared to be in perfect condition. However, as it was quite evident that the gas was passing too freely through the tower and as we had been unable to get any 66° acid from this unit for several days previous, it was decided to remove the packing, not disturbing, however, the 18-in. brick lining between the packing and lead. After the packing had been removed and the tower repacked, the plant was started up, but with no better results than before. It is needless to say that the writer was very much concerned about the matter, as the tower would not produce 66° acid and yet there was nothing apparently wrong with the packing. However, the top was removed again and a very careful examination was made to determine, if possible, how the gas was slipping through the tower with so little resistance. It was observed that the brick wall between packing and lead was very open, there being spaces of from $^1/_4$ to $^1/_2$ in. between the bricks and as the bricks had been laid dry, with the exception of about 3 in. on the edge of the wall, it was decided that the heat was evidently coming up through the wall and not through the packing, as it should. The wall was taken down to the level of the packing (about 5 ft. from top of tower) and acid-proof cement, consisting of silicate of soda and silax, was poured down through crevices in the wall and a small amount of it appeared under the arches, proving that the theory of the heat going up through the wall was a correct one. The wall was then laid from the top of the packing up in mortar made from silicate of soda and silax. This mortar was used very liberally, making the bricks tight with it, just as would be done in building an ordinary brick wall. When this work had been finished the top was replaced and plant started up; it worked beautifully, even better than it had ever worked before.

LOSSES OF ACID IN THE CONCENTRATOR AND REGULATION OF DRAUGHT

In regard to losses of acid in the concentrator under normal conditions, when the tower was being fed with 60,000 lbs. of 60° acid in 24 hrs., the losses would amount to from 2,000 to 4,000 lbs. of 60° Bé. acid per day of 24 hrs. and there would be recovered as 66° Bé. acid about 39,000 lbs., equivalent to 46,792 lbs. of 60° Bé. acid and the balance, or 9,208 lbs., would be recovered in the distillates from scrubbers. This scrubber acid runs about 46° Bé. It is pumped over to the sulfuric acid plant and sent down the Glover tower, where it is brought up to 60° Bé. along with the other acid passing over a Glover tower, after which it is returned to the concentrating plant again.

The losses varied greatly, according to the amount of draught that was used. When a very strong draught was being used it was found that the loss of H_2SO_4 was very much greater than was sustained when only a moderate draught was being used on plant. We, therefore, tried to get the happy medium of using just enough draught to take the distillate from the top of the tower and at same time not to have too great a loss at the exit stack.

In connection with the above, it was found that when using Lunge's method, namely, 10 cc. of $N/10$ caustic soda solution and aspirating gas through the same that the loss of SO_3 would run from 0.25 to 0.5 per cent. This test was made twice daily on each plant and was depended upon to a certain extent to determine the amount of draught which should be used, but as the tower very rapidly became choked, necessitating a constant increase of draught, the testing of the gases was of very small benefit in regulating the plant. However, if it were possible to get a tower packing that would not disintegrate, so that the opening would stay uniform, the testing of the exit gases could be used to a great advantage as a method of control.

Southern Fertilizer and Chemical Company
Savannah, Georgia

PRINTING PLATES FROM PHENOL RESIN COMPOUNDS

By L. V. Redman, A. J. Weith, F. P. Brock

Received January 26, 1917

The growth of syndicate work in illustrated advertising, comic supplement and "filler" for our 30,000 American Newspapers, has created a need for a material which will lend itself to the rapid production of printing plates in manifold.

The plate requires to be produced rapidly and inexpensively and must be of such quality as will print clearly on the cheap sheet used by daily papers.

Such a plate is in no way intended to take the place of copper, zinc, stone or wood cuts where there is needed only one cut or at most a very few cuts of any one subject, such as in the printing of magazines, books, and catalogs. The new plate is designed to fill the need of thousands of daily papers which require the same news to print at the same time, either advertising, comic supplement, news of general interest to the country or "filler" for dailies or weeklies.

Printing plates for this work have been made from celluloid compounds and shellac by pressing the celluloid or shellac plastic into the original papier mâché mat which had previously received an impression from the zinc etching. The celluloid plate is used extensively. The shellac plate does not seem to have made its way to a commercial success. The shellac and celluloid plates will not stand the heat, pressure and moisture required for making the papier mâché mat for stereotype machines. Also the "dots" making up the screen in half-tones of celluloid are not full and perfect. The shellac plate is brittle and requires careful handling.

It is possible that a hard rubber plate would be highly satisfactory. The time of vulcanization, high cost of materials and the fact that hard rubber at 70° C. will distort under pressure are the chief factors against such a plate.

The qualities possessed by phenol resin molding compounds make these materials highly valuable for printing plates. The heat resistance, strength in thin sheets, resistance to water, and the accuracy and speed with which they may be molded make them an excellent material for the production of printing plates in multiple. These plates may be used for direct printing on flat bed presses or may serve as a cut from which to make the papier mâché mats for stereotypes.

Practical difficulties have presented themselves in obtaining a satisfactory mold for use in making manifold plates from phenol molding compounds. If the molds be made from a high-grade steel and case-hardened, the expense is prohibitive; if the original zinc etching be used, a negative figure or picture is produced on the molded phenol sheet; and if a mold be made of the zinc or lead etchings, the pressure required for forming the phenol resin into shape destroys the sharpness of the zinc or lead cut after a few operations.

A satisfactory mold in every way can be made from the phenol molding compounds. The method of producing the mold in which is made the printing plate in manifold is as follows:

A sheet of the plastic phenol molding compound is placed on a hot plate or steam table the same as in shellac molding and is kept there until the sheet has heated through and become soft and pliable. The original zinc etching is then placed on top of the warm plastic sheet and both are placed in a hot press. Any source of heat, gas, steam or electricity, will do for the hot press. In this case steam is the most satisfactory and electricity the least desirable. The pressure is raised gradually to about 2000 lbs. per sq. in., and the compound is allowed to harden for a few minutes. Controlling bars prevent the press heads from coming too close together, and insure an accurate thickness for the mold and later also for the printing plate. Open on every side, the plastic compound is allowed to flow out around the edges. The mold is formed this way to a pre-determined thickness, generally $^1/_{16}$ to $^1/_{32}$ in.

The temperature at which the operation is carried on varies from 285 to 400° F., depending upon the quality of the material used, and the time during which the material is to be left in the press. Longer time and lower temperature give a tougher product than do the higher temperatures and shorter time. In this respect, the hardening of all phenol resins bears a very close similarity to the vulcanization of rubber.

The plastic sheet as soon as it has hardened is removed hot from the press, and the zinc or lead etching is taken off. The plastic sheet is now hard and has on its face the negative of the original zinc etching, and in practice is known as the *mold*. On this negative cast or mold, warm fresh plastic sheet is laid, placed carefully in the press and subjected to pressure for a few minutes. As soon as the fresh sheet has hardened it is removed from the mold. This time the positive printing plate is produced, it being the reverse of the negative mold. This second molding operation requires about ten minutes for a complete cycle of operations, and may be reproduced many thousands of times with no appreciable deterioration to the original mold made from the phenol plastic. Since the average single column cut is about two inches by three inches, and a satisfactory commercial press is eighteen inches by eighteen inches, this allows three hundred plates per hour to be made in a single two-platen press.

Fig. I - Printing Plate Molded already blocked

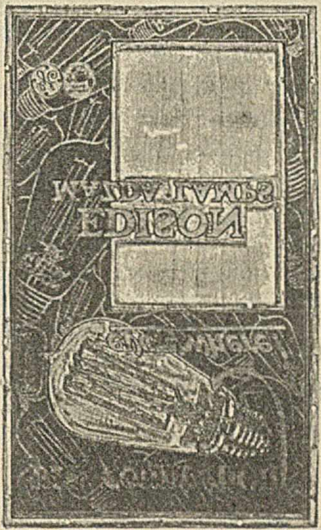

Fig. II - Printing Plate Ready for Mounting Combination of Half-tone, Line & Print

Fig. III - Boiler Plate Ready for Mounting Showing Different Types Reproduced on One Cut ⟶

As the plastic sheet and mold would naturally weld together in the hot press, various methods are used to prevent the plate sticking to the negative mold or cast. A layer of oiled paper, thin metal, talc dust, etc., between the mold and cast has proven satisfactory but care must be taken when using paper or foil to see that it is not torn or trouble may result.

The use of the foil or paper produces a rounded point to the half-tone screen and produces a more desirable printing plate than the original zinc etching which generally has a protruding crown or shoulder thereby allowing ink to collect behind the point, soon blurring the plate. The smooth rounded point produced on the phenol plastic by the use of the intermediate paper or metal foil makes a plate which does not gum up and blur with the printing ink.

Half-tones have been produced from 150-mesh screen and 150 screen is the highest used in ordinary half-tone work. The ordinary newspaper cut is produced from screen not exceeding 100 mesh, as the larger dot is required for printing on coarse cheap paper.

Any form of line work can be reproduced with accuracy and is in general an easier proposition to handle than the half-tone.

Mounted plates may be molded directly upon the block of wood and come from the press blocked and ready for flat bed printing. In this form the cut cannot be unblocked. The plates are also produced in thin form (1/16 inch thick) and are afterwards in another operation blocked by tacking or gluing like the regular zinc cuts. Plates blocked or mounted on wooden blocks by tacking may be readily unblocked.

The weight of the molded plate is one-sixth the weight of the corresponding zinc etchings, and contributes a saving in shipping costs equal to the original cost of the plate. One square inch of plate weighs 1/9 oz. Ready for shipping 35 sq. in. weighs 4 oz. It should be borne in mind in this case that in extensive advertising the cost of mailing or expressing the zinc cuts is often equal to the original cost of the etching.

REDMANOL CHEMICAL PRODUCTS COMPANY
636 W. 22ND STREET
CHICAGO

THE SETTING OF LITHARGE-GLYCERINE CEMENT[1]

By H. E. MERWIN

Received December 26, 1916

A little litharge which had passed a 200-mesh screen was spread in a large excess of glycerine on a microscope slide under a cover-glass. After an hour indications of the crystallization of another substance around the surfaces of the litharge grains could be seen; after three hours the new substance was very apparent; and after 24 hrs. the original grains of litharge were replaced or firmly bound together by interlocking crystalline aggregates of the new substance. These aggregates consisted of radiating fibers.

Grains in a similar slide held at 80° C. for an hour were firmly cemented. The new crystals had similar optical properties in both cases.

Glycerine, pure or diluted with 5 to 10 per cent of alcohol or water, heated to boiling and agitated with litharge, gave similar crystals which were much less closely aggregated. Agitation prevented to a large extent the covering of the litharge grains by the new crystals. In the best sample of material thus prepared—afterwards used for analysis—about 10 per cent by volume of unattacked litharge and 90 per cent new crystals were estimated microscopically. Analysis showed 70.8 per cent of Pb, which corresponds to 5 per cent residual PbO, and 95 per cent of the compound[1] $C_3H_6O_2.PbO$, representing the new crystals.

The crystals are apparently orthorhombic. The refractive indices are, $\alpha = 1.75$, $\beta = 1.80$, $\gamma = 1.84$, with γ parallel to the length. The crystals had been slightly attacked by the alcohol used in washing them.

After standing with glycerine for several days at ordinary temperatures the centers of the larger grains of litharge that had passed a 200-mesh sieve were still unattacked. Probably coarser grains would remain indefinitely.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, D. C.

THE USE OF A CONDENSER TO PREVENT ARCING IN BOMB CALORIMETERS

By FRED F. FLANDERS

Received January 16, 1917

Commercial lighting current of 110 volts is quite commonly used for igniting the charge in bomb calorimeters. A typical arrangement is to connect two 32-C. P. lamps in series with the fuse wire.

Objections have been raised to the use of current of such high voltage on account of the uncertain amount of heat developed by the arc formed at the instant the fuse wire burns out.[2]

The arc may be entirely obviated by the use of a 2 mf. condenser. This is connected across the leads running to the fuse wire and as close to the latter as possible. When protected in this manner the 110-volt current produces scarcely a visible spark when the current is broken.

The use of the condenser might also prove advantageous where a storage battery or other source of low voltage current is used, for even with voltages as low as 10 or 12 volts there is still an appreciable arc when the current is broken. Condensers satisfactory for the above use may be had of almost any electrical supply house, particularly those dealing in wireless apparatus. They are listed as flat telephone condensers, should be of about 2 mf. capacity and tested for 500 volts. A very neat one, 2 × 4 × 3/4 inches, was supplied by the Clapp-Eastham Co., of Cambridge, Mass., for ninety cents.

CHEMICAL LABORATORY
MASS. COMMISSION ON MENTAL DISEASES
74 FENWOOD ROAD, BOSTON

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[1] This cement is very important and not fully appreciated, *e. g.*, it is used in very large quantities in lining the digesters in the manufacture of sulfite pulp.—EDITOR'S NOTE.

[1] This compound was prepared by T. Morawski [*J. prakt. Chem.*, **22** (1880), 401, and *Dingler's polytech. J.*, **235**, 213] in his original studies of this cement.

[2] U. S. Bureau of Standards, *Circular* **11**, p. 7, issue of May 15, 1911. THIS JOURNAL, **9** (1917), 106. Under (6), Firing current.

ADDRESSES

DEVELOPMENT OF CHEMICAL INDUSTRIES IN SOUTHERN CALIFORNIA SINCE JANUARY 1, 1916[1]

By Arthur W. Kinney
Industrial Commissioner, Los Angeles Chamber of Commerce

An eminent authority says that the measure of a country's appreciation of the value of chemistry in its material development and the extent to which it utilizes this science in its industries, generally measure quite accurately the industrial progress and prosperity of that country.

The year 1916 has been the most notable year in the history of Southern California in the amount invested in chemical manufacturing enterprises and in the number of new products exploited. Millions of dollars have been expended in modern plants and more than twenty new products have been developed, samples of which are on display at the industrial bureau of the Chamber of Commerce.

Very few of the people of this region appreciate the opportunities and possibilities which prevail here with regard to an important chemical industry. The great European war, which has curtailed and in many instances completely shut off the old supply of chemicals heretofore imported, has caused an enormous awakening throughout our nation, and has been productive of a large amount of chemical research and investigation. The reason for this is apparent, in view of the statement that the volume of trade and manufacture in the United States at the present time, which is directly dependent on the needs of the chemist, is about $7,000,000,000 per annum. As the months roll by it is being demonstrated that American chemical manufacturers have the brains and ability to produce nearly all substances which have heretofore been imported. In view of the authoritative statement that in California there exists a wider diversity of the crude chemical materials of nature than in any similar area of the world, it is not strange that this section is playing such a prominent part in the exploitation of new materials and is doing its full share in the building up of a great American chemical industry.

In this article we shall dwell only upon those Southern California enterprises which have commenced operation since January 1, 1916.

During the year the Hercules Powder Company has come into the field and invested $1,500,000 at Chula Vista, below San Diego City proper. The improvements consist of barges and harvesters, two of the latter costing $45,000 and $60,000, respectively; a pier 2300 feet long, a floating machine shop, 156 tanks holding 50,000 gallons each and 9 holding 400,000 gallons each. There are housings for an intricate mass of machinery, engines, electrical equipment, laboratories, evaporators, separators, presses, conveyors, etc. Potassium, iodine and acetone are taken out of solution by processes known only to the chemists, of which there are sixteen. Power is supplied by six batteries of Edgemoor boilers, with a capacity of 2700 horse power. The plant covers an area of several acres.

At the harbor district of Los Angeles five good-sized kelp products concerns have begun operations during the present year—the National Kelp Potash Company, Oceanic Engineering Company, Pacific Products Company and International Potash Properties Company of Long Beach, and the Diamond Match Company at Wilmington. The product of the latter company is used by the great plants of the Diamond Match Company of national fame. After considerable investigation the Department of Agriculture has decided to locate and operate at Summerland, Santa Barbara County, an experimental kelp products plant which will have a capacity of 200 tons of kelp per day. This institution will cost approximately $175,000, and will give the potash industry a thorough tryout.

POTASH INDUSTRIES

The American Trona Corporation, of which Baron A. de Rapp is president, has completed during the year two costly refineries, one at Trona, Searles Lake, San Bernardino County, where the raw material is obtained, and the other at Los Angeles Harbor, where the concentrated salts are to be refined.

The buildings at Searles Lake, extending a distance of one-third of a mile, are of fireproof construction and include laboratories, engineers' building, auxiliary building, evaporator building, machine shops, power plant equipped with four 500-horse-power Babcock & Wilcox boilers, spray pond, restaurant, offices, sleeping quarters, physicians' quarters with hospital and operating-room and cottages for married employees. A supply of fresh water is brought from the mountains sixteen miles distant.

The buildings of the plant at Los Angeles Harbor are also of fireproof construction and include a refinery building, office building, laboratory, warehouse, machine shop and power plant containing two 500-horse-power Babcock & Wilcox boilers.

The American Trona Company is now shipping potassium chloride from the Searles Lake plant. Other probable products from this and the harbor plants are caustic potash, permanganate of potash, bicarbonate of potash, borax, sodium carbonate, chloride and sulfate.

Another large chemical enterprise which will handle similar products is that of the Solvay Process Company, an $18,000,000 corporation, now erecting a modern plant at Borosolvay, Searles Lake. The buildings of this concern include a power plant, evaporator building, machine shop, crystallization building, warehouses, clubhouse, commissary and cottages. The Solvay Process Company is the discoverer of the process for manufacturing caustic soda and now operates large chemical plants at Syracuse, N. Y., and other cities.

Other sources of potash exploited during the year have been the plant of the Riverside Portland Cement Company and various Southern California beet-sugar factories. From the first-mentioned source many thousand dollars' worth were obtained as a by-product.

At San Diego the Lower California Chemical Company is erecting the first unit of a plant which will be devoted to the making of orcein dyes, using as a raw material the orchilla weed, a moss found growing in vast quantities along the western coast of Lower California. It is claimed that these dyes can be produced cheaper than the imported article and are equal, if not superior, to the same.

DYESTUFFS

Another dyestuff enterprise of the year is the Internal Dye Products Company, which has recently equipped a new plant at Vernon. This company is backed by Los Angeles men and will engage in the manufacture of aniline dyes, using as raw materials the by-products of the local oil refineries and gas plants.

At Corona, Riverside County, the Citrus By-Products Company, a coöperative organization composed of various members of the California Fruit Growers' Exchange, has been in active operation manufacturing citric acid from cull lemons, having used this year over 2000 tons of the latter. The principal source of this commodity has been Italy, where in some sections the industry consumes from one-third to the whole of the lemon crop.

During the year three new concerns have gone into the manufacture of strontium nitrate. This chemical is largely employed in the manufacture of red fire and is used by manufacturers

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[1] Reprinted from the *Los Angeles Sunday Times*, December 17, 1916.

of fireworks and railway signals. The raw material comes from San Bernardino and Imperial Counties. Prior to the war practically all this commodity was imported from Europe. The new companies in operation are F. G. Mortimer Company, at Vernon; Long Beach Chemical Company, and Southern Reduction Company, both at Long Beach. The latter concern also operates a new plant at Vernon, where it is making a high-grade of chloride of lime and chlorine. Another new enterprise at Vernon is the California Chemical Company, which is now erecting a plant for the manufacture of orchard sprays.

The Linde Air Products Company, which operates factories in twenty or more American cities, has just completed in Los Angeles a modern plant for the manufacture of oxygen gas.

During the year the Grand Canyon Lime and Cement Company has equipped and placed in operation a complete establishment for the manufacture of hydrated lime.

The Industrial Bureau has been advised of the erection of a factory at Escondido which will handle eucalyptus lumber from the large groves in that vicinity. One of the important by-products will be eucalyptus oil, now largely used in manufacturing pharmaceutical preparations.

OTHER NEW PRODUCTS

Other new products of the year are molybdic acid salts, made by the Rose Chemical Company and American Alloy and Chemical Company, tungstic acid by the Tungsten Mines Company, and oxide of antimony by the Western Metals Company. In addition to the foregoing there have been made in limited quantities molybdic oxide, ammonium molybdate, ferro-tungsten, ferro-manganese, ferro-vanadium, ferro-molybdenum and strontium hydrate. Crude sulfur from Nevada has found a ready sale among our local manufacturers.

Of more than passing importance has been the exhaustive investigation of the Rittman refining process made by the Independent Oil Producers' Agency and the statement made that while fairly good results have been obtained, the installation of a small plant more closely adapted to California requirements is being considered.

This has been a remarkable year in chemical development, made so largely through the incentive of high prices, and the things accomplished must be gratifying indeed to our business men and chemists. We have here raw materials of great variety; we have by-products almost without number. Adequate research work and the solving of the problem of keeping down the manufacturing costs of production should enable us to convert these raw products into commodities that will eventually bring hundreds of millions of dollars to this region.

Los Angeles, California

INITIATION OF EXPLOSIONS[1]

By Walter Arthur

Received February 2, 1917

Just when gunpowder was first known is a matter of most vague conjecture, but its use was recorded many centuries ago. Its advent into the world brought most marvelous changes into political matters, and at present, is playing the most important rôle in the greatest of all human activity. Accompanying the use of powder and explosives, and closely allied with their development, is another and most important problem—the initiation of the burning or explosion. Powder and explosives afford us a convenient means of doing work, if the energy represented can be made use of at a desired moment and in a manner perfectly safe to those using them. The character of the explosion is dependent upon the efficiency of the method of ignition. Hence the importance of the question of initiation.

Until quite recent times, black powders or kindred mixtures were the only explosives in use; the energy contained was liberated by the burning of the mixture. This required only the minutest flame to start the ignition, as the particles of the various components were extremely finely divided, and a very small amount of heat was sufficient to raise them to the ignition point. The method of ignition was to fill with powder a small opening which led into the powder chamber, and by means of a flame or spark, ignite this powder train from the outside. This was the old method of the match locks and flint locks. Most of the old cannons we see in our parks and public places were of this type.

PRIMERS

In 1799, Howard discovered the substance we know as mercury fulminate. Its ability to fire gunpowder gave rise about the year 1815 to the development of the percussion cap. This is the beginning of what might be termed internal ignition in contradistinction to the earlier method which we may style external ignition.

The percussion cap may be briefly described as a small metal capsule containing a small amount of mercury fulminate, or mercury fulminate mixture, or other mixture with similar properties. This was used by placing it over the ends of a small tube which lead to the powder chamber. When struck a sharp blow, the mixture detonated, giving rise to considerable heat, thus igniting the powder. This method of ignition for firearms was in common use until very recent times and is occasionally seen to-day. The significance of this invention was as great as the discovery of guncotton or smokeless powder. It made the ordinary firearms much more effective by relieving the gunner of any anxiety as to whether he had powder in his pan. It permitted of ready use and made the arm independent of the weather. The combining of the projectile, powder charge and priming charge into one cartridge, has made our breech-loading firearms and machine guns possible.

There are a number of methods of internal ignition; all of them are much alike. In some substances, as in light ammunition, where a cartridge case with a thin head can be used, the priming mixture is placed in the rim of the head. This rim is struck a sharp blow by the firing pin where it is desired to ignite the powder; hence the so-called "rim fire." In most instances the priming mixture is placed in a small cup and inserted in a chamber in the head of the cartridge case, the firing of the priming charge being done by crushing the priming mixture between the cup bottom and the anvil. Many manufacturers of such ammunition place the anvil in the cup, but others make the anvil a part of the cartridge case, the result of the explosion of the primer pellet being a flame of considerable length and intense heat. The primer cup, being held securely in its chamber, allows no escape of flame except through a vent into the powder charge.

The length and heat of the primer flame will determine very largely the character of explosion in the cartridge case. If the flame be short and the temperature not very high, only a portion of the powder may be burned before the projectile leaves the muzzle of the gun. This, of course, lowers the pressure behind the projectile; as a result, a lower velocity of the projectile is obtained. On the other hand, if the primer flame be long and the temperature high, all of the powder may be fired.

The number of mixtures proposed for use in percussion caps and primers is legion; four of these are as follows:

21.9%	Sulfur (flowers)
30.8%	Antimony Sulfide
47.2%	Potassium Chlorate

35.01%	Ground Glass
28.01%	Mercury Fulminate
14.00%	Potassium Chlorate
1.97%	Shellac
21.00%	Antimony Sulfide

53%	Potassium Chlorate
25%	Lead Sulfocyanide
17%	Antimony Sulfide
5%	Trinitrotoluene

51.2%	Potassium Chlorate
25.5%	Antimony Sulfide
8.9%	Sulfur (flowers)
12.4%	Ground Glass
2.0%	Shellac

It will be seen that either potassium chlorate or mercury fulminate is to be found in each of them.

In order to increase the sensitiveness of the primer, an abra-

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[1] Presented before the January Meeting of the Philadelphia Section of the American Chemical Society, January 18, 1917.

sive, such as ground glass, is added. The glass, due to the sharp edges and hardness of its particles, cuts into the particles of fulminate or potassium chlorate, and assists in their breaking when the mixture is crushed under the firing pin, and as the firing of the primer is a result of the breaking of the crystals of the potassium chlorate or fulminate, the sensitiveness is thus very much increased.

MANUFACTURING PROBLEMS

The difficulties encountered in the manufacture and loading of primer mixtures are many. Owing to the extreme sensitiveness of such mixtures to friction or blows, they are usually mixed in the wet condition, and dried after loading into the caps.

In order to secure perfectly uniform results, it is necessary to have a thorough mixture of the various components. In using such materials as potassium chlorate or antimony sulfide, a great deal of difficulty is encountered in getting the proper granulation. Very coarse materials, about 100 mesh, give very poor results; the flame is short and the sensitiveness is poor. The best results come from materials of about 200 mesh; here sensitiveness and flame length are good. The difficulties in using such fine mixtures comes in the mixing. These excessively fine materials are very difficult to mix thoroughly owing to the tendency to collect in small pellets which resist the usual mixing. One of these very small pellets is often sufficient to cause a misfire if it gets into the primer cups.

Another difficulty, comparatively simple in its nature, yet disastrous in its results, comes from overloading the cups. Each cup is designed to hold a certain charge. Sometimes, in careless filling, the maximum charge is exceeded. The anvil is forced in under great pressure, the result being that the pellet of priming material is so hard that the firing pin cannot break it; the result is a misfire.

MODERN EXPLOSIVES

We shall turn now to another class of explosives which require the use of a primer to liberate their energy. In the year 1864, Alfred Nobel, a Swedish engineer, used mercury fulminate for the purpose of filling priming caps to initiate the explosion of nitroglycerine and dynamite. This discovery forms one of the greatest advances of the last century—an advance to which we owe the development of the whole modern technique of explosives, and such giant accomplishments as the building of the Panama Canal. Although discovered some twenty years previous, it remained but little more than a scientific curiosity until a convenient detonator was devised. These detonators or dynamite caps are of two types—that which is fired by burning of a slow fuse, and that fired electrically. They consist of small copper capsules partially filled with mercury fulminate, or a mixture of mercury fulminate and potassium chlorate. The detonating cap to be fired by a slow fuse is exactly as described above, the fulminate being fired by the burning powder at the end of the fuse. The detonating caps fired electrically are as just described, except immediately above the charge of mercury fulminated is a small charge of guncotton which is fired by the heat from a short resistance wire. The electric current necessary for such work depends upon the number of charges to be fired. These detonators are made up in various sizes and strengths, and are numbered from 1 to 10.

Designation No..	1	2	3	4	5	6	7	8	9	10
Charge in grams.	0.3	0.4	0.54	0.65	0.8	1.0	1.5	2.0	2.5	3.0

By the use of electric detonators, a great many charges may be fired simultaneously, thus accomplishing what would otherwise be impossible. This method also allows all persons to retire to a safe distance before the explosion occurs. It also affords a means of detonating quantities of nitroglycerine deep down in the earth, as in oil well shooting.

SUBSTITUTES FOR MERCURY FULMINATE

Recently a great part of the mercury fulminate in these detonators has been replaced by picric acid, trinitrotoluene, or tetranitromethylamine. The strong initial effect is thereby increased; in this way 0.5 g. of mercury fulminate has been made to detonate a charge which required 3.0 g. of mercury fulminate in the earlier caps.

The use of priming substances for high explosives in modern warfare is at present of much interest. The methods of application are much the same as in commercial explosives, the only difference being in the use of a time element in many cases. The initial primers are provided with firing pins which are actuated either by the sudden movement of the projectile in the gun or by the striking of the shell against some resisting body. Since the space in high explosive shells through which a firing pin might move is quite limited, a very sensitive priming mixture is used. Mixtures of mercury fulminate, potassium chlorate, a strong reducing agent, and often an abrasive such as ground glass are used. In order to protect these primers against abrasion and atmospheric agencies, shields or caps of paper or metal are provided. The whole of it must be so arranged that a light blow of the firing pin measuring only a few inch-ounces will suffice to bring about the necessary explosion of the primer. The explosion of the primer detonates a greater charge of mercury fulminate which communicates its detonating influence to the body of the main explosive. Quite often a booster charge is added between the fulminate and the explosive, and in this way the detonating action is built up.

In armor-piercing shells it is desirable that the explosion take place after the shell has penetrated the armor. In this case the action is such that the primer is fired as a result of impact with the shell against the armor plate, this in turn igniting a train of powder so arranged that the main detonating mass will be exploded at the correct moment. Owing to the fact that these shells travel at a great velocity, only the briefest delay is required between the action of the primer and the detonator.

In high explosive shells where the entire action is to be instantaneous, the delay action is omitted, the explosion of the priming charge, detonator and boosting charge taking place in most rapid succession.

In the case of shrapnel shells where an adjustable time action is required, movable trains of powder are interposed between the primer and the main charge, the primer being fired from the set back in the gun. Shells of this type are often provided with two primers—one to be used with the time action, another one to function on impact.

There are various types of cannon primers which we cannot discuss at this time; most of them differ from the small arms primers in size and mechanical details. Some of them are exploded by friction instead of a blow.

MIXING

Some of the difficulties encountered in the manufacture of the various priming mixtures might be of interest at this time. The first thing that naturally attracts attention is the mixing of these compositions, as they must be sensitive to blows and friction. The handling and loading is attended with much danger. As the presence of some liquid in the mixture acts as a sort of cushion between the various particles, these mixtures are usually made up with water or alcohol. After the mixture has been put into place, the liquid is dried out. Some firms handle these mixtures dry, but it is always attended by considerable danger—even in the wet condition, the mixing must, or should be done by hand. Great care must be exercised during the mixing lest some portion become too dry and the friction from the rubbing start an explosion. The mixing tables and the room must be kept thoroughly clean.

Attendant upon the danger from explosion is the danger from poisoning when mercury fulminate is used in the mixture or loaded separately. Not only is mercury fulminate a poison when taken internally, but the dust from it produces dermatitis and skin eruptions.

FIRING PINS

It is interesting to note that the functioning of artillery primers made with a shallow layer of a friction mixture backed by mercury fulminate, is dependent upon the character of the blow. If a light blow is delivered, the fulminate only burns; if a severe blow is delivered, the fulminate is exploded. The character of the point of the firing pin has a great deal to do with the sensitiveness of primers of this type. If a blunt point be used, a much heavier blow is required than if a sharp firing pin be used. If a long taper point be used, much less disturbance of the mixture is produced than if a short taper point be used. A round point also gives less disturbance to the mixture than a triangular or a square point. The maximum effect should be produced by a short taper sharp square point.

THEORY OF EXPLOSIONS

The question has often arisen, "Why does a mixture of potassium chlorate and some easily oxidizable agent explode when struck a sharp blow?" This is not easily answered. The explosion depends, of course, upon the fact that crystals of potassium chlorate are broken or fractured in the presence of some substance that unites with the oxygen very readily. If a substance, like red phosphorus, be in contact with the broken crystals, an explosion of great brisance occurs. If some substance like sulfur is present, which unites with oxygen much less readily, an explosion occurs which is less active and the report therefrom is much less dull. In fact, potassium chlorate and red phosphorus are so active that they can scarcely be mixed without an explosion, while potassium chlorate and sulfur will admit of quite considerable mixing. If potassium chlorate and sugar be mixed we get merely a burning—so slow is the exchange of oxygen.

We may picture in our minds a crystal of potassium chlorate as made up of centers called potassium, chlorine and oxygen all arranged in some perfectly definite manner and held together by lines of force of some kind. When a crystal is broken, some of these lines of force between the oxygen and the other elements are severed, and for the moment are free. If phosphorus be present, which is always on the lookout for its friend oxygen, it immediately seizes upon the opportunity to add another member to its household. The warmth of friendship produces sufficient heat to warm up the neighboring oxygen communities to a state of activity, hence heat, flame and general rearrangement of affairs!

The question is asked, "What happens when a crystal is broken when no phosphorus or oxidizable substance is present?" Of course, this question cannot be answered at present; our knowledge of the molecular arrangement is too scanty. If crystals of mercury fulminate and a few other like substances be broken rather quickly even when unattended by an oxidizing substance, a most severe explosion occurs. But why? This is just as difficult as the other questions. The answer may be made that crystals of mercury fulminate are unstable. This explains nothing. Perhaps some of the recent work of Bragg in crystal structure may eventually give us some information.

The question has often been asked, "What properties of mercury fulminate enable it to act as a detonator, and in what way is the primary explosion related to the principal explosion?" The chief characteristic of mercury fulminate which makes it valuable as a detonating agent, is the ease with which it can be exploded by simple and ordinary means and the wonderful pressure developed therefrom, which brings about the explosive decomposition of the explosive mass. A large number of chemicals are violent explosives and many exceed mercury fulminate in explosive power but are less suitable or are not suitable at all as detonators. Some are too sensitive to shock or friction; some are too insensitive. Some may cause the explosive wave in the main explosive mass to proceed too slowly. Mercury fulminate occupies the middle position. A great number of investigators have attempted to account for the initiating effect of detonating compounds. Abel advanced the theory of synchronism of molecular vibrations between the primary and secondary explosives. This theory is supported by the fact that many substances, as diazo-benzene, nitrate and nitrogen chloride, could be used only in large quantities, if at all, as a detonator of explosives. While mercury fulminate in small quantities was sufficient to produce a detonation, Abel ascribed this exceptional behavior to a resonance phenomenon, which he described as a molecular vibration which brought the molecules of the explosive to be detonated, into a synchronous vibration, thence to detonation. L. Wöhler made a thorough investigation of the Abel theory and came to the conclusion that it was not sufficient to account for the phenomenon. No theory advanced so far seems wholly satisfactory.

It was found by Abel that the most violent exploding compounds, nitrogen chloride and iodide, are practically without detonating action on nitroglycerine and guncotton. Only once could he cause detonating action with 3.25 g. of nitrogen chloride, while 0.32 g. of mercury fulminate was sufficient to produce the detonating action. This remarkable difference is explained by Wöhler, by the enormous pressure which mercury fulminate shows in contrast to that of nitrogen chloride, and, in addition, calls attention to the fact that, although the gases evolved by the explosion of the two compounds are very nearly equal, the heats evolved are only 312 calories per kilo for nitrogen chloride as against 411 calories for mercury fulminate. Wöhler attaches the greatest significance to the fact that the loading density of mercury fulminate is far beyond that of nitrogen chloride.

In spite of the fact that nitrogen chloride has a smaller calorie number and a lower loading density, it is likely that nitrogen chloride produces a greater instantaneous pressure than mercury fulminate. Judging from the shattering effects produced upon glass and similar bodies, nitrogen chloride greatly exceeds mercury fulminate in brisance. If we take into consideration the difference in loading density and heat evolved, we find that difference is not sufficient to account for the tenfold difference in effect.

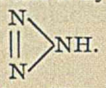
It is common practice to manufacture detonators which are intended for explosives that are brought to explosion with difficulty with a booster charge of a like or similar substance, such as trinitrotoluene or tetranitromethylaniline. This supports rather than opposes Abel's theory.

In the year 1883, Berthelot offered the theory that the detonation of a brisant explosive was to be considered as a sudden wave-like decomposition, propagating through the whole mass, brought about by the kinetic energy of the detonator. According to modern views, however, neither the pressure as such, nor the violent changes brought about by it, is sufficient to account for the detonating waves of a secondary explosive. Another author of recent date agrees with this view that it is the adiabatic heating of the medium in contact with the priming substance, caused by the great pressure which initiates the exceedingly high velocity of the detonating waves.

The action of a blow of a hammer is often explained upon the assumption that the heat, into which the energy of the hammer is transformed on being suddenly brought to rest, heats the portion of the explosive struck to a temperature at which a sudden increase of the velocity of decomposition leads to an explosive velocity. It is quite well known that very sudden heating of an explosive leads to an explosion.

How then can the detonation of an explosive be carried over an intervening air space? The thermal hypothesis will not account for this. This is explained by the compression and rarefaction of the surrounding air. Since the force of such waves decreases as the square of the distance, this theory is not sufficient. From what has been said, it can be seen to be a very complex subject, and how many theories fail when all the facts are taken into consideration.

DETONATORS

For many years mercury fulminate has held its place as a detonating substance as superior to all others. Of recent years, however, its place has been threatened by other compounds which bid fair to displace it. One of the most promising of these is lead azide; lead azide is a salt of hydronitric acid whose constitution is expressed thus:  Some investigators unite it thus: $N \equiv N = N - H$. This acid forms a great number of salts, as mercury azide, silver azide and sodium azide.

The heavy azides, such as lead azides, are prepared by treating a solution of sodium azide with a soluble metallic salt, such as lead acetate, the sodium azide being prepared from nitrous oxide and sodium amide.

Large crystals of lead azide and mercuric azide have been found to be very sensitive to mechanical shock, the sensitiveness increasing with the size of the crystals. Even the breaking of a single large crystal is said to bring about explosion. Crystals as large as 3 mm. in length, when dry, often explode when brushed with a feather. If a hot saturated solution be allowed to cool slowly, large crystals sometimes form, which detonate under water. The formation of such crystals must be avoided. This property is scarcely obtainable with the fulminates.

Mercury fulminate and lead azide differ very greatly in flash point—lead azide flashing about 330°, mercury fulminate flashing about 180°. Lead azide in fine crystals appears to be less sensitive to blow than mercury fulminate. It is very stable when stored at high temperatures, such as 50° C.; it is, however, decomposed by strong sunlight. The action of lead azide upon metals is slight, while fulminate is quite active.

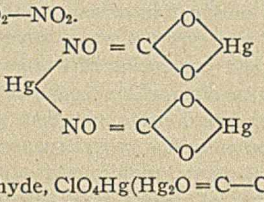
Mercury fulminate may be dead-pressed, while lead azide increases it brisance and explosive power with pressure. If detonator caps be loaded with lead azide and a booster charge, much less lead azide is necessary to produce the desired detonation. The sensitiveness of fulminate to mechanical shocks is much lessened by the presence of as much as 1 per cent moisture, while lead azide is not much lessened by this small amount. This particular property is extremely valuable in case of storage of detonating caps in humid atmosphere.

Many other substances have been proposed as detonating agents. Trinitro-resorcine or lead styphnate $[C_6H(NO_2)_3O_2Pb]$ has been found to be an excellent explosive. Hexamethylamine tri-peroxide-diamine $[N(CH_2O.OCH_2)_3N]$ is said to exceed mercury fulminate 4 or 5 times in priming power.

A number of others may be mentioned as:

Nitrogen tetra-sulfide, N_4S_4.

Diazo-benzol-nitrate, $C_6H_5NO_2—NO_2$.

Basic mercury nitro-methane, 

Perchlorate of tri-mercur-aldehyde, $ClO_4Hg(Hg_2O=C—COH)$.

Dr. Alfred Stettbacher, in *Zeitschrift für das gesamte Schiess und Sprengstoffwesen*, of Oct. 1 and Dec. 1, 1914, has presented a most splendid résumé of recent developments in this field, from which paper I have drawn freely.

Frankford Arsenal
Philadelphia, Pa.

WATER-METERS IN THEIR SANITARY RELATIONS[1]

By Henry Leffmann

Received September 30, 1916

The management of an American city is the despair of the efficiency expert. Ex-President Taft expressed the view that in two respects the promise of better things that had been seen in the formation of the United States under the Constitution had seriously failed of fulfilment: procedures in courts and the administration of American cities. The administration of civil and criminal law in most parts of this country is legalized robbery, and the business and engineering administration of cities is chiefly remarkable for stupidity and dishonesty. I come from a city that has been widely advertised as "corrupt and contented," and daily experience compels me to admit the substantial accuracy of the phrase. In spite of the development of the science of city-planning, miles of small streets are allowed to be laid out, and while the street prism is being excavated for water and gas supply and for telephone conduits, no provision is made for electric light and power wires. High-tension currents are permitted to be carried on hideous poles through residential districts, involving danger to persons and property, and subjecting the service to frequent interruptions from storms. Situated with an enormous supply of fresh water at its boundaries, which, by the construction of simple storage reservoirs, could have been rendered safe for all uses, it was for many years one of the worst typhoid nests in the world. Now, after spending many millions for installing a plant for purification of these supplies, its "Solons" are debating the problem of meeting a greatly increased demand, and, instead of seeking rational means of preventing waste, are looking towards an expensive enlargement of the plant.

I am presenting this paper, however, not to inveigh against any particular municipal administration, but to call attention to a relation between engineering and chemistry that I think is often overlooked. I have long felt that the main sanitary problems of municipal administration are essentially engineering ones, and that undue emphasis is given to the purely chemical data. There is, of course, no phase of municipal sanitation more important than water supply. Water, by the very necessities of our existence, is largely consumed now, and it must be furnished freely and continuously in a perfectly safe condition. We are, unfortunately, accustomed to regard it as without price; we think it should be "as free as air," but this cannot be expected in municipal life, and the sooner the citizen realizes that water should be paid for like food, clothing and transportation, the better for all of us. Indeed, it would be well if the community could be brought to feel that water of high purity is a luxury and should command a good price.

The interrelation between chemistry and engineering becomes still more intimate by the growth of the modern practices of sewage disposal. It has become necessary not only to secure an abundant supply of good water, but to restore it to reasonable purity after it has been used. The time is rapidly passing when a community may take as it pleases from the upper reaches of a stream, and throw into the lower reaches its drainage. From two points of view comes, therefore, the need for preventing water-waste, and thus the question of a controlled distribution is brought vividly to the notice of the sanitarian.

Such control may be obtained in two ways: by an intermittent distribution, the places supplied being provided with storage tanks, thus limiting the amount of water available during the 24 hours, or by measuring the water delivered to each consumer and charging for it, with a minimum rate. The storage-tank method with intermittent pumping is used in many foreign cities, and has some features to recommend it, but with the lavish use of water among Americans, very large tanks would be

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[1] Presented at the 53rd Meeting of the American Chemical Society, New York City, September 25 to 30, 1916.

needed. The meter-system is preferable. The mechanical problems in regard to water-meters are solved and many forms that are accurate, inexpensive and durable are available.

I have residential experience in but two cities, Philadelphia and Atlantic City, but it happens that these present a decided contrast in the matter of water-supply, and serve well to illustrate the point that I wish to discuss.

Philadelphia has been notoriously wasteful of water. This is not due to any tendency to excessive cleanliness. Although about the middle of the 19th century it was often praised by visitors for the conditions of its streets, yet it rapidly fell from grace in this respect, and except as to an incomprehensible and reprehensible practice of frequently washing the sidewalks, it shows, at present, a good deal of general neglect in street management. Many years ago, an English visitor—Tupper, I think—said that "the carriage-ways are always dirty and the footways always clean." At the present time, owing to lack of system for control of the distribution, the consumption is about 300 gals. per person per day; an enormous amount, surely indicative of great waste. Metering is almost non-existent. A few householders have discovered that by installing meters a considerable saving of water rent may be secured, but this is merely the outcome of the ridiculously low meter rates. For some years, indeed, the city ordinances forbade the installation of a meter in a private house, and left it practically optional to large establishments. The mass of consumers are on a flat rate, that is, based on what they may, not on what they do use. How any person charged with the administration of a municipality in any capacity can be so indifferent to business methods as to favor such a method would seem to be beyond human comprehension, but it is after all a "strictly business" matter. Large manufacturing establishments and certain private individuals are interested in maintaining conditions which permit them to use water unrestrictedly, while paying less than their proper share of the expense of the supply, and as these persons exert a good deal of support to the dominant political party, especially in the matter of campaign contributions, a subservient administration ignores the just method.

Turning to Atlantic City—which offers an interesting contrast to Philadelphia, in this as in some other respects—we find according to the 1915 report of the Water Department, that nearly the entire consumption is metered, and that during the months in which the visitors are comparatively few (October to May) the consumption is about 150 gals. per person per day. It must, however, not be overlooked that many hotels have an independent supply from artesian wells, and that the city has almost no industries that are large water users. On the other hand, during the dull season, it is especially the large hotels that are running at restricted output, and bathing is a special feature of the resort. This is largely sea-bathing, yet even this necessitates the use of fresh water both for rinsing the person and for the laundry of bathing suits. Most of the large renting establishments now have running fresh water in every room. The fact that residents are required to pay for the water used does not seem to cause any undue restraint in the ordinary uses, though, of course, it tends to the installation of good plumbing and to keeping this in repair.

The consumption per person in Philadelphia is somewhat difficult to determine, and in any case, regard must be had to the fact that the city is spread over a wide area, and contains a very large number of industrial establishments that are heavy water users. Private sources of supply are not numerous. As a rule, both the subsoil and deep water obtainable within the city limits is unfit for drinking and manufacturing purposes. The pumping data show that frequently the consumption is about 300 gals. per person per day, as noted above, but this figure is based on what is termed by engineers "plunger displacement" and is generally regarded as too high. Moreover, it does not consider leakage in the street distribution system, which is probably rather high. House leakage, especially in the flushing apparatus, is very high.

It is hardly necessary to present any statistics of water waste in American cities for nearly every one is aware of it, but as a brief illustration I give the results of an investigation made a few years ago by John C. Trautwine, Jr., who was for several years chief of the Bureau of Water of the City of Philadelphia. A block of the characteristic two-story, small-street dwellings was utilized.

Number of dwellings (7-roomed)	142
Total number of openings	782
Number leaking slightly	22
Number running continually	32
Gallons delivered in 24 hours	119,800
Gallons wasted by leakage	103,600
Gallons per capita: Delivered	222
Actually used	30
Wasted	192

A large portion of the waste is brought about by a small proportion of users, so that a restriction by metering would affect mostly those who are indifferent to the welfare of others.

As I remarked above, the problem of waste-prevention has assumed an additional interest by reason of the necessity of sewage purification. All communities, and even occupiers of isolated country houses, now recognize that the effluent water must be brought to a fair condition of organic purity, at least, and that the greater the dilution of this effluent the greater the cost and difficulty of treatment.

In the discussion of this subject, the main opposition to measured supply comes from the owners of manufacturing establishments and from a limited number of well-meaning, but misguided people, who believe that some harm will be done if any restriction should be put on the use of water. Their slogan is that "water should be free as air" and that everybody should be encouraged to be clean. A careful examination of the houses in which the worst leakages occur would probably show no greater degree of cleanliness than in those in which the plumbing is kept in repair and the water used with judgment.

The truth is, however, that the same line of argument that is used to prevent the introduction of meters may be used to justify free distribution of food and beverages and free amusement. Moreover, all the data available show that all reasonable requirements may be met by the system of assigning a minimum allowance, and changing a flat rate, imposing additional charges only by those who exceed this. Careful investigations in American cities have shown that 7 cu. ft. (somewhat over 50 U. S. gallons) per person, per day, will meet all necessities in a high-class home in a large city. In Philadelphia, at present, a minimum charge of $8.00 per year allows the use of 200,000 gals., but this is much too large, and it is proposed to raise the price and reduce the allowance so that $12.00 will be charged for 90,000 gals. per year, which in a household of five persons will give about 7 cu. ft. per person per day.

Briefly, then, my thesis is that in view of the importance of pure water the enormous amount now required, and the necessity of purification of sewage, the sanitary engineer and chemist should use every effort to have public water supplies managed with rigid prevention of wastes and reckless use, and that this cannot be done without complete metering of the supply. Consumers should be taught that principles of conservation of resources, as well as proper management of filtration and sewage-disposal plants, require such a system, and further that the installation of meters with the provision of a minimum charge does not interfere with the use of water as freely as health and comfort require. Municipal supplies must depend almost entirely on surface waters. Here and there, artesian and subsoil sources may be available, but these exceptions are of no practical importance. I am still of the opinion that I expressed many years ago in a paper before the Pennsylvania State Board of Health, that unpurified surface-water is always unfit for drinking, and that, as concerning it, analyses—bacteriological and chemical—are academic. The object of science is, of course, the discovery of truth, and from this point of view, any addition to knowledge, whether the discovery of a new marking on Mars or the properties of the circle in non-Euclidian space, must be appreciated, but the sanitarian deals with the purely utilitarian phase of science. I think there is no more important problem before the people of the United States than the conservation of the water supply, and it is the duty of informed persons to insist with all possible energy upon the necessity in economy in the use of water, for maintaining the quality of the original material and for reducing the cost of the subsequent purification of the effluent. For these reasons, I regard the water-meter as a most important sanitary agent.

1839 N. 17th Street
Philadelphia

ADVANTAGES OF SOFTENED WATER IN LAUNDRY WORK[1]

By J. H. Ryan

Received November 8, 1916

My topic to-day is what advantage softened water has over hard water, the saving not only to the laundryman, but also to the customer, and what the possibilities are for the equipment of a modern laundry with an efficient water-softening plant.

The laundries of this country in 1914 transacted business amounting to $142,503,350, and there was paid for labor $71,764,059; the amount invested in machinery, equipments, buildings, etc., was $98,055,000. These figures give some idea of the magnitude of the laundry business, and yet, as a matter of fact, it is still in its infancy. The majority of the laundries in this country are devoting most of their time to the laundering of the provincial stiff collar and shirt, but this portion of the business is by far the smallest part of the work that the average American home has to offer. For example, one man in Michigan decided he would enter the family wash field and in less than one year increased his business over $1400 per week. When the American laundry is properly equipped and makes the proper effort to obtain this class of work, the field is practically unlimited.

It might be well for us to consider for a moment the class of work, also the difficulties that the laundrymen have to contend with. Laundry is cosmopolitan in its service. There is, of course, a wide range in the quality of the fabrics treated. Not many years ago fabrics manufactured in this and other countries were heavier, very much stronger and would therefore stand more grief in the laundry. This class of goods is seldom ever used now; it has been replaced with thin delicate fabrics which are "loaded," sometimes to the extent of from 10 to 70 per cent in order to make them heavy and apparently more durable. Aside from this, every conceivable color known comes to us from day to day, which, in treatment, must receive the utmost care. Hence, the problem is a very different one from that of twenty years ago. The question that the laundrymen are trying to solve is how to do this class of work for American homes with the least wear and tear and at the lowest possible cost.

For more than a quarter of a century I have been in the laundry business. About half of that time I was connected with a laundry that used hard water exclusively. I can best illustrate the point I am trying to make by giving you a little personal experience I had more than twenty years ago. In those days we heard very little about water analysis, or at least the laundrymen knew very little about it. All they knew about washing was this: if they used plenty of caustic soda or soda ash in the soap and a plentiful supply of bleach, their clothes would come out of the machine clean, but very often they were in serious difficulties and did not know just why; neither did they know just how to work their way out of their troubles. The story I am about to tell you will demonstrate beyond any question of doubt, the value of water softening in a laundry and the danger of using hard water.

The laundryman I worked for was troubled a great deal with a yellow or brown cast in his work. His collars always had yellow seams. He insisted that it was the iron in the water that was causing this trouble and at a considerable expense he installed a filter, but this did not do away with his difficulty. At that time, and even now, a great many of the laundrymen use chloride of lime and soda for bleaching purposes; soda is used to soften the bleach, in other words to prevent it from destroying the soap. It mattered very little how much of this bleach was used, there would still be yellow seams and edges on the collars. About this time I read somewhere that oxalic acid was a good bleacher, so I made up my mind that I would do a little experimenting on my own account. I took some collars home and prepared a solution of oxalic and water; in this solution I placed the collars, rinsed them, and immediately the yellow seams vanished but a green tint remained and I had considerable difficulty in washing out the effects of the acid. After the proprietor had inspected the work, he asked me one day how I did it and I told him I had a new bleach; he thought so favorably of the work I was doing that he offered to form a stock company, if I would turn over the formula to them so they could manufacture it.

About this time I became a little negligent about washing the green tint out of the collars, so one day when I had an extra large amount of collars delivered to my home and did the necessary work, the foreman and the proprietor made up their minds I was using sulfuric acid; they proceeded to experiment, sent out for a bottle of sulfuric acid, filled a wooden pail three-quarters full of water and poured in the acid until they thought the solution was sufficiently strong to do the work. They then rinsed in this solution a nightshirt which had a decided yellow tint; the third time the garment went into the pail the boss found himself hanging onto two sleeves, the rest of the nightshirt resting quietly and unattached in the pail; but it had the green tint the same as I had left in the collars; after this operation was over I told them of my secret bleach and when they used oxalic acid in their rinsing and blueing water in sufficient quantities the yellow edges would disappear.

This particular laundryman never knew just why or how the acid was taking care of the yellow seams, neither did he know just what was making the yellow seams; it was the result of attempting to break hard water in the machine by using an excessive amount of alkali.

It is not necessary for me to go into detail in attempting to bring to your minds the great hazard the laundryman takes when he attempts to break hard water in the machine, especially when it is loaded with clothes. You might ask me if there is any danger in using soft water when the water is treated in a water softener. The facts are that the danger is identical with that of the hard water, so far as the use of acid is concerned; the minute the alkalinity is raised above 7 grains trouble starts and then the acid remedy will have to be applied.

There are three water softener systems that are generally used in the laundries of this country: the intermittent, the continuous and the four-pipe systems. The intermittent system is seldom used, so it leaves the field open, practically speaking, to the continuous and four-pipe systems.

About twelve years ago, we had what was known as the old Tweedale system of water softening. The process of treatment

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[1] Read at the 52nd Meeting of the American Chemical Society, Urbana-Champaign, Illinois, April 18 to 21, 1916.

was purely caustic soda; we used this system for about three years and always had trouble whenever we reduced the hardness below 8 grains, because we would always have an excessive amount of alkalinity in the water so that it would take a large amount of acid to neutralize it before we were able to blue or destroy the yellow color that would appear in the goods after they were ironed. The four-pipe system, as I understand it, uses a caustic soda treatment, but they do not attempt to rinse or blue their clothes in softened water; hence the necessity of the four-pipe system. I am very much opposed to the system of washing in soft water and then rinsing in hard, because it destroys all the visible effects of soft-water washing, *i. e.*, that soft velvety feeling that clothes possess when washed and rinsed in soft water. Our water in Kalamazoo is 21 grains and is quite hard—about 3 lbs. of solids to every 1000 gallons of water. It is impossible to wash clothes in our water and reduce the hardness below 3.5 and 4 grains with any degree of safety, for just as soon as the hardness is decreased below that point there is trouble, due to an excess of alkalinity.

We have had splendid results with our water softening system. It has been in operation now for a number of years and we have never had a particle of trouble in our washroom; on the contrary the results have been unusually satisfactory. We use a continuous water softener. The treatment is 280 lbs. of building lime and 40 lbs. of soda ash to every 100,000 gals. of water. Under this treatment our water tests hardness 4, alkalinity 5 and causticity 3.5 grains per U. S. gallon.

We have not used any chloride of lime or oxalic acid since we installed our water softening plant. We use a little acetic for our blue. We have always claimed that the secret of good washing was pure clear soft water and I believe we have demonstrated this beyond any question of doubt. We believe we are doing more family washing than any other city in America twice our size and we attribute this largely to the method of treating our water and our washing methods in general.

SAVINGS MADE BY USE OF SOFT WATER

As an experiment we washed recently 100 shirts in raw hard water with 3 lbs. of neutral soap; we washed this same number of colored shirts in the same machine with the same amount of soft water with 1 lb. and 6 oz. of the same soap. We washed 95 lbs. of family washing in raw hard water with $2^1/_2$ lbs. of neutral soap; we repeated the same operation and with the same weight of clothes and the same amount of soft water as hard water with $1^1/_4$ lbs. of soap. All the soft water used tested 4 grains. This is not all the saving, however; the bleach is reduced to a minimum and no acid is required for the purpose of neutralizing alkalinity left in water or getting proper color. If we did not have a water softener, we would use about 1400 lbs. of neutral soap per week. The present market value of neutral soap is about $0.07, which would make our soap bill $98 a week. Our saving is thus about $50 per week.

The laundries using chloride of lime and oxalic acid are finding them a very expensive commodity at present. To my mind the present abnormal condition of the market is one of the best things that has happened to many laundrymen for a number of years, because it has taught them that laundries using the proper kind of water softener can and do get along without the use of those chemicals and do better work. After all, what the laundry business needs more than any other one thing is plenty of pure clean soft water, and when a laundry will install a system of water softening that will produce this kind of water, a large share of its troubles will cease and the customers will be happier for they will receive their clothes clean, clear and soft. White goods will be white, soft, and last longer than when washed under any other process known to the writer.

KALAMAZOO, MICHIGAN

STREAM INSPECTION IN CONNECTION WITH THE OPERATION OF SEWAGE TREATMENT WORKS[1]

By C. B. HOOVER

The treatment of the sewage of municipalities is made necessary in order that the natural advantages of our streams may be conserved. These natural advantages consist in the opportunities which our streams furnish as sources of supply for public water works and power purposes, for recreational activities, and as an important factor in adding beauty to the land.

The discharge of sewage into a stream of water may convert it into a foul open sewer, or, it may have no appreciable effect upon the stream, the result in any case being governed largely by the composition of the sewage, the dilution which the stream affords, and the prevailing temperature. There may be found to-day almost any combination of these three factors and in fact in most of our larger inland towns and cities, a wide range of combination of these three factors may be observed within a period of one year, *i. e.*, a given volume of sewage will encounter in the stream a widely varying dilution, and, in turn, the mixture of sewage and stream water will be subjected to widely varying rates of oxidation, due to changes in temperature during the year.

The object of sewage treatment is to prevent harmful stream pollution and broadly speaking, this means the prevention of the discharge of pathogenic bacteria into the stream, or, the prevention of a nuisance in the stream, or both. When the problem is simply one of eliminating pathogenic bacteria, chemical sterilization is practiced and stream inspection will reveal but little that cannot be ascertained through an inspection and analysis of the effluent of the works.

When the problem is one of the prevention of a nuisance, the desirability of stream inspection will increase as the dilution afforded by the stream decreases. The minimum dilution by the stream may be such that stream inspection will be unnecessary because a satisfactory stream condition may be safely assumed from the results of tests and analyses of the effluent of the works; furthermore, the minimum dilution may be such that assumptions of this character cannot be relied upon and the only way to check the adequacy of the treatment of the sewage is to inspect thoroughly the stream into which the treated sewage is discharged. If the stream is polluted from other sources, the results of stream inspection will not be a very reliable index of the adequacy of the treatment of the sewage which is discharged into the stream either above or below the other points of pollution.

It is thus evident that stream inspection, in order to be of value, must be comprehensive and must be made both above and below the point of discharge of the effluent of the treatment works. The absence of definite standards of purity for polluted streams would seem to indicate a difficulty as to what should be looked for in stream inspection. Where the polluted stream passes through a sparsely settled district where land values are low, the standard of purity need not be as high as where the stream passes through a thickly settled agricultural district where land values are high and where a foul-smelling and unsightly stream would seriously reduce the value of riparian properties. The keeping of a stream in a non-offensive condition might be all that would be required in the first case and if the effluent from the works will not develop an offensive odor after a two days' incubation in a closed container at 37° C., it may be safely assumed that such an effluent when discharged into a stream will not produce an offensive odor regardless of the dilution which the stream may afford, and under these circumstances, comprehensive stream inspection would hardly be necessary.

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[1] Presented at the 53rd Meeting of the American Chemical Society, September 25 to 30, 1916.

Where circumstances demand much better stream conditions and where the dilution at best is slight and where the volume of sewage is often greatly in excess of the stream flow, comprehensive stream inspection is a necessity in order to determine the adequacy of the treatment of the sewage.

At Columbus, Ohio, a situation of this kind must be dealt with and the difficulty of the problem may be appreciated from the fact that the volume of treated sewage (18 to 25 million gallons) which is discharged daily into the Scioto River is often, during the dry, hot summer months, four times that of the daily volume of flow of the stream. The critical period with respect to the maintenance of satisfactory river conditions is from April 1 to December 1, this being the period of higher temperatures and small dilutions. The routine of river inspection during this period consists of an inspection trip once a week from a point about two miles above to a point about twenty-five miles below the effluent outfall of the treatment works. There are two inspection stations above and five below the works and at each of these stations the following observations, tests, and analyses are made:

1—Temperature of the water of the stream.

2—Dissolved oxygen content of stream water. From this value and the temperature of the water, the percentage of saturation is calculated.

3—A sample of the water is taken to the laboratory and the dissolved oxygen consumed (called by some the oxygen demand) test is made.

4—The methylene blue test is made on a sample of the water having its *in situ* dissolved oxygen content.

5—The odor test (48 hours at 37° C.) is made on a sample of the water having its *in situ* dissolved oxygen content.

6—The chlorine value is determined on a sample taken to the laboratory.

7—The presence or absence of odor from the stream is noted.

8—The presence or absence of color (particularly black) is noted.

9—The presence or absence of floating sewage solids or sludge is noted.

10—The stream bed is dragged to disclose the presence or absence of sludge deposits.

The collection of this data every week for 8 months of the year during the past 5 years has given the City of Columbus a very complete record of the condition of the Scioto River above and below the treatment works and has aided materially in the enlargement of capacity and improvements in the treatment, which have been accomplished and are being planned.

The interpretation of this river data is often simple, but sometimes very confusing. Chlorine values can often be used to approximate roughly the stream flow and thus to indicate the dilution which the stream is supplying. Chlorine values in connection with dissolved oxygen consumed values have in several instances indicated that the stream was suffering from sludge deposits. This condition has been found above the works near storm sewer outlets and a week or more after the storm flow had ceased, the chlorine content below the outlet would be the same as that above the outlet, but the dissolved oxygen consumed value would be very much higher below than above. The chlorine value indicated an absence of recent pollution and the much higher dissolved oxygen value indicated that the stream was suffering from sludge deposits, the presence of which was also verified.

When an incompletely oxidized sewage effluent is discharged into a stream of water there are two possible sources of oxygen loss in the stream. The effluent rarely is more than 70 per cent saturated with dissolved oxygen and if the water of the stream has a higher saturation than the effluent, there will be a loss of oxygen when they become thoroughly mixed and the loss will be more noticeable as the dilution decreases. The second loss results from the absorption of dissolved oxygen by the unoxidized material in the effluent and this loss will also be more noticeable as the dilution decreases. The stream water supply of dissolved oxygen is constantly being replenished by absorption of oxygen from the air. When there is a very low or negative dilution, the oxygen may be absorbed by the sewage more rapidly than it can be replenished and this results in the establishing of offensive anaerobic putrefaction; this condition may continue for several miles down the stream; then dissolved oxygen will begin to appear in the stream and the oxygen content will continue to increase to the point of saturation, if no additional pollution occurs. After the point of minimum oxygen content has been passed and an increase in the oxygen content is noted, the stream may be said to have thrown off its burden and from that point on it is convalescent and in due time will recover its original condition of cleanliness.

Just how far oxygen depletion in a stream should be permitted to go has never been definitely settled and it does not seem probable that a standard for general application will or should be adopted unless it should happen to be in the nature of an absolute minimum requirement. It seems more probable that every case will become a law unto itself, the standard being evolved on the basis of local conditions and public sentiment.

In interpreting river inspection data, especially where the stream is pretty heavily burdened with sewage, no single test will give a satisfactory diagnosis of the stream condition, and in fact, single tests of either methylene blue or per cent of saturation with dissolved oxygen very often give very erroneous ideas as to the relative condition of the stream from one station to another. The stream at one point near the source of pollution may show a fair percentage of saturation and a fair stability value and at a point farther down-stream the saturation and stability value may be very much lower: these lower values would apparently indicate a worse river condition, but the dissolved oxygen consumed test may give a value much lower at this point than at the point farther up-stream, and, when the results of the three tests are considered it becomes apparent that the per cent of saturation and stability values often mask a great deal of potential pollution, which can be revealed only by the dissolved oxygen consumed test.

It has been found at Columbus that when the stream is heavily burdened with sewage the inspection must be very comprehensive in order to diagnose accurately or correctly the condition of the stream.

Division of Sewage Disposal
City of Columbus, Ohio

SOME REMARKS ON THE BIOCHEMICAL TREATMENT OF SEWAGE, WITH ESPECIAL REFERENCE TO THE ACTIVATED SLUDGE METHOD[1]

By George T. Hammond[2]

The discoveries of Pasteur and others, in the field of biology, led to the recognition of the necessity of sewage treatment, not only to prevent a nuisance, but also as a protection to the community from disease.

At quite an early period the filtration of sewage was proposed and undertaken in England,[3] but the real nature of purification by this means was not understood. It was supposed that the effect of the filter medium was physical and mechanical, a kind of straining out of suspended matter, and it was not until the discoveries above mentioned, and experiments that followed, that the real nature of the filtration processes became understood.

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[1] Read before the 53rd Meeting of the American Chemical Society, New York, September 25 to 30, 1916.

[2] Engineer of design, and in charge of the Sewage Experiment Station, Brooklyn, N. Y.

[3] Report, Metropolitan Main Drainage, London, 1858.

Meanwhile, various methods were suggested and tried for the treatment of sewage with chemicals. The object at first appears to have been the destruction of the putrescible matters, which was soon found to be impracticable; then the removal of them by means of chemicals effecting a separation of the organic matters from the liquid, and a precipitation thereof as sludge, which could be removed and disposed of separately.

It was also thought that the chemicals might be employed to destroy the biological activities (discovered by Pasteur) or the "germs," as these at first were called, and that this was the most important object to attain; as the study of biochemistry advanced, the absurdity of this object became apparent, until at length no further attempt at sterilization, than disinfection, is thought by most authorities, to be desirable in sewage treatment. It is now well known and recognized that the so-called germs, or as we now call them more correctly, the bacteria, are our allies and agents in sewage treatment, and the only varieties of them we fear and desire to destroy are the pathogenic bacteria: these have their natural habitat in living animal tissue, or in animal organs, and, therefore, are dangerous, but, being adapted especially to life conditions within a narrow range of temperature, are readily destroyed.

Besides various forms of filter beds, sewage application to land under cultivation was employed before the biological processes of oxidation, etc., were understood. Experience had demonstrated their success and usefulness. Of these, the most interesting instances are the extensive farms of Paris and Berlin.

While much was done abroad in the early days of sewage disposal study, especially in England, it was in our own country that the most important experimental results were accomplished, and the honor of carrying the work onward to success belongs, very largely, to the Commonwealth of Massachusetts, and to the Lawrence Experiment Station.

As a result, we now recognize that the object to be aimed at in sewage treatment is biochemical oxidation of the unstable organic materials contained in the sewage, and we employ methods and processes, which make use of bacterial life. If we now use chemical precipitation, we expect that the effluent finally will reach stability by means of natural biological agents, and, as at Worcester, either prepare it for dilution in a river containing myriads of bacteria, or discharge it upon filter beds, removing previously as much suspended matter as possible, to be treated in a more intensified form. We have found that the removal of solids from the sewage, as soon as practicable, prevents their becoming dissolved and saves the expense of removing the organic material after it has disseminated through a vast quantity of water, to handle which is attended with a cost in proportion to its amount and the contained pollution. Such matters as we are able to remove by screens or tanks decreases the burden on filter beds, or on the oxygen content of waterways, into which the sewage may be discharged, where the method employed is dilution.

Following the information published by the Massachusetts State Board of Health, it has become the principal object of sanitary engineers, in designing sewage treatment and disposal plants, to bring together in the most suitable and efficient manner the decomposable materials, the oxidizing bacteria and an abundant air supply for the bacteria. All forms of sewage disposal on land, in the method known as broad irrigation or sewage farming, all filtration methods, such as the sand filter, the percolating or sprinkling filter, called in England a "bacteria bed," the contact filter, etc., no less than the various forms or methods of treatment using compressed air forced into sewage in a tank, or a filter bed, depend upon this fundamental principle, which is also nature's principle, by means of which brooks, streams, rivers, ponds, and indeed all natural waters, are purified. This principle, in short, consists of the biochemical oxidation of the decomposable materials present in foul water or sewage.

Since the discovery of oxidizing bacteria, there has been a continuous evolution or progress in the growth of scientific knowledge on this subject, to the investigation of which some of the foremost scientists have given freely their best efforts.

METHODS OF BACTERIAL OXIDATION

The various methods may be briefly referred to as *Broad Irrigation*, or sewage farming, which, on account of the small amount of sewage that can be applied per acre per year, is not now in much favor. As already mentioned, Paris and Berlin still employ the method, although the latter has at Wilmersdorf a large percolating filter plant. *Sand filtration*, instances of which may be seen at Saratoga, N. Y., and Worcester, Mass., which latter has 70 acres of sand filter beds. *Contact beds*, or *contact filters*, as employed at Manchester, in England, and at many places in Europe and America. *Sprinkling*, or *percolating filters*, which may be seen at Salford and Birmingham in England, Wilmersdorf in Germany, Baltimore in this country, and many other places, both in Europe and America, which are doubtless the most efficient sewage treatment plants in operation at present.

These plants all depend for their treatment upon the cultivation of bacteria on the surfaces of media of various forms, over which the sewage is applied, after having, to a greater or less extent, received some preparatory treatment by means of screens, tanks, etc.

The most recent method of sewage treatment is by means of compressed air discharged into it in a tank. This has been denominated the "activated sludge method."

Aeration of sewage in a tank by means of compressed air is in reality only a reversal of the method by filtration. In the former the bacteria are not only afforded their necessary oxygen by compressed air, but they are moved up and down through the liquid and brought into contact with it until the entire liquid is caused to have the greatest possible number of these agents of oxidation within it, and until they have by their life processes converted the unstable organic contents into a stable condition.

In the filter the same identical result is secured by applying the sewage to a bed of sand or of broken stone, the particles of which are surrounded with films formed of bacterial and other growths, over which the sewage percolates in the presence of abundant atmospheric air. The liquid in passing through the filter flows over the surfaces of the medium, and the more vascular the character of the latter, the better.

Mr. Wilkinson, of Manchester, England, has given us a graphic presentation of the relation of the ordinary filtration to the activated sludge process:

"On starting up a new filter, the sewage shows but little change after passing through, but, as time goes on, a growth shows itself in the body of the filter, in what may be termed the stationary framework, and colonies of bacteria accumulate there, which attack the sewage and effect putrification, or oxidation, of the organic matter.

"These bacteria being mainly aerobic, an ample supply of air is necessary, in order that they may thrive, hence the necessity for adequate ventilation of the underdrainage. * * * Let us take a given volume of the stationary framework from a ripe filter, and carefully remove the coating, or growth, throughout the material. We shall then have a certain volume of what may be termed sludge, rich in aerobic bacteria, which may be referred to as the activated sludge of this particular process. In the new process (activated sludge), the active sludge is circulated throughout the sewage in the presence of air, as against the present-day practice of passing sewage in thin films over active sludge retained on a stationary framework, as in the case of percolators.

"The real problem then, is as follows: To ascertain the most economical method of applying air to sewage with maintenance of complete circulation of the activated sludge, without any formation of dead banks of material. The problem may now be said to resolve itself into one of reproducing in a tank the changes which take place in a percolating filter. We have our tank, which represents the walls and floor of the filter; we have our colonies of bacteria and the air necessary to support their life; and what we require to do is to provide means for supporting an even distribution of this life throughout the body of the tank, other than by allowing the bacteria to adhere to a stationary framework, such as stone, slate, or clinker material. Compressed air will both insure sufficient agitation and effect the desired results as regards preserving uniform contact and even distribution in the liquid. * * * * "

Experimenters had been investigating the treatment of sewage by forced aeration for many years, but the honor of naming the process was reserved for an English chemist. In a happy moment of inspiration, Dr. Gilbert Fowler, of Manchester, England, bestowed upon it the name "Activated Sludge." As is well known, the process antedates the name. Dr. Fowler saw the work of Clark at Lawrence in 1912, and has given the latter credit for his share in the development of the process.

The method itself was, in fact, the offspring of many fathers. It would scarcely be worth while in a brief paper like this to attempt the determination of the question of parentage. It will serve our purpose to call attention to the fact, that previous to the experimental work of Colonel (now General) William M. Black and Professor Earle B. Phelps (a member of this society), at the Brooklyn Twenty-Sixth Ward Sewage Works in 1910, there had not been demonstrated anywhere a practical method of sewage treatment by the direct application of compressed air. The elaborate experiments made by these investigators with various forms of tanks of sufficient size to make the tests on a working rather than a laboratory scale, were described fully in a report made by them to the Board of Estimate and Apportionment of the City of New York, dated February 16, 1911. As stated in the report, it was found possible to reduce the demand of sewage for oxygen 33 per cent to 50 per cent in a retention period of about 3 hrs., with the application of about two volumes of air per volume of sewage and by larger volumes of air and longer application, to obtain complete stability. As the cost of the process appeared to be low, about $2.00 per million gallons of sewage for the air, this method seemed to be a very attractive means of treating sewage. It was, however, recommended that further and larger experiments be conducted, or that the old sewage treatment plant at the Twenty-sixth Ward Works be equipped for using the method in a full size trial. As the latter measure was found to be impracticable, on account of the expense of equipping the old plant for the new method, it was determined to establish an experiment station for the study of sewage treatment at this location, to try out this and other methods of treatment, and $50,000 was provided by resolution of the Board of Estimate and Apportionment, dated April 18, 1912, to carry out the work, which was placed in the charge of the Bureau of Sewers, of Brooklyn.

The experimental work of this plant began in 1913, and has continued up to the present. The results to last fall, so far as aeration and activation methods were concerned, were presented to this society in a paper read by Mr. E. J. Fort, Chief Engineer of Sewers, Brooklyn, at the meeting held at Urbana, Ill. Since that time the work has continued along these lines, but varied somewhat from the experiments described by Mr. Fort. It is not our intention to go over the ground already so ably covered, especially as the final report of the work of the Experimental Station will soon be available.

As this paper is presented by an engineer, it will be excusable if the chemical side of the subject is left for the chemist.

AERATION METHOD FROM THE ENGINEER'S VIEWPOINT

From the engineer's point of view, the most interesting question to be considered relates to the availability of the method for employment in the treatment of sewage preparatory to disposal. The engineer's problem and the chemist's are, no doubt, the same whenever the technical side of sanitation is to be considered; but, ordinarily, the engineer has also a duty to perform that perhaps is less scientific, but scarcely less important in effect, for he is charged with the design and installation of sanitary structures to meet the pressing needs of rapidly growing towns and cities, the tax papers of which are usually overburdened already with public expenditures. These structures must not only be designed and built, but also maintained at a considerable yearly cost, a mistake or failure in which is little short of a public calamity. The engineer's problem, in short, is quite as much related to municipal affairs and the limitations imposed by financial and political conditions as to the technical problems.

The engineer is taught by his daily practice to recognize that the sewage treatment and disposal system which experience and experiment demonstrate to be the most reliable, economical and simple in operation, which, without offense or nuisance, will insure an effluent satisfactory and suitable at all times for discharge under local disposal conditions, is the most available for the purpose.

This is a conservative view and, if always adhered to strictly, there would, perhaps, be few rank failures; but, on the other hand, there would be but slow progress in the science of sanitation. Had we been content with the early methods of treatment, we might, perhaps, have perfected some of them to a much greater degree, but we would not have made much advance in our profession. While we ought to be conservative, we ought also to have our eyes open for new things, in order that we may give our clients the benefit of new ideas and inventions.

So much has been published about the principal activated sludge plants, that it would be scarcely necessary to give a particular description or account of either of them. The writer visited nearly all of them during the winter and spring of the present year, and has been in communication with them all very recently.

The method certainly produces a clear sparkling effluent, without smell or nuisance. The ground required for installing a plant is probably the least for any method of treatment, and the tanks are less costly than filter beds that would produce an effluent of equal stability. The removal of bacteria effected, as observed, in the effluent is remarkably high. The sludge contains constituents that make it of value for use in the manufacture of fertilizer. So far the picture is roseate. But there are many difficulties that make dark shadows in this fine prospect, and while it is true that progress is being made toward their solution, they must be recognized and given due weight under the present condition of the art.

The amount of sludge which must be disposed of easily stands first among these problems. This varies from 2,000 to 4,000 gallons, or even more, per 1,000,000 gallons, with a water content of from 99 to 96 per cent. This sludge is highly putrescible, unless dewatered, which is an expensive operation. Success in dealing with this problem is reported by Mr. Hatton, from Milwaukee, but the details and cost data are not yet available. None of the other plants report that they have solved the difficulty, although encouraging remarks are indulged in by a few experimenters.

At the Armour & Co. plant at the Chicago Stock Yards, experiments are still under way with dewatering methods, and their conclusions are reported as not final. It seems to them, however, at the present time, that a battery of vertical flow settling tanks which decrease moisture to 97 per cent, followed by a Worthington, or similar, press, is the best method up to the present. The sludge, after pressing, is dried by a direct or an indirect heat drier to 10 per cent moisture, which is necessary, in order that the material may be used in making fertilizer. The cost of this method is such that the commercial value of the product must be considerable, in order to make the treatment available. If means of transporting the dried product to market are costly, or fail at a critical moment, serious trouble may arise.

The only other methods mentioned are drying on sand, or Imhoff sludge beds, or discharging wet sludge upon land by various means.

One does not feel like asserting that the requirements of sludge disposal have as yet been successfully supplied at a cost that mere sludge disposal will stand. The value of the dry material as a fertilizer base is, however, considerable, if markets are available, and transportation sufficiently easy from the plant to the factory.

"Our further analyses of the sludge for fertilizer value," writes Mr. Noble, of Armour & Co., "shows it will run between 4.5 and 5 units of ammonia, the value of it being, therefore, about what we have previously estimated, namely, $9.00 to $10.00 per ton in the dried state." These figures, it will be observed, refer to the sludge derived from the stockyard sewage, and will probably not be equalled with ordinary domestic sewage.

It is quite probable that this difficulty can be overcome to a considerable extent by means directed to the removal of sludge-producing material from sewage previous to the treatment, as for instance, by screens or tanks. So far no complete data are obtainable on this point, but experiments seem to justify the expectation of success. Experiments are needed to show how fine such a screen should be, for if it removes too much suspended matter, the process may be seriously interfered with. So far as the writer can speak from experience, the Imhoff tank is not likely to prove as successful as the screen in this preliminary treatment, as the tank takes out too much of the best size material in suspension for the activation process. But this is not stated as having been proved conclusively, and more data are needed on the point. If an Imhoff tank is used, the surplus activated sludge might be reduced to the condition of Imhoff sludge, by being introduced into the digestion chamber, as suggested to the writer by Mr. Leslie C. Frank sometime since.

While the conditions at Milwaukee are rather unique and favorable to the activated sludge method, as well as to the transportation of the dewatered sludge, it is doubtful if other cities less favorably situated will feel justified in going to the expense of installing extensive plants for dewatering sludge. The combination of a commercial venture with sewage disposal need not necessarily prove a failure, but the chances against its success do not make the project seem attractive.

A recent communication from Mr. Hatton states: "After elaborate experiments on the dewatering of sludge and sludge drying, we find that there are very few problems connected therewith that have not already been solved in industrial establishments where material of like character must be treated. Either of two kinds of presses reduce the moisture from 99 per cent to 75 per cent, and there is no difficulty by either the direct or indirect dryer to reduce this moisture from 75 per cent to 10 per cent or lower."

This statement is at least of great interest and it seems very promising. It seems to the writer, however, that in most places the problem will always be, how to minimize the formation of surplus sludge, and how to get rid of what does form without dewatering it in a plant especially provided for this purpose. If it cost more per ton to dewater than the sludge will sell for, or the net value obtainable therefor, then even though the value figures at $9.00 to $10.00 per ton, few will care to undertake such a venture, or at least go further than what would be the fair cost of sludge disposal by other means.

PARTIAL DRYING OF SLUDGE

Dewatering sludge is a matter of difficulty and expense and cannot but add a burden to the maintenance of a plant. This may be provided for in large plants, if the value of the sludge recovered warrants; but in small plants it would probably lead to a nuisance and would not be usually undertaken where the sewage amounts to less than 10,000,000 gals. per day. To install the necessary plant would be expensive, and the cost of maintenance out of proportion to the possible benefit. In great cities like Milwaukee, Chicago, Cleveland, etc., where transportation can readily be secured to a fertilizer factory, it may succeed, but in smaller places its success is doubtful, and unless new methods by which it may be cheaply and efficiently accomplished are found, it probably will seldom be undertaken. It is well recognized that the problem of dewatering is mainly one of proper design of plant and of cost. The apparatus for use in this process has long been known and used in the various trades. But the application of such apparatus to the sludge problem is as yet undeveloped, and in the stage of experiment. It is quite possible that the best method available has not yet been discovered.

The Schaefer-ter-Meer centrifugal sludge dryer, used on a large scale at Frankfort-on-the-Main, and at Hannover, in Germany, has been thoroughly developed as a sludge-drying machine, which can handle with success large volumes of sludge and dry it sufficiently to burn in an incinerator plant. This machine was experimented with at our Jamaica Sewage Disposal Plant, and tests show that operating on sludge containing 91.5 per cent of moisture, from a lime precipitation tank, it effected a removal to 64.2 per cent moisture, and operated continuously while effecting this removal. The cost of this method, as shown by the tests, was rather high, but the tests were really not a complete exhibition of what these machines can do.

The Dickson method of sludge dewatering, which employs brewers' yeast to effect a separation of water and sludge, also offers a possible means of success, and has the advantage of a fully developed system by means of which the dewatering and drying can be carried from the commencement to the completion of the process, without extra handling between the various steps. The dried sludge leaves the apparatus in bags ready for shipment to the fertilizer factory, or may even be made a complete fertilizer ready for market as it leaves the plant.

So far the cost of these methods has not been determined for activated sludge, but the writer believes it will not be lower than the cost for drying ordinary sludge.

It is quite possible that the sludge may be destroyed by a septic process where the amount of it is not great enough to make dewatering an attractive measure. But little study has been done in this direction and much is desirable.

As the sludge tends to break up and dissolve with overaeration and in doing so diminishes in volume, this gives promise of still another method that so far has received but little study.

We have found at the Brooklyn Experiment Station that by means of long-continued aeration, activated sludge may be broken up and reduced to 10 per cent or less, of its original volume. The problem is to get rid of the water during this reduction, so as to decrease the volume to be aerated. That this may be done seems fairly possible.

Taking the surplus activated sludge as a special problem, it would seem that we should be able to design a plant to reduce its putrescible contents by means of biological agencies. If we may treat the sewage by "activation," why may we not also find such a means of treating the sludge? Since we have found that long-continued aeration will reduce it to a very small volume, cannot we find means of doing this without excessive cost for air?

We observe that after a short aeration period with activated sludge, clarification of the sewage takes place, and that out of a million gallons we have a net amount of 2000 to 4000 gals. of sludge, which we must dispose of separately, and this is about 99 per cent water. Clearly we can afford to aerate this small volume for a long time, if necessary, to effect its reduction to a form which will not cause a nuisance. Experiment shows that about half of this volume is free water which can be removed by an hour's tankage, and that 24 hours' aeration of the sludge will separate a large part of its remaining water, and the bacteria will keep on working for us.

Thus we are continually treating a diminishing quantity of sludge, and the problem of plant design seems the principal problem.

AERATION PROCESS

Another matter that is receiving the most careful attention is the aeration process. Mr. G. L. Noble, of Armour & Co., writes: "We are attempting, by experimental work, to decrease the period of aeration by the introducing of pure cultures of organisms from activated sludge, which appear to be especially active in producing nitrification. Our work, however, along this line is only in its infancy, and we have no data to report, * * * ; we have found that the action of the organism is inhibited by sewage warmer than about 95° F." This shows the trend that experimentation is now taking, and suggests great possibilities; also that we have yet very much to learn about the method.

In the matter of design of activated sludge plants, much might be said about what we have still to learn. The shape, depth, size and arrangement of tanks is as yet in the study period, and this remark applies also to the best method of supplying the air to the sewage in the tanks.

The earliest experiments, those made successfully by Messrs. Black and Phelps, at Brooklyn, in 1910, out of which it is quite possible that the entire activated sludge invention, directly or indirectly, developed, employed perforated pipe grids; similar methods were used elsewhere, until in England, Messrs. Ardern and Lockett used a porous material in their experiments with success. Following this, similar material came into use in this country, and this, while still employed extensively, has probably achieved no greater success that pipe grids. In the writer's work, both methods were employed, but the pipe grid proved much the best on the average.

In conclusion, it may be said that while a great deal remains to be learned about the problems which we have referred to, as well as others, and many difficulties must be overcome, the activated sludge method seems very promising; and while it may not prove as cheap as other methods of sewage treatment, there are many conditions which will favor its use. A word of caution should be added, that the method is still in the stage of experiment and in using it one should frankly admit that there is much to be learned about it before full confidence is justified.

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RE-AERATION AS A FACTOR IN THE SELF-PURIFICATION OF STREAMS

By Earle B. Phelps

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In the administrative control of stream pollution, the economic principle of maximum utilization of a resource may usually be applied to divide streams into two major groups, depending upon whether or not they must be used as sources of domestic water supply. In the class of water supply streams, permissible pollution is limited in bacterial terms, with secondary reference to organic matter *per se*, and to such special impurities as acidity, iron or harmful mineral compounds. In the case of streams which are not used as sources of domestic water supply, or where self-purification intervenes to such an extent that permissible pollution is not limited by water supply standards, nuisance conditions become of controlling importance. Physical effects, visible floating material, discoloration, oily scums and deposits upon the bottom and side of the channel, and chemical changes resulting in the depletion of the dissolved oxygen and consequent odors as well as destruction of fish life, all may contribute to the general condition of nuisance. Each kind of effect has its specific remedy and a properly designed treatment plant is one which accomplishes the specific improvement required without involving additional and unnecessary expense in dealing with non-essentials. In fact sewage treatment may be overdone. Consider a stream providing ample dilution but with a sluggish flow. Removal of settleable solids by a tank is obviously required. Now if zealous authorities insist upon the addition of a trickling filter and stop there then conditions in the stream are made actually worse because of the additional settleable solids discharged, whereas the additional reduction in oxygen demand is of no advantage with the ample dilution present.

Of the various types of sewage treatment, those involving oxidation of organic matter are at present by far the most expensive, and in our endeavor to protect streams against nuisance conditions every effort should be made to utilize the maximum oxidizing power of the stream itself. A stream will oxidize sewage according to its own oxygen resources which are of two kinds, initial dissolved oxygen and oxygen obtained through reaeration. It has usually been assumed in discussions of nuisance conditions that the dilution ratio is the essential criterion of safety but this assumption has led to unfavorable results and a simple computation with the data of modern sewage chemistry will serve to show its fallacy.

The oxygen demand of the sewage of the District of Columbia has a summer value of about 300 p. p. m. The normal sewage flow is at a rate of about 0.25 sec.-ft. per 1000 population. The summer value of the dissolved oxygen in the Potomac above the city is approximately 8 parts. Allowing a depletion of oxygen down to 4 parts, a minimum value for non-nuisance conditions, there is required a dilution of 1 : 75 or nearly 19 sec.-ft. per 1000 population to satisfy this oxygen demand by mere dilution. Experience has shown that in open river conditions and with reasonably pure diluting water a stream flow of 6 sec.-ft. per 1000 is ample for the prevention of nuisance, and the Chicago Drainage Canal was designed upon a basis of 3.3 sec.-ft. In the case of the rivers with 6 sec.-ft. per 1000 it is evident that over two-thirds the total oxygen requirements are satisfied by re-aeration. In a canal purposely designed to avoid any interference with smooth hydraulic flow, re-aeration is at a minimum and it is not surprising that results are unlike those obtained in rivers under like dilution conditions. In so far as disposal of sewage by dilution in a running stream is a process of true purification and not merely one destructive of stream values, it depends upon self-purification of the stream, in which reaeration is an essential factor. Curiously this important matter has received little or no scientific attention.

BASIC PRINCIPLES OF RE-AERATION

In the present discussion of re-aeration as a factor in the self-purification of streams certain underlying principles will be stated and discussed for the purpose of establishing the present status of our information and the proper direction of future study.

1—Pure water exposed to the air, at a given temperature, will dissolve atmospheric oxygen up to a maximum amount, this value being known as the saturation value.

The solubility of a gas in water is proportional to the gas pressure. Since the oxygen pressure in the air is approximately one-fifth an atmosphere, the true solubility of oxygen in water exposed to pure oxygen at atmospheric pressure, is about five times as great as the so-called saturation value. In the presence of green plant life, exposure to nearly pure oxygen is frequently observed and oxygen values of several hundred per cent of saturation are frequently recorded. A correct knowledge of the true physical relation existing is quite necessary to the understanding of the apparently abnormal results which have often in the past been ascribed to faulty chemical analysis. The solubility of oxygen is also a temperature function. Tables of saturation values are to be found in any standard work on water analysis. Approximately 10 parts by weight of oxygen will dissolve in 1,000,000 parts of water at 16° C. and the solubility increases roughly by about 2 per cent per Centigrade degree decrease in temperature and *vice versa.*

2—Self-purification in a polluted stream is the result of the biochemical oxidation of organic matter and requires oxygen for its consummation. The more concentrated the organic matter the greater the rate of oxygen depletion.

American sewages have a biological oxygen demand of from 200 to 400 p. p. m. This means that if diluted with saturated water at 16° C. they would exhaust the oxygen supply of that water in dilution ratios of one part of sewage in from 20 to 40 parts of water. With greater dilutions corresponding partial oxygen depletion will result.

3—A stream saturated with oxygen will withdraw no more oxygen from the atmosphere. If partially depleted it absorbs additional atmospheric oxygen and the rate of such absorption or re-aeration while dependent upon many other factors is directly proportional to the state of depletion.

4—Under any given condition of pollution and re-aeration, a point of maximum oxygen depletion is reached, somewhere down-stream, at which the rate of depletion and the rate of re-aeration are equal. This will be termed the critical point since it determines the maximum effect of the pollution.

Above the critical point the oxygen content of the stream is diminishing, below it is increasing. The location of this point is evidently conditioned by the time of passage or by distance in hours rather than in miles. It is also a temperature function since depletion is accelerated by higher temperatures. As the velocity of stream flow is usually at its minimum during the hottest months, the critical point moves up-stream rapidly with increasing temperatures.

5—The condition of the stream at the critical point, representing a balance between rate of depletion and rate of re-aeration, is, at constant temperature, a function only of pollution and of re-aeration.

6—The capacity of a stream to dispose of sewage within any specified limits of nuisance is obviously measured by the condition of the stream at the critical point. Since it is at a minimum at maximum temperature and minimum stream flow, it becomes under fixed temperature and flow conditions a function of re-aeration only:

7—The capacity of a stream for re-aeration under extreme conditions of high temperature and low stream flow, therefore, measures its capacity to receive and dispose of sewage by self-purification within any prescribed limits of stream depreciation or nuisance.

In the past, although the relation of dissolved oxygen to the condition of a stream, as well as the fact of re-aeration, have been fully recognized, the relations set forth in the above principles have been partially or wholly overlooked because of imperfect ideas of the rôle of oxidation.

Mr. Hering evidently voiced the best opinion of the day when he wrote in 1887,[1] "Oxidation and total destruction of sewage by decomposition was for a long time thought to be the main cause for the clarification of polluted rivers. To-day it is known to be but a minor cause, compared with dilution and subsidence."

Observation made upon the old Michigan Canal showed that the sewage which, with a dilution in water of 1 cu. ft. per sec. per 1000 population, and after flowing 30 miles in about as many hours, was quite offensive, became inoffensive after discharge into the Desplaines and later into the Kankakee River and with dilution increased to about 3 ft. It was erroneously concluded that the same inoffensive condition would have been obtained throughout by a primary dilution in 3 sec.-ft. per 1000 inhabitants.

IMPORTANCE OF OXIDATION DATA

Such a conclusion followed logically from the assumption of the minor importance of oxidation and the latter was apparently justified by the chemical methods of the times. Oxidation was measured in terms of nitrogen rather than oxygen and it is only within the past few years that the chemist has been in possession of methods which correctly record the progress of the oxidizing reaction.

In 1906, Hering and Fuller reported upon this matter further, and stated,[1] "The disposal of sewage by dilution depends upon the amount of oxygen in the diluting water being sufficient to prevent putrefaction of the organic matter in the sewage as the latter undergoes bacterial decomposition." Their recommendations were based upon results obtained in Massachusetts upon flowing streams, and were to the effect that a dilution of not less than 3.33 sec.-ft. per 1000 population would be necessary, after the elimination of trades wastes. Throughout the discussion emphasis is laid upon the oxygen initially present in the dilution water.

The application of observational data, obtained upon running and comparative shallow streams where conditions are ideal for re-aeration, to deep canals with sluggish flow and minimum re-aeration conditions cannot but lead to unsatisfactory results. A large part of the residual oxygen found in streams of the former type can now be shown to have been derived from natural re-aeration. If it be assumed that such residual oxygen was initially present and had not been utilized by the sewage, the capacity of the sewage to consume oxygen is thereby underestimated and the application of the data to streams of the second type with deficient re-aeration will lead to insufficient dilution and a condition of nuisance not anticipated.

As early as 1900, Palmer[2] found the dissolved oxygen at the lower end of the sanitary canal in August to be 5.88 per cent of saturation, increasing to 70 per cent after passing the dam. Wisner[3] reported in 1911 the frequent absence of oxygen for many miles above the lower dam at Lockport with a dilution of about 3.3 sec.-ft. per 1000. Passage over the dam increased the dissolved oxygen to about 19 per cent of saturation. The relative importance of dilution and re-aeration will be appreciated if it be noted that simple passage over the dam had the effect of a 25 per cent increase in saturated dilution water, or was equivalent to raising the dilution from 3.3 to 4.1 sec.-ft. per 1000.

Numerous other examples of the same sort are to be found in the literature but enough have been given to illustrate the point.

The problem of the moment deals not so much with present conditions as with the future. It is of the utmost importance to determine the future effect of gradually increasing pollution upon any given stream. In connection with purification treatments it is highly desirable to know what degree of stream improvement may be anticipated from any specified degree of purification in order that the cost of various treatments may be properly balanced against the benefits to be expected. Finally there frequently arises the problem of the effect of a very large

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[1] Quoted from Fuller, "Sewage Disposal," **1912**, 227.

[1] Fuller, "Sewage Disposal," **1912**, 252.

[2] Report on Streams' Examination, Sanitary District of Chicago, **1903**, 95*A*.

[3] Quoted by Fuller, "Sewage Disposal," **1912**, 214.

pollution of a hitherto unpolluted or slightly polluted area, following the location, for example, of new intercepting lines and discharge points. The essential elements of the specific and the general solution are as follows: Determination of the extent of pollution at a given point, measured in terms of the new sewage chemistry which deals with oxygen relations, and of the degree of self-purification and amount of residual oxygen at some lower point, together with temperature and hydraulic data, furnish the basic facts. The oxygen requirement and rate of oxygen depletion are then known. The condition of the lower station in the same terms is calculable. The actual condition compared with the calculated gives the re-aeration factor for the stretch. This must be determined for the same stretch over a considerable period of time in order properly to include the variations in hydraulic conditions. In particular the re-aeration is a function of depth, velocity of flow and degree of turbulence. Similar data may be obtained at the same time over other typical stretches and the relation of the re-aeration factor to other physical and hydraulic conditions noted. From such a comprehensive study there will be obtained eventually the necessary data for the determination of the re-aeration constant of the stream in question under various physical conditions. Then the result of increasing or decreasing pollution, always measured in proper terms of oxygen demand, will be readily calculable. Repetition of the study upon another stream will give similar data for that stream and also permit some study of the effect of stream type upon re-aeration. With accumulating data of this sort it is not unreasonable to anticipate that the fundamental constants will ultimately be derived with which the capacity of any stream to receive and dispose of sewage within stated nuisance limits may be determined in advance. Such constants will furnish the only rational basis upon which to estimate the effect of increasing or decreasing pollution, or the degree of purification necessary or desirable in any case. As these matters have been shown to be of primary importance in any application of the principle of conservation to streams, the importance of work of this character is obvious.

In the foregoing discussion it will be noted that no reference has been made to either of two distinct phases of the pollution problem, the matter of dangerous bacteria and that of sludge deposits. Both are separate and distinct problems capable of solution independently of the problem of oxygen supply and leading to nuisance of distinct character. The presence or absence of these factors does not influence the methods or conclusions of this discussion, although the matter of deposits does enter the analytical problem.

TURBULENCE OF STREAMS A FACTOR

An important conclusion of this discussion will be touched upon briefly in passing. Re-aeration is conditioned among other things by the degree of turbulence of the stream. In quiescent water a diffusion gradient is established which practically stops re-aeration. The effect of dams and rapids in increasing aeration is not so much dependent upon the momentary exposure of the water but is largely due to the mixing action whereby the diffusion gradient is broken up and re-aeration permitted to proceed. In artificial canals turbulence is avoided as largely as possible. The effect of a single dam upon de-aerated water has already been shown to be equivalent to a large increase in initial dilution. Where dilution is for any reason limited, the capacity of sluggish and non-turbulent streams can be greatly augmented by providing for artificial turbulence at certain points in their course. Such turbulence need not be of the character of a fall, nor need it cause a loss of head. A number of mere overturns or "boils" will be found more efficient than a single large fall.

The determination of the re-aeration coefficient of a stream has been undertaken for the first time in connection with the investigation of the Ohio River now being made by the U. S. Public Health Service under the direction of P. A. Surgeon Wade H. Frost. The actual analytical problem is exceedingly complex and the mathematical reduction and analysis of the results is both complicated and laborious. The work has progressed to a point at which it is obvious that results of value and consistent with the theory here stated have been obtained.

SUMMARY

In the development of the maximum economic use of a stream, its capacity to dispose of sewage and waste within any specified degree of depreciation or nuisance is a factor of first importance.

This capacity is limited by stream conditions and is a function of the capacity for re-aeration.

For this reason the dilution unit is an improper one for a discussion of nuisance and self-purification and results obtained upon one stream, expressed in such units, are not applicable to another.

Re-aeration is capable of experimental determination not only in single instances, but in terms of general applicability.

Its determination in such general terms involves laborious work of a hydraulic and analytical nature. A beginning has been made along this line in the Ohio River Investigation by the U. S. Public Health Service.

25TH AND E STREETS
WASHINGTON, D. C.

CURRENT INDUSTRIAL NEWS

THE GERMAN NITROGEN INDUSTRY AND THE FUTURE OF GERMAN AGRICULTURE[1]

During the last ten years German agriculture has succeeded in increasing the yield of the land to an extraordinary extent, and in this connection a comparison with France is of interest.

Thirty years ago the yield per hectare in France was about the same as in Germany. Since then the yield in France has risen about 0.1, whereas Germany has nearly doubled her yield as indicated below:

WHEAT YIELD PER ACRE IN 100 KILOS

Yearly Average	1881/86	1911/13
Germany	12.8	22.3
France	12.0	13.6
Russia	?	6.9

This excellent result is partly due to Farmers' Associations, Agricultural Schools and the employment of modern methods, but chiefly to the ever-increasing quantities of fertilizers used. The following is a comparison of the amounts of fertilizers used per hectare during the last few years:

	Potash	Nitrate of Soda
Germany	12.05 kg.	8.10 kg.
France	0.806 kg.	4.10 kg.

Germany has always been well provided with potash, but up to about 10 years ago had to rely almost entirely on imports of nitrate of soda for her nitrogen. The following table shows the increase in the imports of nitrate and in this connection it should be mentioned that about 10 to 15 per cent of these quantities have been used for industrial purposes.

GERMAN CONSUMPTION OF NITRATE OF SODA (METRIC TONS)

1880	1885	1890	1901	1910	1911	1912	1913
55,000	155,000	330,000	517,000	723,000	703,000	785,000	747,000

Gradually, however, the German Chemical Industry has been building up a substitute for nitrate in the form of sulfate of ammonia. At the beginning of this century the production in

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[1] Extract from the *Frankfurter Handelsblatt*, May 29, 1916.

Germany was still small and imports amounted to about 48,000 tons per annum. Since 1906, however, things have changed and Germany has exported larger quantities than she has imported.

The development of our consumption of sulfate of ammonia is shown by the following table:

German Consumption of Sulfate of Ammonia (Metric Tons)

	Imports	Exports	Excess of Imports over Exports	Excess of Exports over Imports	Product from Coke Ovens, etc.	Total Consumption
1888	35,000	.....	35,000	.....	?	....
1900	23,000	2,000	21,000	.....	104,000	125,000
1909	58,000	59,000	.....	1,000	281,000	280,000
1910	31,000	93,000	.....	62,000	313,000	251,000
1911	24,000	74,000	.....	50,000	418,000	368,000
1913	35,000	76,000	.....	41,000	501,000	460,000

The increase in the use of sulfate of ammonia has, therefore, been extraordinarily rapid. In the year 1913, 460,000 tons of ammonia were used as against 750,000 tons of nitrate of soda. Taking the manurial value of sulfate compared with nitrate as 4 to 3, the 460,000 tons are equal to 610,000 tons of nitrate, so that the two competitors were running each other pretty close already in 1913.

In 1914 synthetic sulfate of ammonia first entered the lists as a competitor of nitrate of soda on a practical scale. Theoretically, the possibility of producing ammonia by purely chemical means had long been known, and the well-known Norwegian method was first of all developed, the German chemical trade being largely interested.

The difficulties in introducing this process into Germany on account of the lack of water power forced the Badische Aniline and Soda Works to develop a process of their own. In conjunction with Professor Haber they proceeded to do this, putting all their energy into the Haber process and giving up their Norwegian interests.

At the beginning of the war, the Badische were producing on a scale large enough for one single works, but yet not sufficiently large to compensate for the loss of nitrate of soda. In the first year of the war there was accordingly a considerable shortage of fertilizers for agricultural purposes. But our chemical industry quickly came to the rescue, and should the blockade of Germany be prolonged, we shall soon be in a position to deliver more nitrogen for agricultural purposes than formerly consumed in peace times.

The following particulars give an idea of the extraordinary rapidity with which the Haber process has developed. The capacity rose from 30,000 tons in 1913 to 60,000 tons in 1914, and about the middle of 1915 the output of the original works was about 150,000 tons. For 1916 the production is reckoned at 300,000 tons. It is no secret that the Badische Company has lately put up further large plants in another part of Germany, so that its producing capacity for 1917 will no doubt be considerably in excess of 1916.

Assuming that the Haber production in the near future will reach 500,000 tons, this process alone will represent the production of an amount of nitrogen nearly equal to the amount of nitrate of soda we used to import. In passing, it may be mentioned that such a production at a price of $60.00 per ton would represent an annual turnover of 30 million dollars for this one firm.

In addition further large quantities of nitrogen have been produced with state aid in the form of cyanamid, with the aid of which German agricultural needs can easily be met. Furthermore the whole tendency in the coal industry has been towards the increase of by-product ovens. Up to the time when the war broke out, about one-fifth of our coal was coked, but the war has forced resort to coking to a far greater extent than before. Everything points to the conclusion that in the near future the direct combustion of coal will be recognized as altogether uneconomic and disappear, and its place be taken by by-product processes. This of course means increased recovery of ammonia from coal. Assuming that only double the quantity of coal hitherto used is employed for the recovery of ammonia, the increase in sulfate of ammonia production amounts to 450,000 tons. Based on the above the following comparison between 1913 and 1917 can be made:

German Consumption of Nitrogen, 1913, in Metric Tons

Sulfate of Ammonia	460,000 tons =	92,000 tons Nitrogen
Norwegian Nitrate of Lime	35,000 tons =	4,500 tons Nitrogen
Cyanamid	30,000 tons =	6,000 tons Nitrogen
Ammonia—Haber Process	20,000 tons =	4,000 tons Nitrogen
Total		106,500 tons Nitrogen
plus Nitrate of Soda	750,000 tons =	116,000 tons Nitrogen
Grand Total		222,500 tons Nitrogen

German Production of Nitrogen, 1917, in Metric Tons

Sulfate of Ammonia	700,000 tons =	140,000 tons Nitrogen
Norwegian Nitrate of Lime	...... tons =	......
Cyanamid	400,000 tons =	80,000 tons Nitrogen
Ammonia—Haber Process	500,000 tons =	100,000 tons Nitrogen
Total		320,000 tons Nitrogen
Nitrate of Soda		None

If these statements are only approximately correct our own production will already next year be greater than our consumption before the war including the amount of nitrate of soda imported. In case of need, therefore, we can altogether do without the importation of nitrate of soda for agricultural purposes. This does not mean, however, that the import of nitrate of soda is either unnecessary or undesirable. Nitrate will remain very much wanted for certain purposes and agriculture will be glad to make use of it as long as prices remain competitive, especially in view of the amount of German capital invested in the Chili nitrate industry. If our home production of nitrogen can be supplemented by nitrate of soda, so much the better, for our experts are agreed that we cannot give our agriculture enough nitrogen. The dire necessity the war has brought upon us, forcing us to help ourselves in all sorts of ways, has in this respect added a valuable gift for the future in that these new sources of nitrogen will enable us to increase our agricultural production.

All sorts of possibilities are involved. It would be thoroughly in keeping with the character and accomplishments of the German Chemical Industry to proceed with the production of combined fertilizers after having successfully solved the problem of the synthetic production of ammonia. These new fertilizers may perhaps some day drive out the old material in the same way that synthetic indigo drove out the natural product.

It is not impossible that Germany may become the great exporter of nitrogenous fertilizers. The most important point, however, is the increase in the productivity of our land. The economy of 9,000,000 pounds per annum on nitrate of soda imports cannot be compared in importance with the saving in our imports of wheat and foodstuffs which would be effected by means of increased fertilizing.

FORMATION OF TOLUENE BY ACTION OF ALUMINUM CHLORIDE

According to *Chem. Soc. Abstracts*, F. Fisher and H. Niggemann [*Ber.*, 49 (1916), 1475] have studied the conditions for the most productive degradation of xylene to toluene by the action of aluminum chloride. The best temperature is found to be that of boiling xylene, while 2 to 4 per cent of aluminum chloride is quite sufficient and 2 hours long enough for the purpose. Under these circumstances, xylene gives an approximate 12 per cent yield of toluene and also benzene and polymethylated benzenes. Benzene is decomposed by the energetic action of aluminum chloride but without producing more than traces of toluene. Experiments with xylene-benzene mixtures have also been carried out with the hope of transferring a methyl group from the one to the other, but this ingenious idea has not yet led to definite results.—A. McMillan.

STARTING MOTOR ENGINES FROM COLD

A device for starting motor car, aeroplane and similar engines from cold introduced by Messrs. Gunspray, of 39 St. James Street, London, consists of a petrol reservoir into which dips a fuel tube ending in a gauze cap. This tube leads to a spray jet, which is enclosed in a passage through which atmospheric air is supplied. The jet is inserted in the induction pipe of the engine and, under the influence of the suction created by turning the starting handle, is sucked up the fuel tube and atomized at the jet as it is mixed with air. A control screw, which can be locked in position by a locking screw, permits the air supply to be adjusted to form the correct explosive mixture. Combined with the starter, and operated by the same control, is an arrangement which enables extra air to be admitted to the cylinders, and which, it is claimed, effects considerable economy of fuel if judiciously used. The starter acts independently of the carburetor, and, in cases where a heavy fuel such as paraffin is employed, can be used to effect the necessary pre-warming of the engine.—M.

MINING IN SWEDEN

According to an article in *Mining World*, 92 (1917), 59, all the coal obtained in Sweden is got from the provinces of Malmöhus and Kristianstad in the southern part of the Kingdom. The seams, which are of Rhaetic age, are interstratified with beds of fire clay and the two minerals are worked together. The thickness of the coal seams, including partings in the shale, varies from 3 to 5 feet. Copper is furnished from the well-known Falu Mine in the province of Kopparberg. There are enormous deposits of excellent iron ore. The output is 6,700,000 metric tons, of which the province of Norrbotten furnishes 63 per cent. Sweden possesses the largest supply of peat in the world with the exception of Russia. It is reckoned that there are 4,000,000 hectares of peat with an average depth of 2 metres. This may be calculated to yield about 2,000 tons per hectare or a total of 8,000,000,000 tons. The peat is used as household fuel and also for peat-litter and peat-mould. Granite is quarried on the west coast and also on the Baltic and forms an important article of export. Porphyry and marble are also products, the annual value of the stone exported being $360,000. As regards zinc, the Åmmeberg mines supply most of the ore which is exclusively blende.—M.

ZIRKITE

Zirkite deposits, according to the *Brazilian Review* of Dec. 19, 1916, have been found in the Caldas region of Brazil which is a mountainous plateau about 130 miles north of the City of Sao Paulo. Several large outcrops of the ore occur on the extreme westerly edge of the plateau, one or two isolated boulders weighing as much as 30 tons. No extensive development work has yet been attempted, although several cross cuts have been run to determine the width of the vein and a few shallow prospect holes to ascertain the depth. The cursory examination of the deposits makes it unsafe to venture any conjecture as to the quantity of ore available. Deposits have been traced for a distance of 15 miles between Cascata and Caldas and, from surface indications, the deposits seem to be of vast extent. Owing to the hardness of the ore, it is almost impossible to drill holes for explosives; consequently, the method employed is the primitive one involving fracture by fire and water. In some of the deposits the ore occurs as gravel and large pebbles embedded in the reddish clay. The clayey matrix greatly resembles boulder clay and, if exposed to the sun and air, readily dries and the zirconia can then be separated from the clay by a coarse screen. Before shipment, it is thoroughly washed to remove the small percentage of ferruginous matter still remaining.—M.

BRITISH ENGINEERING IMPORTS AND EXPORTS

With the Board of Trade returns for December, the figures of our engineering imports and exports for the whole of last year are now complete. The imports of iron and steel and the manufactures thereof in 1916 were valued at $53,860,929, an increase of $1,993,051, as compared with 1915 and of $1,650,134 as compared with 1914, but the quantity was 775,033 tons as against 1,177,340 tons in 1915, and 1,618,015 in 1914. The figures for electrical goods at $7,933,262 were higher than 1915 by $2,731,392 and than 1914 by $1,967,966, while machinery valued at $38,364,177 was less in 1915 by $4,105,790, but more than in 1914 by $6,142,182, though its weight was less than in either of these two years, being 71,456 tons against 90,006 and 88,748 tons, respectively. Other metals and manufactures thereof were worth $186,378,588 or $15,257,241 less than in 1915, but $45,277,795 more than in 1914. As regards raw materials, the imports of iron ore were valued at $56,288,035, against $34,388,308 in 1915 and $24,742,891 in 1914 and their weight was 6,905,936 tons compared with 6,197,155 tons in 1915 and 5,704,748 tons in 1914. The value of other metallic ores rose to $65,672,827 from $55,556,088 in 1915 and $45,760,632 in 1914. As regards the exports of engineering products manufactured in the United Kingdom, increased values were recorded in most classes. Thus, iron and steel and manufactures thereof went up to the value $272,072,496 from $193,949,740 and $200,005,584 for the two preceding years. Other metals and manufactures thereof were valued at $61,059,148 and showed an increase. Electrical goods and apparatus exported were valued at $19,714,713, showing an increase over the two previous years, while machinery valued at $97,110,595 was higher than in 1915, but $53,432,251 behind 1914. Among raw materials 41,157,746 tons of coal, coke and manufactured fuel valued at $243,218,899 were exported; in 1915 the weight was 45,770,344 tons and in 1914 the corresponding figure was 61,830,485, the value being $202,570,214.—M.

RUSSIAN WATER POWER

It is reported that the Russian Government has authorized the issue of a bill for the "notification of centers of water-power from waterfalls or stretches of water suitable for supply of such centers of national or public importance." Up to the present, says the *Board of Trade Journal*, Russian law has never provided for the utilization of water-power except in the case of ordinary mills. Permits to make use of water-power have been more in the nature of certificates setting forth that the utilization of water-power would not interfere with navigation, than concessions. These certificates were issued only after consulting the local owners of water frontages and thus the utilization of water-power depended entirely on the consent of private owners. The present bill, without making any attempt to decide as to the ownership of water-power, proposes to empower the Government to declare any waterfall or stretch of water capable of being used as a source of water-power as being of national importance, and to take possession, either for government use, or with a view to granting concessions for its use in industries which it is desirable to foster.—M.

CINNABAR AND MERCURY FROM NEW ZEALAND

It is reported that H. M. Commissioner in New Zealand has forwarded some samples of cinnabar obtained from a deposit at Puhi Puhi (North Island) and a sample of mercury distilled therefrom. The deposit has not been worked to any extent as yet, owing to lack of capital and experience. At present, drives are being made to ascertain the extent of the deposit, and, according to a calculation made by the Department of Mines, 10,000 tons of ore are in sight. At a low estimate the ore is calculated to yield 2 per cent mercury.—M.

CONDENSER-TUBE REPAIRS

A method of mending condenser tubes is described in a recent issue of the *Electrical World*, and it is said to have effected considerable saving. The method consists in cutting out the section containing the break and inserting a new one which is joined with the other sections by an inner sleeve or ferrule about 2$^1/_2$ in. long. The latter is composed of a piece of tubing about half as thick as the condenser tube and has a diameter that will make it fit tightly in the sections to be joined. Both the ferrule and the ends of the section to be joined are thoroughly tinned and sweated together. Special care must be taken to cut the ends square so that they will meet and make a practically continuous tube. Any solder adhering to the outside of the joint should be wiped off or removed by emery cloth so that the tube can be inserted with tube plates in the regular manner. To save delay in making repairs, usually several ferrules are prepared and tinned in advance.—M.

INDIAN SAFFLOWER OILSEEDS

In an article in the *Indian Trade Journal*, Mr. J. P. Gore points out that there are two varieties of Indian Safflower—*Carthamus tinctoria* and *Carthamus oxycantha*, the first being cultivated in different parts of India while the latter grows as a weed in the Punjab. The seeds of the former are small and flat, somewhat resembling linseed. They contain 6 per cent moisture and on extraction with ether yield 28.02 per cent of a pale yellow oil. There is also a considerable amount of woody fiber in the seed. The fully extracted meal gave the following analysis: Moisture, 9.30 per cent; albuminoids, 13.50 per cent; carbohydrates, 22.80 per cent; fibrous matter, 51.70; and ash, 3.70 per cent. The oil is described as being a good drying oil and might be used in the manufacture of soft soap. The author considers that this oil is worth more attention for manufacture of varnishes. It is at present used in the Northwest Frontier Provinces for the manufacture of varnished wax cloth.—M.

A NEW HYDROCARBON

A new hydrocarbon, to which the name Spinacidene has been given, was described in a paper read by Mr. R. Chaston Chapman at a recent meeting of the Chemical Society, London. The author explained that a sample of cod-liver oil submitted to him for analysis gave a value indicating the presence of 89 per cent mineral, with 11 per cent of some fish oil, but, owing to the large amount of unsaponifiable matter and bromine absorbed, he determined to investigate the matter further. The oil was found to have been obtained from the livers of certain members of the sub-family *Spinacidae*, of the *Cetacea*, and the product yielded about 90 per cent of the new hydrocarbon. The compound is described as being colorless and mobile, and on warming gave odor of the lemon terpenes. It is optically active and on exposure it becomes viscous. The ultimate analysis seemed to suggest the formula $C_{25}H_{52}$ and the molecular refractivity indicated presence of three double bonds.—M.

PLASTIC CELLULOID

A simple method for rendering celluloid plastic is described in the *British Medical Journal* of a recent date, so that it can be molded into any shape for application in the tissues in certain parts of the body for certain conditions. The celluloid is placed in ether solution and, in a few hours, it swells slightly and becomes soft as a jelly. It is then taken out of the solution and molded into any shape and set aside to dry. The celluloid regains its original thickness and general appearance, but retains its new shape. As ether is a powerful bactericide, it will effectively sterilize the mold and make it ready for insertion.—M.

CHROMITE

Crude chromite ore, so important in modern steel metallurgy, says *Engineer*, 123 (1917), 59, has generally to be dressed to make it suitable for sale. It has usually to be broken up by hand or mechanically to a suitable size so that it can be hand-picked. The output should contain about 50 per cent of chromium sesquioxide. Chromite is obtained in large quantities from New Caledonia in the South Pacific. There is a large output from Rhodesia, and Greece exports chromiferous ores in considerable quantities. There are large deposits of low-grade ore in both Germany and Austria. Great Britain and France have to import all the chromite they require. North America has a small output, about 2000 tons annually, but has also to import. There are many chromite mines in the Ural district, mainly along the outcrops of the rivers Kameuka and Top Kaja, which have yielded as much as 20,000 to 30,000 tons annually. The mineral is also found in some of the areas from which platinum is recovered. In Japan, outcrops have been found but there is no output as the quantities available appear to be too limited to encourage enterprise.—M.

CALCIUM CARBIDE INDUSTRY

According to the *Times Engineering Supplement*, No. 507, p. 16, the importations of calcium carbide into the United Kingdom for 1916 were, approximately, 24,000 tons as compared with 26,000 tons in 1915 and about 28,000 tons in 1914. The decrease is not due to any falling off in the consumption, but there seems to have been a considerable shrinkage in the demands of private users, owing to the closing down of country houses, etc. This falling off was made up by the extensive demand for carbide in the manufacture of war appliances by means of oxy-acetylene welding. A gradual increase in the use of small light miners' lamps burning acetylene took place in this country during the past year following the lead given by the United States. The employment of these lamps has been shown to be very advantageous in increasing the output of minerals and providing better illumination. The supplies of cyanamide made from carbide greatly decreased during the past year owing to the large proportion of cyanamide being used for the preparation of nitrate of ammonia and nitric acid.—M.

A NEW CELLULOID CEMENT

The *Oil and Color Trade Journal*, 51 (1917), 416, quoting from a Swiss contemporary, gives an account of a new and valuable celluloid cement for gluing leather splits together so as to form solid slabs of plates of leather. As is well known, celluloid solutions possess the drawback of being much too sticky. If a celluloid solution is prepared in acetone or other solvent, it is impossible to obtain a substance of sufficient liquidity with more than 16 to 18 parts by weight per 100 parts by weight of acetone, as, if the proportions of celluloid be increased, then the resulting liquid will not penetrate between the fibres of the material and the parts will not adhere. In order to secure a highly liquid solution containing a greater percentage of celluloid, the following process must be observed: Chemically pure acetone, celluloid and oxalic acid are placed in a hermetically closing iron receptacle. The amounts are: acetone 100 kilos, celluloid 20 to 30 kilos, oxalic acid 0.5 to 2 kilos. After hermetically closing the receptacle, the ingredients are thoroughly mixed by suitable stirring gear at normal temperature. This is continued either incessantly or at intervals for a period of 12 to 14 hours. The product obtained can be used at once or kept for an indefinite period in the hermetically closed receptacle. This adhesive must correspond to the absorptive capacity of the material. If too thin, it must be suitably thickened and pressure may be used to force it into the material, if necessary. It is insolvable in water, it is highly valuable for fastening leather, and will be of special use in driving-belt factories.—M.

METAL POWDERS AND SPANGLES

Vigorous efforts, says the *Times Engineering Supplement*, No. 506, have been made to capture certain of the industries which once were wholly in German hands, and, even in cases where the trade did not exist before the war, steps have been taken to assist firms who are willing to embark in the new manufacture. It is stated that in 1913 not a single pound of bronze powder was made in France although the annual consumption of imported metallic powders attained a total value of over $2,304,000. This was the more remarkable because the industry was first started in France at the close of the 18th century. The restarting of this trade is associated with the manufacture of spangles which has existed in the Department of the Oise since 1850. These spangles are stamped out of extremely thin sheets of metal, chiefly alloys of copper, but at times silver and gold spangles are produced from very thin leaves of the precious metals. The uses of the different kinds of spangles are too numerous to mention. A very important one, in the case of thin brass spangles, is for the brushes of dynamos, but they are mainly employed in decoration. The fragments, chippings and metallic laminae which result from the manufacture are now being employed successfully for the preparation of various kinds of bronze powders, the tints and shades of which are produced in a wide range of colors. A process has, moreover, been devised for imparting a high polish to the powders thus prepared.—M.

CHINESE GAMBIER

Reports from Hong Kong, says the *Oil and Color Trade Journal*, 51 (1917), 502, state that an increased trade is now being done in "cunao," or Chinese Gambier in South China, and the amount of trade passing through Hong Kong runs to about 30,000 short tons per annum. For many generations past, the Chinese have used this product for dye and preservative purposes and, now that aniline dyes have disappeared from the Hong Kong market, this gambier is coming into more general use. The dye is got by crushing and soaking the roots of a plant known as cunao, the resulting liquor being drawn off and concentrated. Two qualities reach Hong Kong. The second-grade quality is the product of Indo-China and is employed for the first dyeing of the material, while the actual Chinese product is used for the finishing dye on account of the deep brown gloss it imparts. The dye is of a brown color, is highly astringent, goes excellently with various mordants and is extensively used in China for dyeing silks, etc. The coarser quality is the chief component of a mixture used for fishing nets, sails and the like to prevent them rotting away. It has all the merits of gambier but is much cheaper. It is exported in the form of a paste but is said to lose its finer qualities if kept too long. If properly packed and further concentrated, there seems to be no reason why the product should not keep indefinitely.—M.

DISPOSAL OF WASTE TIN AND SCRAP

According to a contemporary, the borough of Hornsey, England, has put down a furnace for dealing with waste tin and scrap. It is heated by the destructor flue gases and is arranged in such a way that the work can be carried out without increasing the staff. The results of the first three months justify the experiment as the annual receipts for 194 tons should amount to 203 pounds ($964). It will be noted that, notwithstanding the difficulty of disposing of waste metal, the destructor yard has been kept clear of accumulation and, it may be said, that the trade has been secured with an increase of about 49 per cent upon the returns received from pre-war German trading and this by a simple process involving no material encroachment upon the yard space or additions to the working staff and a comparatively nominal capital outlay.—M.

THE GERMAN LIGNITE INDUSTRY

According to a report in *Engineering*, 103 (1917), 104, the German lignite industry has fared well during the war and better than ever in 1916. This industry has gained considerable importance, notwithstanding the development in coal mining and, although it comprises some 300 installations, these are controlled by comparatively few companies, some of which are large concerns with substantial capital. The shortage in the production of coal since the war broke out, some 28 per cent for the first year and about 10 per cent for the second year of the war, caused an immense increase in the demand for lignite and, as the following figures show, the production in spite of the shortage of labor was larger in 1915 than in 1913:

	Production in Tons	
Year	Raw Lignite	Briquette
1913	87,000,000	21,400,000
1914	84,000,000	21,400,000
1915	88,400,000	23,300,000

The year 1916 is expected to show a further rise. From a financial point of view, the results of the lignite industry during the war have proved satisfactory in spite of increased expenditure. The aggregate profits of the 20 leading lignite concerns show but a slight decline for 1914–15, as compared with 1913–14, and in 1915–16 the result surpassed 1913–14. For 1913–14, the average dividend was 10.4 per cent, while for 1915–16 it was 10.8 per cent, and is likely to be higher for the present year. The war seems to have opened up new markets and lignite has now become a factor of some moment in various chemical industries and deposits of the substance are eagerly sought after. The rises have increased considerably as is shown by the fact that the German Petrol Company which is going in for tar production from lignite, paid 185 per cent for shares in the Rositz Lignite Company, which shares were below par before the war.—M.

FLAX-GROWING INDUSTRY

In the January issue of the *Times Trade Supplement*, the possibility of a revival of the flax-growing industry in Great Britain is the subject of an article by Dr. J. V. Eyre. The writer states that the experience of the last three seasons has shown that high-class flax-crops can be raised in the British Isles, and Belgian experts have declared the crops to be generally equal to those raised in their own country. The main difficulty since war broke out has been to obtain labor at harvest time to pull the crop. To meet this difficulty, engineers and others have been engaged for a long time on the design of a machine to effect the pulling satisfactorily and several machines are now under construction or are in the experimental stage in both Canada and Ireland.—M.

OILSEED CROPS

According to the *Chemical Trade Journal*, 60 (1917), 71, the first forecast of winter oilseeds (rape, mustard, and linseed) crop issued by the Department of Statistics, India, states that the total estimated area under rape and mustard reported up to date is 3,888,000 acres. This is 10 per cent above the area at this time last year. The total area under linseed is estimated at 2,627,000 acres or 3 per cent below the area for last year. The latest information published by the International Institute of Agriculture, Rome, shows that the estimate of the linseed crop of 1916 in the United States is 1,590,000 acres and 384,000 tons against 1,366,000 acres and 345,000 tons in the preceding year. For the Canadian crop of linseed, the estimates are 723,000 acres and 194,000 tons as against 806,000 acres and 265,000 tons in the previous year. From unofficial sources, it appears that in the Argentine, the condition of the linseed crop is disastrously bad on account of drought and the yield is expected to be only 250,000 tons as compared with 980,000 tons last year. In Russia, also, the linseed crop is reported to be poor both in quantity and quality.—M.

BRITISH OIL TRADE IN 1916

The *London Chamber of Commerce Review* for 1916 states that a marked feature during the year under review has been the continued demand for oils of every grade and more particularly the higher grades of lubricating oils. Owing to increased freights and extra cost of insurance, prices throughout the year maintained a very high level. In early spring conditions were very stringent, supplies being at a premium, and even the common oils brought as much as the best oils in normal times, while some grades were almost unobtainable. Easier conditions prevailed later, but towards the end of the year the market again hardened and, at the time of writing, there is every indication of a rise in prices and a shortage of supplies. It is generally agreed that for some time after the war a return to normal will be impossible. Stocks have been depleted by the abnormal demands and the difficulty of securing freights from the other side of the Atlantic has increased and will not disappear as soon as hostilities cease. The question of future supplies is at present one of great anxiety to importers. There are no indications of any lessening of the demands by ordinary users from which it may be argued that, during the new year, business will be extremely brisk with high prices ruling all around.—M.

THE EXTRACTION OF SUMACH

According to an article in *Leather World*, 9 (1917), 76, when using sumach, it should be remembered that this material is very liable to loss through faulty extraction. Of all the common tanning materials, sumach is the one in which the tannin is most easily destroyed. This loss or destruction may take place if the sumach is not extracted at the correct temperature. Many tanners think that, in order to get the whole of the tannin from sumach, it is necessary to boil it, but this is quite wrong as, by boiling the substance, 20 to 30 per cent of the tannin may be destroyed. The correct temperature for extraction is between 120 and 140° F.; if the temperature is raised above this, some may be destroyed. The sumach should be mashed with water at this temperature but, after the extraction of the tannin, the solution should not be kept for any length of time before being used. A sumach infusion ferments more quickly than that of any other tanning material and, if allowed to stand for some days, a large proportion of the tannin is lost. Contrast this with mimosa bark, the liquors of which can be kept almost indefinitely without appreciable loss. Sumach should, therefore, not be extracted before it is required for use. By observing these points, considerable economy in the use of sumach may be exercised. —M.

FRENCH COLOR INDUSTRY

The *Dyer and Calico Printer* says that a long discussion between the chemists and the pharmaceutists in the pages of La Revue des Produits Chimiques reveals the fact that the French artificial color industry is handicapped by ancient enactments, the first of which became law in 1777. These date from the time when chemistry was ranked with astrology or even black magic, and the result is that, in the words of our contemporary, the administration officially ignores chemistry and the chemist. The authorities know only the engineer, the physician and the pharmaceutist. If, therefore, a French works wishes to put synthetic medicine on the market, it must "interest a pharmaceutical chemist in the manufacture of these products." The law seems to enact that a pharmaceutical chemist shall alone make medicine and must be on the staff of the color works. Certainly, he need not be resident at the works and may conduct his department from some other town, but he must accept pay for the use of his name. This adds to the cost of production and it is easy to see that it is an unnecessary drawback to the French color industry in its competition with imported products.—M.

CRANE AND HOIST MOTORS

The British Thomson-Houston Co., London, have designed a new type of motor for intermittent service, special attention being given to the need for avoiding breakdowns. The machine is described as being of the totally enclosed reversible series, wound commutating pole type and has been standardized for ratings up to 50 H. P., these ratings being based on continuous operation for 30 minutes at full load with a temperature rise not exceeding 55° C. The machines are of the 4-pole type. The magnet frame is of cast steel made in two parts, the top half carrying the brush holders and being provided with lugs to support the assembled motor, while the bottom half has a strong foot drilled for holding-down bolts. The fact that the drillings for the holes can be made at any place along the feet is an advantage. The armature core and commutator are assembled on a sleeve, a form of construction which permits the removal and insertion of a shaft without the necessity for disturbing the armature windings or the commutator. The armature windings are composed of former wound coils inserted in open slots. A valuable feature is that the shaft extensions are arranged to permit the spur gear of the brake to be mounted on either end of the shaft. —M.

A NEW POCKET-LAMP

A pocket-lamp without a battery is a recent Hungarian invention. An engineer of Budapest transforms muscular energy into electrical energy producing light. In shape and intensity of light, it equals the ordinary torch-lamp. The thumb moves a small lever outside the case, which on being depressed and released, springs back into its original position. This movement is transmitted through a rachet and pawl to a set of pinion gears which drive a small dynamo, the field of which is fitted with a permanent magnet. It is necessary to keep on moving the lever with the thumb as long as light is required, but the energy stored up in the spring is sufficient to maintain light for a few minutes after the movement of the lever has ceased. When the design is carried out in a heavier form as a hand-lamp; the lever is actuated by squeezing two parallel handles attached to the case, one of which is fixed and the other movable. The principle, says the *English Mechanic*, 105 (1917), 4, might also be applied to other purposes, as to ignition dynamos for blasting.—M.

RUSSIAN PLATINUM MINES

Some time ago H. M. Consul at Ekaterinburg reported that the annual sale by auction of the gold and platinum mines in the Urals was to take place at the Ekaterinburg Mines Department on February 6. In all 600 mines were to be put up for sale, the majority being situated, as is usually the case, in the Orenburg Government. As a rule, these mines are bought up with the idea of reselling them abroad at an enhanced price. H. M. Consul, however, in a later report, states that the government authorities have decided that, until further notice, all platinum mineral is to be held and sales refrained from, in view of the proposed requisition of platinum by the government.—M.

MAGNETOS

When war broke out, says *Engineering*, 103 (1917), 84, there was only one British firm manufacturing magnetos, its output being under 100 per week. Practically every magneto which went on motor vehicles, motor boats and aircraft of Great Britain came from Germany or America. To-day there are twelve or more British firms making magnetos. Their entire output, which reaches a total of over 165,000 magnetos, has been made for war purposes, being used on aeroplanes, sea-planes, airships, motor-lorries, motor-ambulances, motor cycles, "tanks," big-gun tractors, motor boats, wireless sets, searchlight sets, lighting sets and other contrivances where magnetos are required.—M.

CHEMISTRY IN WARTIME[1]

By Richard B. Pilcher[2]

Owing to the conditions of modern warfare, chemists have been more than ever in request. To give a full account of their work, if it were possible, would be imprudent, but it is well to place on record a statement confined to what it is permissible to relate, giving some indication of the importance of the profession of chemistry to the nation in these times.

The Government has secured the guidance of chemists and other men of science to assist in the investigation of suggestions and inventions, and to bring their knowledge and experience to bear on measures and devices of offence and defence, while apart from those acting in an advisory capacity, chemists have been called for service in the field as well as in the factory. In such times there is a demand for the solution of problems of an unusual character which can be entrusted only to men of the highest scientific training, with initiative and foresight.

So much had we come to rely on foreign sources of supply for many of our needs that means had to be found for dealing promptly and efficiently with difficulties, some of which, unless overcome, threatened serious disaster. The chemists of the country have not been found wanting.

The laboratories of our universities and colleges have become small factories for the preparation of drugs and medicaments, and many institutions have been trusted with the examination of materials used in the manufacture of explosives. The measures taken in this emergency secured uniformity in method and the standardisation of processes which would otherwise have been difficult to attain. Under the supervision of their professors, students unfit for service with the colours have been helping the country, and at the same time gaining useful experience.

Several hundred chemists have been engaged for assistance in the laboratories and in the works of Government and controlled establishments supplying armaments, munitions, and other materials of war. Many of these have found an opportunity of helping the country through the registers maintained by the Institute of Chemistry and other societies for this purpose. In cases where the number of men having technical experience in some branches was limited, the authorities have made arrangements for probationary training, so that their services should be available when required in new factories.

The staffs of the chemical departments of Woolwich Arsenal and other Government factories have been considerably augmented, as also that of the Government Laboratory, which, as the recently published report shows, has been largely responsible for the examination of foodstuffs and many other requirements of the Expeditionary Forces.

In previous wars the authorities have considered officers of the R. A. M. C. sufficiently trained for all necessary military duties involving chemical knowledge, but in the present conflict, with an unprecedented demand for medical men, qualified chemists have volunteered in such numbers as to give practical force to the suggestion that they should be engaged for the purification and examination of water supplies and for dealing with matters of hygiene requiring chemical knowledge. As a result many have been appointed to commissions and engaged for scientific work, not only with the R. A. M. C., but also with the A. S. C. and A. O. D., and other units. Attached to various forces at home, with the armies on the Continent and in Africa, chemists have thus rendered valuable service.

In consequence of methods of offence initiated by the enemy, such as the employment of poisonous gases, there arose a further demand for men with training in chemistry for service in the field. For the duties involved the authorities deemed it expedient to enlist men with such training rather than entrust them to men without any scientific knowledge, and the unit thus formed is a fighting force. With the assistance of the universities and technical colleges and the various bodies interested in chemistry, an entirely new force was brought into existence. The officers were mainly selected from chemists who already held commissions, while sergeants and corporals with knowledge of chemistry were transferred from other units. That they did their work well is shown by the despatches of Lord French and Sir Douglas Haig.

From the experience gained in the campaign it is clearly advisable that the State should have control of such an organization of professional chemists as to ensure at any time their efficient service in the many requirements of the naval, military and air forces. In addition to competent chemical advisers of undoubted standing, the following appear to be essential: Chemists to control the manufacture of munitions, explosives, metals, leather, rubber, oils, gases, food, drugs; chemists for the analysis of all such materials and for research; chemists, on active service, to assist in the control of water supplies, in the detection of poison in streams, in the analysis of water and food, in the disposal of sewage, and in other hygienic matters; chemists, both at home and in active service, to assist in devising safeguards against enemy contrivances of a scientific nature, and methods of offence to meet the same, as well as for the instruction of troops in such matters.

It has been called a "chemists' war" and an "engineers' war." Many regard it largely as a conflict between the men of science of the countries engaged. Our chemists have not been dismayed at that, but it is impossible to foresee to what limits beyond accepted tenets the enemy is prepared to go in the application of science to warfare, and we cannot reproach ourselves with having set an example of frightfulness.

To sum the matter up, chemists have met the situation with a spirit of true patriotism, and have been promptly organized for the service required of them. It is not too much to hope that, as the discoveries of science have been applied to the destruction of humanity, they may be devoted more and more to the furtherance of the arts of peace, to the uplifting of civilisation, and the pacification of the world.

During the war, in spite of the shortage of labour, considerable additions have been made to the large manufacturing concerns throughout the country in the extension of factories, both for the production of things hitherto obtained from abroad and for the requirements of the war.

One important lesson which on no account must be lost sight of is that the country must be self-supporting in all such requirements.

The chemists engaged in connection with the production of materials of war include a large number who were previously occupied in works which have passed under Government control. Most of these were members of the Institute or graduates in science, and many were teachers, who thus obtained an insight into operations on a manufacturing scale. If they return to teaching, this experience will have broadened their views; but many will no doubt prefer to remain in industry. Of those with the forces, probably the majority will return to their former work. In any case, many good British chemists should be available for the furtherance of British industry.

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[1] *Proceedings of the Institute of Chemistry* (1917), copied from the *Chemical Trade Journal and Chemical Engineer*, **60** (Feb. 24, 1917), 163.

[2] Registrar and Secretary of the Institute of Chemistry.

RESTRICTION ON MAGNESIA

The British Minister of Munitions gives notice that, under the Defence of the Realms Act, he prohibits the use of magnesite and magnesite products for and in connection with (1) construction or repair of any building (other than furnaces) or any flooring or deck or, (2) the manufacture of any insulating or non-conducting material except under and in accordance with the terms of a permit granted by the Minister of Munitions.—M.

ALUMINUM PRICES

The selling price of aluminum ingots of ordinary commercial purity, 98 to 99 per cent, has been fixed in Great Britain by the Ministry of Munitions at $1080 per ton, carriage paid to consumers' works. The maximum price of remelted aluminum scrap or swarf ingots of 98 to 99 per cent purity has been fixed at $1008 per ton, carriage paid to consumers' works. This maximum price must not be exceeded but a lower one may be fixed by agreement between seller and buyer based upon the metallic aluminum content. These prices take effect from February 1, and permits will be granted for such dealings in the above-mentioned materials as are in accordance with the above prices which are subject to alteration at any time by the Minister of Munitions.—M.

NEW COMPANIES IN JAPAN

According to reports from H. M. Commercial Attaché at Yokohama, the following are among the latest industrial developments in Japan: A company with capital 2,500,000 yen ($1,250,000), has just been formed at Tokio for the purpose of refining zinc by electrolysis and for mining and smelting other metals. A glass factory is being erected at Yokohama with a capital of $1,500,000 and it is expected that operations will be started in March, and orders have already been placed with this company for large quantities of bottles. Another company with a capital of $500,000 proposes to erect in the suburbs of Tokio a factory for the manufacture of plate glass. A mining concession for silica is said to have been obtained by the latter company in the Shizuoka Prefecture. With a view to working an oilfield in the Yamagata district, a company with a capital of $1,500,000 has been formed, while another with a capital of $3,000,000 proposes to take over and work a number of oil concessions at Kwiokawa, Akita Prefecture. As a result of the experiments made in the manufacture of soda ash in Nagoya, a joint stock company with a capital of $500,000 has been formed to manufacture this product and land has been acquired at Nagoya harbor to erect factories. An electrochemical company with a capital of $500,000 will build factories at the river Arakawa for the manufacture of bleaching powder, etc.—M.

BRITISH BOARD OF TRADE

During the month January 15–February 15, the British Board of Trade received inquiries from firms in the United Kingdom and abroad regarding sources of supply for the following articles. Firms which may be able to supply information regarding these things are requested to communicate with the Director of the Commercial Intelligence Branch, Board of Trade, 73 Basinghall St., London, E. C.

ADVERTISING NOVELTIES:
  Knives, cheap, to retail at 10c. each
  Mirrors, small, covered with celluloid
  Pencils
Beech boards for brushes (good quality)
Bells, metal, toy
Bottles, glass, straw-colored
Bootlaces, leather and mohair
Buckles, brace, brass
Candles
Cord-wire
Cases, cast-iron, for electrical fuse-boards and switch-gear

CHEMICALS:
  Amorphous phosphorus
  Alphanaphthol
  Alphanaphthylamine
  Aniline oil
  Dimethylaniline
  Metaphenylenediamine
  Metatoluolenediamine
  Naphthionate of Soda
  Nitrobenzene
  Orthotoluidine
  Saltpetre (refined, granulated)
  Sulfanilic acid
  Caustic Soda, 100 tons 95 per cent
  Epsom Salts, druggists' quality
  Silicate of Soda
Dextrinous substances (powder)
Dyes, cheap, for ink making
Egg-beaters, Dover pattern
Enamelled iron shades for electric lights
Eyelets for boots
Fezzes, felt
Gum Arabic
  Gedda, amber sorts
Hose-pipes, $2^3/_4$ and 3 in.
Isinglass
Latex cups

MACHINERY AND PLANT FOR:
  Making boot lace tags
  Making gelatine
  Making capsules
  Grinding safety razor blades
  Making glass flasks
  Conversion of starch into dextrine
  Making candles
  Stamping out leather, cloth and rubber washers
  Gelatine, shredding plant
  Electric baling presses
  Hydraulic baling presses
Paste, to give a polish to rough twine
Push-buttons
Rosin, American, 1000 tons
Studs, press, also two-piece
Tanks, wagon, for distributing oil
Wheels, chilled iron
Wheels, tracing
Wire, galvanized, 4 mm. thick
Wire-nails, assorted $^7/_8$ in. by 18 B. W. G. to 5 in. by 8 B. W. G.
Wood (ash) rims for sieves
Zinc, sheet, suitable for lining packing cases

—M.

SCIENTIFIC SOCIETIES

CALENDAR OF MEETINGS

American Chemical Society: Spring meeting, Kansas City, Mo., and Lawrence, Kan., April 10–14, 1917. Annual meeting, Boston, September 10–16, 1917.

American Electrochemical Society: Thirty-first General Meeting, Detroit, May 2–5, 1917. Fall meeting, Pittsburgh, October 4–5, 1917.

American Institute of Mining Engineers: Annual meeting, St. Louis, October 8–13, 1917.

American Iron and Steel Institute: New York, May 25–26, 1917.

American Society for Testing Materials: Atlantic City, June 26–30, 1917.

NINETEENTH ANNUAL MEETING AMERICAN CERAMIC SOCIETY, NEW YORK CITY, MARCH 5 TO 8, 1917

The Nineteenth Annual Meeting of the American Ceramic Society was held March 5 to 8, 1917, at New York City with headquarters at the Astor Hotel. All the sessions were held at the Astor Hotel except the one of Tuesday afternoon, March 6, which took place at the Metropolitan Museum of Fine Arts, and was followed by a tour of the Museum. The annual business session of the Society was held on Monday morning, March 5, and was followed by the Presidential Address by Mr. Lawrence E. Barringer, of the General Electric Company, Schenectady, N. Y. On Thursday, March 8, an excursion was made to Perth Amboy, N. J., and vicinity, to visit the Atlantic Terra Cotta Company, Didier-March Company, and the Fords Porcelain Works.

PROGRAM OF PAPERS

HEAVY CLAY WARES: THEIR MANUFACTURE AND TESTING

Study of Effect of Variation of Pressure in the Forming of Dust Pressed Tiles. F. K. PENCE.

The Advantages of Clay Storage and a Description of a Successful Installation. F. A. RIDDLE.

Notes on the Manufacture of Promenade Tile. M. W. BLAIR.

Notes on the Flow of Clay through Hollow-Ware Dies. G. D. MORRIS.

Humidity: Its Control and Relation to Drying Clay Wares. W. A. DENMEAD.

The Effect of the Size of Grog in Fire Clay Bodies. F. A. KIRKPATRICK.

The Relation between the Fusion Point and Composition of Refractory Clays. R. J. MONTGOMERY AND C. E. FULTON.

Volume Changes of Some Quartzites and Commercial Silica Bricks on Heating. D. W. ROSS.

Note on the Fine Grinding of Refractory Materials before Testing. R. J. MONTGOMERY.

Relation of Fusing Point of Ash to Availability of Coal for Burning Ceramic Wares. R. R. HICE.

An Attempted Heat Balance on a Continuous Kiln. C. B. HARROP.

Making Paving Brick from Blast Furnace Slag. J. B. SHAW.

The Principles of Construction of Bucket Elevators. G. D. MORRIS.

Modification of Load Test on Fire Brick. J. B. SHAW.

RAW MATERIALS, MINERALS, THEIR OCCURRENCE, REFINING AND TESTING

Notes on the Use of Sulfuric Acid in the Sedimentation of Kaolins. H. G. SCHURECHT.

Notes on Kaolin Refining. I. E. SPROAT.

American Clays for Floating Enamels. J. B. SHAW.

The Relation of Salt to Clay in the Purification of Clays. H. G. SCHURECHT.

A Study of Some American Refractory Bond Clays. A. V. BLEININGER AND G. A. LOOMIS.

Clay and Shale Deposits in the Vicinity of Toronto. E. W. KNAPP.

Apatite: A Substitute for Bone Ash. N. B. DAVIS.

An Instrument for the Measurement of Plasticity. W. E. EMLEY.

Discussion on Standard Methods of Clay Testing. Led by A. V. BLEININGER.

A Method of Measuring the Time of Set of Calcined Gypsum. W. E. EMLEY.

GLASS AND ENAMEL INDUSTRIES

Glass Sands: Their Origin, Mode of Occurrence and Properties. C. R. FETTKE.

The Physical Chemistry of the Fining of Glass. R. M. HOWE.

Glass Tank-Furnace Operation. R. L. FRINK.

History of Alabaster Glass. A. SILVERMAN.

Discussion: In What Chemical Condition Does Manganese Exist in Glass when Used as a Decolorizer, and What Factors of Furnace Conditions Affect It? Led by R. L. FRINK.

Enamel Surfaces under the Microscope. E. P. POSTE.

GLAZES AND COLORS

The Cost of Raw Lead Glazes. H. F. STALEY AND L. HEWITT.

Chrome-Tin Colors at Cone 9. R. H. MINTON.

A Synthetic Production of Sulfate Blisters in Whiteware Glazes. C. F. BINNS.

A Study of Three-Component Nomative Systems in Raw Lead Glazes. H. F. STALEY AND W. G. WHITFORD.

The Crawling of Malt Glazes. C. F. BINNS AND M. E. SAUNDERS.

Bristol Glazes, Compounded on the Eutectic Basis. Second Paper. A. S. WATTS.

The Control of Fusibility in Fritted Glazes. H. F. STALEY AND R. J. RILEY.

Report of Practical Application of Bristol Glazes Compounded on the Eutectic Basis. A. S. WATTS.

BODIES AND THEIR PROPERTIES

Notes on Flint and the Preparation of Porcelain Bodies. G. H. BROWN AND C. F. GEIGER.

The Interchange of Quartz and Flint in Pottery Bodies. C. F. BINNS AND W. I. SUTTON.

A Deformation Study of $MgO-Al_2O_3-SiO_2$ Mixtures. A. S. WATTS.

A Deformation Study of $BaO-Al_2O_3-SiO_2$ Mixtures. A. S. WATTS.

Latent Heat of Fusion of Lime and Magnesia. E. W. WASHBURN.

A New Principle in Heat Measurement. W. C. HARTER.

Note on the Temperature-Porosity-Volume Changes of Some Porcelain Bodies. G. A. LOOMIS.

Note on the Production of Special Refractories, Marquardt Porcelain and Magnesium Aluminate. F. H. RIDDLE.

SESSION AT THE METROPOLITAN MUSEUM

Ancient Greek Pottery. MISS RICHTER, of the Museum Staff.

An Attempted Reproduction of Ancient Oriental Glazed Pottery. CHARLES F. BINNS AND NELLIE I. WELLS.

Chinese Porcelains. MR. BOSCH REITZ, of the Museum Staff.

An Indigenous American Artist, and His Medium. EDWARD ORTON, JR.

View of the Ancient Greek Pottery and the Chinese Porcelains in the Museum Galleries. Conducted by MISS RICHTER and MR. REITZ.

SPRING MEETING AMERICAN CHEMICAL SOCIETY, KANSAS CITY, APRIL 10 TO 14, 1917

The Fifty-fourth Meeting of the American Chemical Society will be held in Kansas City, Tuesday, April 10th, to Saturday, April 14th, inclusive. The Society and hotel headquarters will be at the Hotel Muehlbach, corner of 12th and Broadway Streets.

DIVISIONAL PROGRAMS: The usual meetings will be held by all of the Divisions, with the following special programs: The *Physical and Inorganic*, and *Organic Divisions* will hold a Joint Meeting, Thursday morning, April 12; the *Division of Industrial Chemists and Chemical Engineers* will hold a Symposium on the Chemistry and Metallurgy of Zinc, Thursday, April 12.

EXCURSIONS: Interesting excursions are being arranged covering trips to the following industries: Packing houses, flour mills and other foodstuffs manufactories, zinc smelters, acids, cement, paper, soap and structural steel factories, and serum laboratories, and probably also a petroleum refinery. A trip will also be made to Lawrence to visit the University of Kansas.

CHAIRMEN OF THE LOCAL COMMITTEES

Executive—W. A. WHITAKER, University of Kansas, Lawrence, Kansas.

Finance—R. HIRSCH, Ridenour-Baker Grocery Company, Kansas City, Missouri.

Reception and Registration—L. E. SAYRE, University of Kansas, Lawrence, Kansas.

Smoker—G. H. CLAY, Procter and Gamble, Kansas City, Kansas.

Banquet—R. CROSS, Kansas City Testing Laboratories, Kansas City, Missouri.

Publicity—F. B. DAINS, University of Kansas, Lawrence, Kansas.

Excursions—C. F. GUSTAFSON, Manual Training High School, Kansas City, Missouri.

Entertainment of Ladies—Mrs. F. B. DAINS, 1224 Louisiana Street, Lawrence, Kansas.

PROVISIONAL PROGRAM

TUESDAY, APRIL 10. *Evening*, Dinner to the Council and Council Meeting.

WEDNESDAY, APRIL 11. *Morning*, Opening Session. *Afternoon*, Public Session: "Petroleum and Natural Gas." *Evening*, Smoker.

THURSDAY, APRIL 12. *Morning* and *Afternoon*, Division Meetings. *Evening*, Banquet.

FRIDAY, APRIL 13. *Morning*, Division Meetings. *Afternoon*, Excursions. *Evening*, Open.

SATURDAY, APRIL 14. *Morning*, Excursions.

PAPERS FOR THE MEETING: All titles for papers should be in the Secretary's hands *on or before March 27th;* or in the hands of the secretaries of divisions *on or before March 25th*, with the exception that titles of papers should reach the Secretary of the Division of Industrial Chemists and Chemical Engineers *on or before March 21st.*

The Division of Industrial Chemists and Chemical Engineers have voted *that the titles of all papers shall be sent to the Secretary of the Division, which title should be accompanied by an abstract, in time to have the abstract passed upon before the paper is put on the program;* that any title sent without an abstract shall not be printed in the program, and that the time limit for the presentation shall be *five minutes*, unless special arrangements are made with the Secretary of the Division.

By vote of the Council no papers may be presented at the meeting, titles for which are not printed on the final program.

ADDRESSES OF THE DIVISIONAL SECRETARIES

Agricultural and Food Chemistry: Glen F. Mason, H. J. Heinz Co., Pittsburgh, Pa.

Biological Chemistry: I. K. Phelps, Bureau of Chemistry, Washington, D. C.

Fertilizer Chemistry: F. B. Carpenter, Virginia-Carolina Chemical Co., Richmond, Va.

Industrial Chemists and Chemical Engineers: S. H. Salisbury, Jr., Northampton, Pa.

Organic Chemistry: H. L. Fisher, Columbia University, New York City.

Pharmaceutical Chemistry: George D. Beal, Chemistry Building, University of Illinois, Urbana, Ill.

Physical and Inorganic Chemistry: Earl V. Millard, Institute of Technology, Boston, Mass.

Water, Sewage and Sanitation: H. P. Corson, U. S. Public Health Service, Grove City, Pa.

LADIES' ENTERTAINMENT: The Committee headed by Mrs. F. B. Dains is actively at work arranging a program for the pleasure of visiting ladies. Ladies may come to the meeting with the assurance that everything will be done for their comfort and pleasure. Details will be found in the final program.

FINAL PROGRAM: The final program will be sent to all members signifying their intention of attending the meeting, to the secretaries of sections, to the Council, and to all members making special request therefor by postal card or attached slip to the Secretary's office.

OBITUARY—FREDERICK ROWLAND HAZARD

Industry and society lost a commanding figure in the recent death of Mr. F. R. Hazard, of Syracuse. He will long be known as a member of the group of men who brought the Solvay process for the manufacture of soda-ash to the United States.

Born in Peace Dale, R. I., Mr. Hazard received his early schooling in Providence, R. I., and was graduated from Brown University in 1881. For two years he was employed at his father's woolen mills at Peace Dale, and then spent a year or more in Europe studying the ammonia soda process. Equipped with knowledge so acquired, Mr. Hazard came to the newly-established plant of The Solvay Process Company, at Syracuse, the first alkali plant built in the United States. In the manufacture of alkali, Mr. Hazard had found a field which was to be the chief interest of his business life. As Assistant Treasurer, Treasurer, and for the past nineteen years as President, he participated in the management which, through its initiative, foresight and energy, not only instituted alkali manufacture in this country, but made this country absolutely independent of European supply.

As an executive, Mr. Hazard possessed unusual attainments. In addition to natural gifts of the first order for executive and financial management, he had a complete and detailed understanding of the ammonia soda process. This minute knowledge of the business made him an executive of unfailing judgment in matters of manufacturing policy as well as in the fields of finance and organization. There is one striking feature of Mr. Hazard's administration that needs particular mention. By sheer force of character he created an "atmosphere" in the multiple organizations of which he was the leader that is best described as "wholesome." Not only by his example of simple and right living did he set a standard of individual conduct, but by his simple and right methods of *thinking*, by his unswerving justice and "squareness," he set a standard of business ethics which affected every man in the organization.

Since Mr. Hazard's advent to the Presidency of The Solvay Process Company, the interests of the Company have been greatly extended, and through its associated companies, it has rendered a service of the very first importance in conserving the coal supply of the country through the application of the retort coke oven. It is not too much to say that the example set by the Solvay interests under Mr. Hazard's presidency, in developing the coal by-product industry, is the prime reason for our nearly perfected independence of Europe in the matter of coal-tar intermediates, dyes and explosives.

Besides being President of The Solvay Process Company, Mr. Hazard was President of Split Rock Cable Road Co., President Solvay Collieries Co., Treasurer Tully Pipe Line Co., Treasurer Semet-Solvay Co., and Treasurer By-Products Coke Corporation. Naturally, Mr. Hazard's business interests reached out beyond the companies that received the greater part of his attention. He was officer or director in several banking institutions, and his breadth of mind and understanding made his counsel always of value. He was President of the Syracuse Trust Co. at the time of his death and at various times had been Trustee in Onondaga County Savings Bank, Director in Commercial Bank, and Director in First National Bank.

From his connections and from inclination, Mr. Hazard was always interested in affairs chemical. The Syracuse Section of the American Chemical Society has had occasion many times to be thankful for his generous help, notably at the holding of the joint meeting of the Ithaca, Rochester and Syracuse Sections. For several years past, Mr. Hazard had been President of the Manufacturing Chemists' Association.

Keeping step with his business vision and accomplishments, Mr. Hazard's place in the social structure of the community was one of pre-eminence. His name is linked inseparably with the success of the Y. M. C. A. and the Y. W. C. A. activities in Syracuse; with the hospitals and free dispensary; with the Boy Scouts; with the Associated Charities; with the work of the Moral Survey Committee, and with the fight against the loan shark evil. He had been President of the Onondaga Provident Loan Association since its inception. He was also Past President of the Y. M. C. A. Chamber of Commerce, Syracuse Athletic Association, Syracuse Music Festival Association, and of Solvay Village.

An account of Mr. Hazard's character would not be complete without a reference to the constant thought he gave to the well-being of the Company's employees, and indeed to all men and women who toil. He was untiring in his efforts to make plant conditions and home conditions safer, better and happier. He worked as well as gave, and society lost in Mr. Hazard a character of rare genius in constructive philanthrophy.

J. D. Pennock

NOTES AND CORRESPONDENCE

DUREX BARIUM PLANT BURNED

Editor of the Journal of Industrial and Engineering Chemistry:

We regret to announce that on Thursday night, March 8th, our plant at Sweetwater, Tennessee was practically destroyed by fire, and at the present writing we are unable to say when we will be able to supply barium carbonate, sodium sulfide and depilatory. Fortunately the Long Island City, N. Y., plant of Toch Brothers will be able to handle all existing blanc fixé and barium chloride contracts. We are trying to make arrangements through other sources to manufacture part of our products. This fire, of course, does not interfere with our raw material supply.

Owing to the fact that the Durex Chemical Corporation had every possible facility for fighting fires and had both the night force and the day force thoroughly trained, it is well to point out to other chemical manufacturers that every precaution be taken against incendiary fires at the present time. Two weeks ago one of the bridges connecting two of the buildings of the Durex plant caught fire during the day, but the men were so well trained that inside of five minutes the fire was extinguished. The present fire took place at 12.30 in the morning, and the time clock of the watchman showed that he had been at the place where the fire originated ten minutes before. In less than 30 minutes the barium carbonate plant and the barium sulfide plant No. 1 were beyond control. In less than a half hour all the smokestacks collapsed.

Mr. Henry M. Toch, the President of the Durex Chemical Corporation, is at present of the opinion that the corporation should build a plant in Chattanooga and another one in Long Island City.

320 5th Ave., New York
March 15, 1917

Durex Chemical Corporation
Per Maximilian Toch

TWO LETTERS ON CORROSION OF INGOT IRON CONTAINING COBALT, NICKEL, OR COPPER

Editor of the Journal of Industrial and Engineering Chemistry:

The authors of the paper published under the above title, This Journal, 9 (1917), 125, have very freely discussed the resistance to corrosion of a pure commercial open-hearth iron manufactured by the American Rolling Mill Company of Middletown, Ohio, and sold under the brand-name of American Ingot Iron and have attempted to contrast the corrosion resistance of this product with certain alloys built upon it as a base, containing cobalt, nickel and copper.

The authors' conclusions are based mainly on exposure and loss in weight tests of small test pieces prepared in the laboratory. American Ingot Iron was melted up in small crucibles in an electric furnace and treated with degasifiers and certain alloying constituents and small castings about 1.25 inches in diameter were made from which small discs were turned, etc., etc. These little discs, about the size of a half dollar were suspended by silk threads or by other means and put out on a roof. After corroding for what is termed a sufficient length of time, the samples were treated with ammonium citrate to remove adherent rust and weighed. The loss in weight is recorded and tabulated, and upon these tabulations some very sweeping conclusions are based. In fact, eleven separate conclusions are appended to this paper, which, if justified by the experimental evidence, ought to settle the much debated question of the relative corrosion of pure iron and some of its alloys for all time to come. As a matter of fact, however, the conclusions are not justified nor are the results in accord with those obtained on samples obtained from sheets of similar analysis manufactured on the large open-hearth scale of operation, as the authors themselves point out.

General Conclusion III, p. 135, states that alloys formed by the addition of 0.25 to 0.30 per cent of copper, nickel and cobalt to American Ingot Iron are more resistant to atmospheric corrosion than the pure American Ingot Iron from which the alloys were prepared. The manufacturers of American Ingot Iron have for many years been interested in studying the properties of all possible alloys built on a pure iron base. The scientific research department of this company is well known to be second to no other anywhere in the iron and steel industry in respect to personnel, laboratories, equipment and plant experimentation facilities. It is a comparatively easy and cheap procedure to make up series of alloys in small laboratory crucibles but the research department of the American Rolling Mill Company has long since discovered that corrosion tests made on such samples are simply unconclusive and misleading. A careful inspection of the results recorded in this paper furnishes abundant evidence, if any were needed, of the truth of this statement. The differences in the corrosion factors derived from duplicate samples of the same heat show a wider variation in many cases than is shown between the samples of the various alloys. To select a few instances only, Sample H, 207 (*a*), a 0.50 per cent nickel alloy, showed a corrosion loss factor of 510, while its duplicate, H, 207 (*c*), showed a loss of 910. A 0.125 per cent cobalt alloy, 34204 (*a*) sample cut from a commercial sheet showed a corrosion loss of 1180, while its twin cut from the same sheet showed a loss of 292, a greater difference than is shown between any of the average differences between the competing types that were under test. Since sweeping conclusions are in order, why is it not fair to conclude that one sample out of any given heat is excellent in corrosion resistance and another very bad indeed, or, perhaps, even better, why not conclude that all such tests are misleading and, therefore, worse than none at all?

Based on very similar methods of testing, E. A. and L. T. Richardson[1] have concluded that the addition of copper to pure iron has a very slight influence on corrosion resistance, while the present authors conclude rather vaguely that "it seems to be conducive to reducing the corrosion of American Ingot Iron under atmospheric conditions."

No one has been more concerned than the manufacturers of American Ingot Iron to discover whether the alloys of cobalt, copper and nickel, as well as many other elements, with pure iron were superior to a carefully standardized and guaranteed purity of iron itself. Not only atmospheric corrosion, which is rarely encountered by uncoated sheet iron in service, but all the multiform and variable conditions of service exposure have been studied. Not wishing to make this discussion too long, it may be stated that although premature publication of results has been carefully avoided, the conditions noted in more than a thousand full size commercial sheets do not agree with the conclusions of the authors who seem to have been a little troubled by this tendency themselves. Having arranged coöperation with the American Rolling Mill Company after supplying the cobalt material, they received a number of full size cobalt alloy sheets made on the big scale of operation usual in open-hearth practice. The authors, however, did not receive any nickel or copper alloy sheets. It is difficult to understand, therefore, how they can discuss the corrosion of Ingot Iron containing nickel or copper, since they did not have any such material in their tests. After Ingot Iron has been melted in a crucible and had other constituents added to it, it is no longer American Ingot Iron. They state:

"The samples, Nos. 34175 to 44009, prepared by the American Rolling Mill Company, so far as this series alone is concerned, do not tend to bear out the conclusions from the series prepared at the laboratory. From these samples alone it would seem that additions of small amounts of cobalt, up to one per cent, have very little effect on corrosion, and that the addition of nickel to about 0.7 per cent was harmful."

In conclusion, I desire to give expression to a fact that is very often overlooked. Independent investigators, with a zeal which may be altogether proper, can publish results of tests and draw sweeping conclusions without any particular sense of duty or responsibility to anybody except themselves by so doing. A great manufacturing company, however, believing in and proud of the excellence of its products which are mainly the fruit of organized research work, has to be very certain indeed that it is right before it urges upon consumers the purchase of new products, possibly at an increased price, and which in any case must be ready to stand the test of service and make good not only under atmospheric corrosion, but under the thousand and one conditions that all-round service must meet.

WASHINGTON, D. C.
February 1, 1917

A. S. CUSHMAN

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Editor of the Journal of Industrial and Engineering Chemistry:

In his comments on the paper by Mr. Blake and myself as printed in THIS JOURNAL, 9 (1917), 125, Mr. Cushman makes a point of "coöperation" with the American Rolling Mill Co. We received their products for our tests in exchange for a considerable batch of very pure metallic cobalt. Beyond that, I recall no coöperation being contemplated for the four series of observations on small samples which were made for the Canadian Bureau of Mines, primarily for the purpose of studying the effect of additions of metallic cobalt. Further independent publications were contemplated regarding the observations on the rolling mill sheets (Series V), concerning which there was considerable correspondence regarding coöperation. This was in 1913, about four years ago, but nothing has since been done by either party about coöperative research, except that each supplied the other with analyses of materials submitted. This has been acknowledged in the text. I take this opportunity again to thank the American Rolling Mill Company and in particular, Dr. Beck, Director of their Research Department, for many courtesies in connection with our exchange of materials. The present paper is not intended to cover Series V, *i. e.*, observations on the rolling mill sheets. We state: "It will take at least another year for these sheets to corrode through to destruction, before which time no final conclusions can be drawn." It is contemplated that our observations on these sheets should form a complete and independent paper to be published more or less simultaneously with those of the American Rolling Mill Company on the same or similar sheets.

In his last paragraph, Mr. Cushman undertakes to lecture "independent investigators" in general, and presumably ourselves in particular, for lack of "sense of duty or responsibility," in contradistinction to a "great manufacturing company." I have served and am at the moment serving as director and executive officer in several corporations, but I have failed to notice that their collective "sense of duty and responsibility" rises to greater heights than that of their individual members. But too much space and time have already been taken referring to the personal

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[1] Paper before American Electrochemical Society, September 30, 1916.

aspect introduced by Mr. Cushman into the discussion. I shall pass to the consideration of the paragraphs referring to technical questions.

Mr. Cushman remarks, "as a matter of fact, however, the conclusions are not justified nor are the results in accord with those obtained on samples obtained from sheets of similar analysis manufactured on the large open-hearth scale of operation as the authors themselves point out." We pointed out no such thing! In the first place, we cut no samples from the sheets. All samples were cut from bars. The remark probably refers to Conclusion IV, following Series II. Mr. Cushman failed to note that this conclusion was from a preliminary series of measurements on samples which were unannealed. We carefully limit that conclusion by the phrase "so far as this series alone is concerned," namely, Series II, and because the samples of this series were unannealed, it was regarded as preliminary, and another full series of alloys was prepared.

The next series of measurements (Series III) were made on annealed samples, from which most of the general conclusions were drawn. This series indicates that the samples prepared by the addition of small percentages of copper, nickel and cobalt (from 0.25 to 3.0 per cent) to American Ingot Iron, as described in the text of the paper, are more resistant to atmospheric corrosion than the original American Ingot Iron, which was used as a base for the preparation of the alloys, and which was used as a standard of comparison.

Mr. Cushman remarks: "It is a comparatively easy and cheap procedure to make up series of alloys in small laboratory crucibles, but the research department of the American Rolling Mill Company has long since discovered that corrosion tests made on such samples are simply unconclusive and misleading." We have in mind, as well as Mr. Cushman, that accelerated corrosion tests, such as are frequently made on small scale samples, are often unconclusive and misleading. I do not regard that these tests, extending over 9 or 10 months under actual atmospheric conditions, may be classed as accelerated tests, nor do I admit that the general results will differ from those on large sized sheets similarly submitted to corrosion action. This point may properly be the subject of discussion and variance of opinion, but I particularly take exception to Mr. Cushman's discussion of this point, which seems characteristic of his attitude throughout. I quote from him: "A careful inspection of the results recorded in this paper furnishes abundant evidence, if any were needed, of the truth of this statement. The difference in the corrosion factor, derived from duplicate samples of the same heat, show a wider variation in many cases than is shown between the samples of the various alloys. To select a few instances only; Samples H 207 (*a*), etc., etc......" Mr. Cushman calls attention to a pair of measurements for Sample H 207 (*a*) of magnitude 910 and 510, respectively, namely, with an average deviation of individual measurements from their mean of about 28 per cent. For the other sample, to which he calls attention, he has quoted the figures 1190 and 292, these being the extreme corrosion losses for the sample, and indeed for any sample. These figures show an average deviation from their mean of approximately 60 per cent. Mr. Cushman prefaces his remarks with respect to these figures by the phrase "to select a few instances only."

With respect to the above, in Series I, there are pairs or triplets of measurements on 19 alloys. Disregarding the two samples to which Mr. Cushman has called attention, and one other, the average deviation of individual measurements from their mean for the entire series is approximately $4^{1}/_{2}$ per cent. In other words, Mr. Cushman has deliberately selected two samples, the observations of which disagree among themselves by nearly ten times as great an amount as the average disagreement of measurements for the rest of the series, and from this selection he attempts to draw conclusions as to the concordance of all the measurements among themselves. Nor is this all—both of the samples to which he makes reference are taken from Series I, which is admittedly preliminary. If, in a similar manner, we take the average of the observations for each of the samples in Series II, and note the average deviation of a single observation from their means, the resultant average deviation for the entire Series II is slightly above 3 per cent. This series represents measurements on 19 alloys from which none are omitted in the above computation. Again making similar computation for Series III, which is by far the longest series, and which reports about 125 corrosion measurements, the average deviation of a single observation from their means is about 4 per cent. Thus Mr. Cushman has selected two measurements with an average deviation from the mean respectively ten and twenty times as great as the average; in fact, so great that, according to the laws for discarding observations, they should probably be considered as containing some gross error. We properly included them in our report for completeness, but it is obvious that no one intending to be fair should conclude as to the concordance of results among themselves, from the particular measurements which he has selected.

Opinions may vary as to whether or not the alloys described in our paper represent what would be produced from American Ingot Iron by the addition of small percentages of nickel, cobalt and copper following the regular manufacturing procedure. We have drawn no conclusions in this regard, preferring to wait until we are in a position to publish our work on the sheets supplied by the American Rolling Mill Company, which are more representative of such a condition. On the other hand, there can be no doubt but that the corrosion measurements on the discs, described in this paper, on the average show a remarkable concordance among themselves for any given sample. For example, the very alloy, No. 34204, for which Mr. Cushman quotes fom Series I the values 1080 and 292 as the corrosion factors, in four independent measurements in Series III shows the values of the corrosion factors as follows: 638, 643, 638, 638. The average of these four measurements is 639, with an average deviation of a single observation from the mean of less than 0.2 per cent. It would be just as fallacious for us to characterize the concordance of all our observations by this particularly concordant set of measurements on Alloy No. 34204, as it was for Mr. Cushman to characterize them all by far the least concordant pair of measurements in the entire set of over 200 determinations.

In conclusion, let me say that we have no elaborate ideas as to the conclusiveness of our results, or of any other single set of measurements on so evasive a subject as atmospheric corrosion. We noted particularly that the primary purpose of our investigation was "measurement and the setting forth of data." These, we consider of the first importance, much more so than any conclusions we may have drawn from these data, and we admit that others may properly conclude at variance with ourselves. We do not, however, admit the particular points of exception which Mr. Cushman has raised, and we very much regret that he thought it necessary to hasten into a discussion savoring so much of the personal aspect and apparently based upon very little consideration of the technical data.

Jacksonville, Florida
February 16, 1917

Herbert T. Kalmus

TWO LETTERS ON RELATION OF FAT IN MILK TO THE SOLIDS-NOT-FAT

Editor of the Journal of Industrial and Engineering Chemistry:

May I suggest that Messrs. Brown and Ekroth, in their article on milk published in This Journal, 9 (1917), 297, have misinterpreted some of the standards referred to. Several standards specify minimum values for the fat and total solids but many of these neither specify nor imply that the solids-not-fat must exceed that difference between these values. The case of 12 per cent of total solids and 2.5 per cent of fat referred to on page 297 is evidently that of Rhode Island and there is probably no difficulty experienced in complying with these values. The solids-not-fat are not specified and there is no warrant for assuming that the minimum value is 9.5 (12.0 — 2.5). The other case referred to, evidently that of Minnesota, presents reasonable ground for criticism and the 9.75 per cent of solids-not-fat is included in the standard. Probably this was inserted under the erroneous impression that a 13.0 per cent total solids and 3.25 per cent of fat standard also implied that the solids-not-fat should exceed 9.75 per cent. This, of course, is an absurd value and is impossible to meet. A similar error appears to have crept into quite a number of the state standards. My opinion is that standards are to be regarded as the minimum percentages of certain constituents that are to be contained in the article sold as milk and it is not essential for this purpose that they should bear any relation to their relative proportions in milk. The standards are definite specifications of what the consumer must receive and in this respect are very different from the English milk standards which are merely presumptive and admit rebutting evidence by the vendor.

As previously stated, the limiting values for the fat and total solids, or fat and solids-not-fat are to be considered separately; it often happens, however, that one standard is much more stringent than the other and that one is consequently redundant. In Ottawa the standard is 12 per cent of total solids of which at least 3.0 per cent shall be butter-fat. On looking over my records for the past year I find that in one group, farmers' raw milks, there are 2,154 samples and of these 10.80 per cent violated one or both standards, 10.75 per cent were deficient in total solids and 2.0 per cent deficient in fat. Only one sample (2.9 per cent fat) was deficient in fat and yet satisfied the standard for solids. The average fat content of the samples below the standard was 3.15 per cent. It is very evident that, in Ottawa, the standard could be simplified to one specifying only the total solids without altering its effect.

If the same samples were examined under the Dominion standard of 8.5 per cent solids-not-fat and 3.25 per cent fat, the samples deficient in fat would be increased to 2.8 per cent and those rejected on account of deficiency of solids-not-fat would have been 14 per cent. In other words the Dominion standard of 8.5 per cent of solids-not-fat is more stringent than the Provincial one of 12 per cent total solids. Less than 0.5 per cent of the samples passed the solids-not-fat test and were rejected by the fat clause.

The standard of 8.5 per cent solids-not-fat in New York is probably equal to one specifying 11.7 per cent of total solids and 3.15 per cent of fat and is therefore tantamount to raising the State standard.

City Laboratory
Ottawa, Canada
March 10, 1917

Joseph Race,
City Bacteriologist and Chemist

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Editor of the Journal of Industrial and Engineering Chemistry:

We beg to suggest the following as comment on Mr. Race's criticism of our handling of the standards in our paper in the March issue of This Journal. We believe the trouble with Mr. Race's whole argument is to be found in his statement: "My opinion is that standards are to be regarded as the minimum percentages of certain constituents that are to be contained in the article sold as milk." It is quite true that the principle here enunciated is the principle on which many food standards are based. It is, however, obvious that all food standards of natural products should be based on the natural composition of the product. Inasmuch as milk was one of the first materials legislated upon and as the legislation was largely done by persons unfamiliar with the principles which should govern the establishment of standards, we think it logical to suppose that these standards represented the ideas of legislators as to the natural composition of milk, based either on experience or on what was supposed to be reliable information. This is borne out by the fact that many of the states require that milk shall be sold as produced.

It follows that standards so made should conform in their requirements to the natural article. The other alternative, namely, the allowing of the manipulation of milk (such as the extraction of the fat) would appear to be foreshadowed by the present trend of ideas regarding milk standards. Such milk would necessarily have to be sold either with a statement on the label of the percentage of fat and total solids (or solids-not-fat) or would have to be sold as of a specified standard of composition, such as "sub-standard," "above standard," etc. In this case Mr. Race's contention that the fat and solids-not-fat need bear no definite relationship to one another is correct, but this, of course, would mean that the legal provision requiring milk to be sold as produced would have to be abrogated, and any milk would be adulterated only if it departed from this declared composition.

Having regard, however, to the present standards, most of them fail to prevent adulteration because their makers (like Mr. Race) appear to think, regarding the figures set for fat and solids-not-fat (or total solids), that "it is not essential for this purpose that they should bear any relation to their relative proportions in milk." The point can be illustrated from Mr. Race's letter. He says "Only one sample (2.9 per cent fat) was deficient in fat and yet satisfied the standard for solids," which, as he tells us, is 12 per cent in Ottawa. A sample of milk analyzed by us in New York City had the composition: fat 4.8, solids-not-fat 9.17, total solids 13.97. The dairyman supplying Mr. Race's sample evidently started with a milk of somewhat this composition, for we could reduce this milk to a fat percentage of 2.9 by the abstraction of about 40 per cent of its fat as cream, and still have milk within the legal limit of total solids (2.9 + 9.17 = 12.07), and this is probably what happened to the sample in question. It is, moreover, a legal sample under the Rhode Island law.

It is because the present unbalanced standards not only allow of but are, especially where certain strains of cattle furnish the milk supply, an invitation to such manipulation, that we object to them.

Bureau of Foods and Drugs
New York City, March 16, 1917

Lucius P. Brown
Clarence V. Ekroth

THE FIXATION OF NITROGEN—CORRECTION

In my article under the above title, This Journal, 9 (1917), 233, the following corrections should be made:

P. 236, Equation 8, 2NaCN should read: Na_2CO_3.

P. 245, 6th paragraph should read: "This shows how easily one can get, etc."

P. 246, foot-note 1 should read: *J. Chem. Soc.*, etc.

P. 248, 2nd equation, $2Na_2CO_3$ should read: Na_2CO_3.

P. 250, 2nd column, 5th line from bottom of page, $(CO(NH_2)_2.HNO_3$ should read: $CO(NH_2)_2.HNO_3$.

P. 251, equation near top of first column, should read: $(CN)_2 + 2H_2O = (CONH_2)_2$.

John E. Bucher

THE GERMAN ALARM CLOCK—CORRECTION

In the article under the above title printed in This Journal, 1 (1917), 59, the following correction should be made:

Page 62, Column 1, Line 19, the figure $10,000,000 should read $10,000.

H. E. Howe

PERSONAL NOTES

President Stieglitz has appointed W. D. Bigelow chairman of the Membership Committee to succeed Frank K. Cameron, resigned, and F. G. Cottrell a member of the Committee to fill the vacancy caused by Dr. Bigelow's appointment to the chairmanship. The other member of the Committee is Charles L. Parsons.

Dr. H. E. Barnard has been elected, by the Council letter-ballot, a Director of the American Chemical Society to fill the unexpired term of Dr. E. G. Love. The Council also approved the election by the Directors of Dr. E. G. Love as Treasurer of the Society.

Prof. Wilder D. Bancroft addressed the Indiana Section of the A. C. S. on "Contact Catalysis," on March 9th.

Edward Dyer Peters, Professor of Metallurgy at Harvard University and the Massachusetts Institute of Technology, died at his home in Dorchester, Mass., on February 17th, in his sixty-eighth year. Prof. Peters became a lecturer at Harvard in 1903 and had been a professor of metallurgy there since 1904.

The lecture by Dr. John Uri Lloyd, which was to be given on April 13th at the College of the City of New York, has been indefinitely postponed.

Mr. Alex. L. Feild has decided to remain with the Bureau of Mines at Pittsburgh. He was noted in our March issue as having accepted a position with the Gulf Pipe Line Company, Houston, Texas.

Prof. Henry M. Howe has been awarded the John Fritz Medal for 1917 for his investigations in metallurgy.

Mr. Stanley B. Pennock has been killed by an explosion in the works of the Aromatic Chemical Company, of which he was a partner. He was working at the time of his death on a new process for chlorination.

Prof. C. C. Todd, of the State College of Washington, announces that early in the week of February 25th there was stolen from their laboratory a platinum dish weighing about 48.5 g. and marked with four ciphers, 0000.

Dr. Jeffery Stewart, of the Philadelphia Section of the A. C. S., has resigned as secretary and superintendent of the India Refining Company, of Philadelphia, and is now connected with the oil firm of E. F. Drew & Company, of that city.

Dr. Lloyd Balderston lectured on "Tanning" at the regular meeting of the Philadelphia Section of the A. C. S. on March 15th. The Second Annual Smoker of the Philadelphia Section will take place on April 12th.

Mr. Walter Laib has been appointed superintendent of The Ohio Salt Company at Rittman, Ohio. This plant has a daily salt capacity of 5000 barrels, in addition to its production of chlorate of potash, manufactured under Mr. Laib's patent.

Mr. Oscar W. Palmenberg announces the removal of his business from the Chemists' Building to the Hudson Terminal Building, 50 Church Street, New York City, where he has taken over the chemical and physical laboratories of Dr. Chas. F. McKenna, who intends to confine his attention to his consulting practice.

Mr. A. E. Marshall has severed his connection with The Thermal Syndicate and has taken up the works management of the Davison Chemical Company's plant at Curtis Bay, Md.

The Burdett Oxygen Company completed the erection of its Salt Lake City plant on March 1st, and is in a position to furnish pure oxygen to users in that territory. The capacity of their Los Angeles plant has recently been increased 50 per cent.

Dr. Gustav Drobegg has been superintendent of Plant D, of the Butterworth-Judson Corporation, at Newark, N. J., since the beginning of this year. He was formerly superintendent for Charles Pfizer & Company until 1912; then manager of manufacturing department for the Synfleur Scientific Laboratory, Monticello; and for the past two years with the Beckers Aniline Chemical Works, in charge of research and part of plant.

The McGraw Publishing Company and the Hill Publishing Company have been consolidated as the McGraw-Hill Publishing Company Inc., with James H. McGraw as president. *Engineering News* (formerly Hill property) and *Engineering Record* (formerly McGraw property) will be consolidated under the name *Engineering News-Record*, with Charles Whiting Baker, now editor of *Engineering News*, as editor-in-chief.

The United States Civil Service Commission announces the following open competitive examinations: *Assistant chemist* (male), salary $1,000 a year, on April 18, 1917; *assistant chemist in forest products* (male), salary $900–$1,500 a year, on April 18–19, 1917.

Mr. M. O. Lamar, of the General Electric Company, has taken charge of the analytical laboratory of the Norton Company, at Niagara Falls.

The Twenty-fifth Anniversary of the New York Section of the American Chemical Society was celebrated with a dinner and smoker at the Chemists' Club, on March 9, 1917. The opening remarks of Chairman Matthews were followed by addresses by Provost Edgar F. Smith, of the University of Pennsylvania, on "Robert Hare;" Dr. Wm. H. Nichols on "The Early History of the Society;" and Dr. E. G. Love on "The First Years of the New York Section." Dr. Charles F. Chandler, who was scheduled to speak, was unable to attend. In honor of the occasion, Dr. Charles A. Doremus presented to the Section a large steel engraving of Prof. J. W. Draper, first president of the American Chemical Society. The officers elected for the coming year are: *Chairman*, Dr. Chas. H. Herty; *secretary-treasurer*, Mr. Chas. F. Roth.

The Pacific Coast Borax Company announce that their potash plant at Searles Marsh started up on the 1st of April. They expect to turn out quite an amount of potash during the month of April and state that from that time forth the present unit should produce 1000 tons per month, running 80 per cent or better.

Harrison W. Craver, chief librarian of the Carnegie Library of Pittsburgh since 1908, has tendered his resignation to the Library Committee of the Board of Trustees of Carnegie Institute, to take effect April 1st. Mr. Craver has accepted a position as director of the library of the United Engineering Societies of New York, and left Pittsburgh the latter part of March to assume his new charge. His new position will put him in direction of what is believed to be the largest engineering library in the world, with approximately 150,000 volumes on technological subjects on its shelves.

Mr. Howard F. Weiss has resigned the directorship of the U. S. Forest Products Laboratory at Madison, Wis., and from April 1st will be connected with the C. F. Burgess Laboratories, Madison, Wis.

At a special meeting of the Cincinnati Section of the A. C. S. on March 7, Dr. Wilder D. Bancroft, of Cornell University, spoke on "Contact Catalysis." A regular meeting of the Cincinnati Section was held on March 28, with the following program: "The Composition of Menhaden Oil Fatty Acids," by Dr. Ernst Twitchell, and "The Progress of Chemical Industry," by Mr. H. B. Schmidt.

Mr. A. Brooking Davis, who is now with the Ault & Wiborg Company, Cincinnati, is chemical director of that concern.

Eimer & Amend give notice that the man under the name of F. H. (or H. F.) Frank, or Fisher, soliciting orders and obtaining money by using the name of their firm, is an impostor and acting entirely without their authority. He has been operating in Chicago, Cleveland and Grand Rapids, and perhaps elsewhere.

The University of North Dakota has been granted an appropriation from the State Legislature of $90,000 for the first unit of a new chemistry building, construction of which will begin immediately. The department of chemistry has more than doubled in the last five years and was sorely pressed for room.

We are informed by Mr. Anton Richard Rose, of New York City, that the "Norsk hydroelektrisk Kvaelstof aktieselskab" has set aside 100,000 kr. to be transferred to the Nansen Fund trustees, Kristiania, Norway, for the promotion of chemical and physical research. Inasmuch as the founder of this company, Sam. Eyde, celebrates his 50th birthday on October 29th, the company desires that this fund be known as "The Sam. Eyde Fund for the promotion of chemical research." Only the interest from the fund is to be expended, and in such manner as the trustees may deem desirable for scientific investigations within the designated field. [See *Tid. Kemi, Farm. Terapi*, 13 (1916), 301.]

The New York Section of the Society of Chemical Industry held its March 23rd meeting in conjunction with the Home Economics Association. Prof. Lafayette Mendel, of Yale University, spoke on "Food Fads" and Dr. Graham Lusk, of Cornell University, on "Food Values."

The Williams Patent Crusher & Pulverizer Company, St. Louis, Mo., have taken larger quarters for their Pacific Coast sales office, at 67 Second St., San Francisco. Mr. O. J. Williams is in charge of the San Francisco office.

The Second Annual Drainage Conference of the University of Illinois was held March 13–15, 1917. The organization and financing of drainage districts, the surveying of drainage areas, the design of systems, and improved methods of construction were among the subjects considered by engineers and public officials of prominence. The meeting was in charge of the department of Civil Engineering, College of Engineering, Urbana, Illinois.

A Public Inspection Day for the new chemical building of the University of Cincinnati has been set for April 7. The program includes an address by Dr. Chas. H. Herty, and a subscription dinner at the Hotel Gibson Ball Room.

Dr. Charles A. Mann, of the University of Wisconsin, has been appointed associate professor of chemical engineering at Iowa State College, to succeed Prof. George A. Gabriel, who goes into practical work.

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. Commerce 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 Commerce Reports mailed daily is $2.50 per year, payable in advance, to the Superintendent of Documents.

BUREAU OF STANDARDS

A Study of Electromagnet Moving Coil Galvanometers for Use in Alternating Current Measurements. Ernest Weibel. Scientific Paper 297. This paper gives the results of a study of the electromagnet moving coil galvanometer that has led to the construction of instruments with sensitivities much greater than those previously obtained and equal to those of the best direct current moving coil galvanometers. The theory of the instrument is developed.

The Recovery of Paraffin and Paper Stock from Waste Paraffin Paper. W. H. Smith. Technologic Paper No. 87. 4 pp. "This paper describes a process for the recovery of the paraffin and paper stock from waste paraffin paper. The waste is pulped with exhaust steam in a vertical boiler. The wax rises to the surface, and is drawn off with the hot water through a screen, the stock settling to the bottom of the boiler. The stock is transferred to a heating engine and further treated for the removal of the residual paraffin. Paper prepared from the recovered stock was free from wax and satisfactory in every respect. Practically all of the paper stock is recovered, but about 10 per cent of the paraffin in the waste is lost during the process."

This paper is no longer available for free distribution; it can be procured only from the Superintendent of Documents. Paper, 5 cents.

Fees for Electric, Magnetic, and Photometric Testing. Circular No. 6, 7th Edition, 30 pp. "Information regarding tests, range of testing, instructions to applicants, and schedules of fees, for electric resistances and instruments, apparatus for radio communication, magnetic testing, testing magnetic parts of materials, radioactivity, and photometry."

National Electrical Safety Code. Circular No. 54, 2nd Edition, 323 pp. Paper, 20 cents, or Cloth, 30 cents. This publication is for examination, trial, and constructive criticism; it gives definitions of terms and rules for installation, operation and maintenance of central station and substation equipment, overhead and underground lines, grounding of apparatus and supports, and for the installation of wiring for electrical utilization apparatus.

Some Technical Methods of Testing Miscellaneous Supplies. P. H. Walker. Unnumbered publication, reprinted from Bureau of Chemistry Bulletin 109, with notes and corrections. 68 pp. Paper, 15 cents. This report includes methods for paint and paint materials, ink, lubricating oils, soaps, etc.

Resistance of an Oil to Emulsification. Winslow H. Herschel. Technologic Paper No. 86. 37 pp. In this paper is described a new test for the emulsification of oils. Certain results obtained by such measurements are also discussed. The test may be briefly described as follows: 20 cc. of the oil to be tested and twice that volume of distilled water are heated to 55° C. in a 100 cc. cylinder, 26 mm. inside diameter, and stirred for 5 minutes at a speed of 1500 revolutions per minute. The cylinder and contents are allowed to stand at the same temperature, and readings are taken at more or less frequent intervals (according to the type of oil) of the volume of oil settled out from the water. From these readings, a maximum rate of settling, called "demulsibility," is easily taken from a table. The paddle is simply a plate of metal 8.9 by 20 by 1.5 mm. Since the test is not sensitive to slight changes of paddle dimensions, they need not be exact, and no calibration is required.

Studies on Paper Pulps. W. H. SMITH. Technologic Paper No. 88. 13 pp. Paper, 5 cents. "Samples of paper pulps, each representing a different method of preparation, with one exception of American manufacture, have been examined to determine their chemical properties. The loss in weight produced by reagents causing hydrolysis and oxidation and the gain in weight when nitrated have been determined with the same pulps. The effect of sunlight, temperature, and ozonized air on the chemical constants of ground wood has been ascertained."

A Specific Gravity Balance for Gases. JUNIUS DAVID EDWARDS. Technologic Paper 89. 17 pp. Paper, 5 cents. "The apparatus described provides a quick and accurate means of determining gas density. A form of balance-beam support has been devised which gives high sensibility. The needles which replace the knife-edge are easily adjustable and, in contrast with the metal or quartz knife-edge usually used, can be obtained almost anywhere, are inexpensive, and can be replaced as often as necessary. The success obtained in the use of this apparatus is mainly due to the high sensibility afforded by this means of support. It is necessary to remove the beam from the case only when it is desired to transport it. No leveling bottle is necessary in adjusting the gas pressure within the balance, this being accomplished by means of a needle valve which affords precise control. The portable outfit combines lightness of weight, convenience in use, and durability without any great sacrifice of accuracy. No preliminary calibration of the apparatus is necessary."

United States Government Specification for Portland Cement. ANONYMOUS. Circular No. 33, 3rd Edition. 43 pp. Paper, 10 cents. This specification is the result of several years' work of the joint conference representing the United States Government, the American Society of Civil Engineers, and the American Society for Testing Materials. It was adopted by the United States Government and by the American Society for Testing Materials, to become effective January 1, 1917.

BUREAU OF THE CENSUS

Census of Manufactures: General Totals for United States by Geographic Divisions, States, and Industries, 1914, 1909, 1904 and 1899. 26 pp. "General statistics for manufactures censuses for 1914, 1909, 1904 and 1899 are shown in two tables. Table 1 presents a comparative summary for the United States by geographic divisions and States, by number of establishments, average number of wage earners, primary horsepower, capital, wages, materials, and value of product. Table 2 gives comparative summary, under same headings as in Table 1, for 333 of principal industries for which statistics were gathered in 1914."

Cotton Production and Distribution, Season of 1915–16. Bulletin 134, 99 pp. Paper, 20 cents. This report includes statistics regarding the manufacture of cottonseed products which are of chemical interest.

FEDERAL TRADE COMMISSION

Fertilizer Industry. Senate Document 551, 64th Congress, 1st Session. 269 pp. Paper, 50 cents. This is a report of the Federal Trade Commission in response to a Congressional resolution calling for a report on an investigation of the fertilizer industry which was begun by the Bureau of Corporations.

NATIONAL MUSEUM

Newly Found Meteoric Stone from Lake Okechobee, Florida. GEORGE P. MERRILL. From *Proceedings*, Vol. 51 (December 21, 1916), 525–526. Reprint No. 2163.

Notes on Whitfield County, Georgia, Meteoric Irons, with New Analyses. GEORGE P. MERRILL. From *Proceedings*, Volume 51 (December 16, 1916), 447–449. Reprint No. 2157.

Recently Found Iron Meteorite from Cookeville, Putnam County, Tennessee. GEORGE P. MERRILL. From *Proceedings*, Volume 51 (November 24, 1916), 325–326. Reprint No. 2153.

DEPARTMENT OF AGRICULTURE

The following seven articles from Volume 8 of the *Journal of Agricultural Research* are of chemical interest:

(1) **Availability of the Potash in Certain Orthoclase-Bearing Soils as Affected by Lime or Gypsum.** LYMAN J. BRIGGS AND J. F. BREAZEALE. (January 2, pp. 21–28.)

(2) **Ewes' Milk: Its Fat Content and Relation to the Growth of Lambs.** E. G. RITZMAN. (January 8, pp. 29–35.)

(3) **Calcium Compounds in Soils.** EDMUND C. SHOREY, WILLIAM H. FRY AND WILLIAM HAZEN. (January 15, pp. 57–77.)

(4) **Effect of Fertilizers on the Composition and Quality of Oranges.** H. D. YOUNG. (January 22, pp. 127–138.)

(5) **Measurement of the Inactive, or Unfree, Moisture in the Soil by Means of the Dilatometer Method.** GEORGE BOUYOUCOS. (February 5, pp. 195-217.)

(6) **Arsenical Injury Through the Bark of Fruit Trees.** DEANE B. SWINGLE AND H. E. MORRIS. (February 19, pp. 283–317.)

(7) **Effect of Irrigation Water and Manure on the Nitrates and Total Soluble Salts of the Soil.** F. S. HARRIS AND N. I. BUTT. (February 26, pp. 333–358.)

Possibility of the Commercial Production of Lemon-Grass Oil in the United States. S. C. HOOD. Department Bulletin 442, from the Bureau of Plant Industry. 12 pp. Paper, 5 cents. Published January 25. This is a report of experiments conducted to determine the commercial possibilities of the cultivation of lemon-grass for the production of the oil which is used in the manufacture of perfumes and soaps.

Composition of Hawaiian Soil Particles. WILLIAM T. MCGEORGE. Bulletin 42, Hawaii Agricultural Experiment Station. 12 pp. Paper, 5 cents. Published January 17.

Improved Apparatus for Use in Making Acidity Determinations of Corn. H. J. BESLEY AND G. H. BASTON. Circular No. 68. 4 pp. Paper, 5 cents.

PUBLIC HEALTH SERVICE

Commission on Milk Standards. Third Annual Report of the Commission on Milk Standards appointed by the New York Milk Committee. Public Health Reports, **32**, 271–96 (February 16).

GEOLOGICAL SURVEY

Tungsten Deposits of Northwestern Inyo County, California. ADOLPH KNOPF. Bulletin 640-L, from Contributions to Economic Geology, 1916, Part II, pp. 311–333. Published February 8. "At present interest in the mining of the eastern black shales as a source of oil must confine itself to localities where one of three conditions is met. The shale can be utilized, first, where it outcrops in a position to permit mining on a large scale by steam shovel at a minimum cost; second, where coal that is overlain by bituminous shale is being stripped; and third, where a coal bed that is being mined has a black shale roof that comes down and must be removed from the mine in large amounts. Of these the second condition seems to offer the best opportunity for a trial plant, as the overlying black shale must be removed in mining the coal. At such pits it would require only that another shovel be installed to lift the shale, or the small shovel now used to lift the coal could be used to lift the black shale first. This black shale over the coal appears to have the advantage of a higher oil yield. Where the roof shale is as rich as at Cannelton, Pennsylvania, it may pay to mine the shale with the coal."

The Cleveland Gas Field, Cuyahoga County, Ohio. With a Study of Rock Pressure. G. SHERBURNE ROGERS. Bulletin 661-*A*, from Contributions to Economic Geology, 1917, Part II, pp. 1–68. Published March 2.

Useful Minerals of the United States. Compiled by FRANK C. SCHRADER, RALPH W. STONE AND SAMUEL SANFORD. Bulletin 624. This bulletin may be regarded as a thoroughly revised edition of Bulletin 585, greatly enlarged and brought up to date. The present bulletin, like the earlier work, gives concisely the location, by states and counties, of the principal deposits of useful minerals, and includes a glossary showing the composition and character of each mineral and the location of its principal deposits. It gives also the principal uses of each mineral, a feature not appearing in the earlier bulletin. As a mineral directory it will be useful to scientific bureaus and educational institutions that deal with the numerous inquiries of the general public concerning what may be called commercial mineralogy, as well as to the prospector, miner, manufacturer, business man, and student of economic conditions.

Gold and Silver in 1915. (General Report.) H. D. McCaskey and J. P. Dunlop. From Mineral Resources of the United States, 1915, Part I, pp. 767–803. Published March 2.

The Inorganic Constituents of Marine Invertebrates. Frank Wigglesworth Clarke and Walter Calhoun Wheeler. Professional Paper 102. 52 pp. Paper, 10 cents.

Baked Shale and Slag Formed by the Burning of Coal Beds. G. Sherburne Rogers. Professional Paper 108-*A*, from Shorter Contributions to General Geology, 1917, pp. 1–10. Published March 3.

BUREAU OF MINES

Abstracts of Current Decisions on Mines and Mining. Reported from May to August, 1916. J. W. Thompson. Bulletin 143. 68 pp. Paper, 10 cents.

Refining and Utilization of Georgia Kaolins. Ira E. Sproat. Bulletin 128. 49 pp. Paper, 15 cents. "Up to the present time mechanical principles only have been applied in the refining of kaolins, but in order to keep pace with the increasing requirements for better quality and uniformity of product, the application of the principles of colloidal chemistry is necessary.

"The investigation described in this report was carried on to determine the practicability of applying technical control of clay disperse systems to the refining of kaolins and the utilization of the prepared clay in the manufacture of vitreous china and wall tile.

"It is hoped that this report will prove a stimulus to the clay-washing industry; will point out a method of refining certain American clays, and will lead to the substitution of domestic kaolins for imported china clays by manufacturers of high-grade ceramic wares."

HYGIENIC LABORATORY

Experimental Studies with Muscicides and Other Fly-Destroying Agencies. Earle B. Phelps and Albert F. Stevenson. Bulletin No. 108. 37 pp. Paper, 10 cents. "A somewhat comprehensive survey has been made of other chemical substances having possible muscicidal properties with a view to substituting them for the arsenic preparations now commonly employed.

"Of the substances frequently recommended, potassium dichromate and quassia sirup have been found to be of little value. Formaldehyde, on the other hand, when properly employed has been found to be much more efficient than the standard arsenite solution. The studies have indicated the most efficient strength of the formaldehyde solution to be from 0.5 to 1 per cent, which is equivalent to 1.25 to 2.5 per cent of the 40 per cent solution sold as formalin.

"A muscicide of almost equal efficiency and of distinctly superior qualities in many ways has been found in the substance sodium salicylate, a 1 per cent aqueous solution of which is recommended.

"At midsummer temperatures the efficiency of either of these preparations is slightly greater than that of solutions prepared for commercial poison papers. Directions for preparing these solutions in the household and recommendations for their commercial preparation and sale are made."

COMMERCE REPORTS—FEBRUARY, 1917

The yield of **indigo** in British India for 1916–17 will be about 75 per cent greater than in 1915–16. (P. 449)

The production of **Chinese wood-oil** in China is described in detail. The methods of extraction are crude but fairly effective. In China the oil is largely used directly for painting boats, for the manufacture of water-proof varnish on cloth, in lacquer and other varnishes, soap, and leather dressing. In other countries, chiefly the United States, it is used in the manufacture of varnish from cheap gums. The possibilities of its cultivation in the Southern States of this country are promising. (Pp. 457–60)

The **sugar beet** crop of Russia shows a marked decrease. (P. 469)

Efforts are being made to develop **electric smelting of iron ore** at Mysore, India. (P. 482)

The discovery of large deposits of **molybdenum** ore in Peru is reported. (P. 495)

Practically no **wood pulp** is now being made in Brazil, though steps are under way to develop the industry. (P. 508)

Direct shipment of **cochineal** from the Canary Islands to the United States is increasing. (P. 519)

The production and export of **nitrate** from Chili is now greater than at any previous time, even before the war. (P. 555)

Efforts are being made in Spain to prohibit the export of **"green sulfur oil"** (crude olive oil) to offset the shortage in Spain of other soap fats and oils. (P. 596)

Efforts are being made by the Bureau of Fisheries to develop the manufacture of **leather** from shark skins. (P. 635)

The amount of **rubber** shipped from Brazil and Peru to the United States is now over two and one-half times that shipped to Europe. (P. 642)

Efforts are being made to develop the cultivation of **sugar beet** seed in this country. (P. 669)

The mineral output of the Kingston district in Canada, includes **mica, iron ore, feldspar, talc, pyrites, fluorspar, molybdenum** and **zinc ores**, and **graphite**; most of which are controlled by American capital. (P. 692)

Efforts are being made in England to promote the spinning of yarn from **kapok fiber**, now used extensively in upholstery and life preservers. (P. 710)

The total production of **potash** in the United States in 1916 represented about 10,000 tons of K_2O. (P. 728)

Commercial methods used for the measurement of **leather** are being investigated by the Bureau of Standards. (P. 738)

Japan is exporting annually about 75,000 tons of **sulfur**, one-half to the United States. (P. 788)

STATISTICS OF EXPORTS TO THE UNITED STATES

KOBE, JAPAN—562
Antimony ore
Bronze powder
Camphor gum
Copper
Albumen
Matches
Menthol
Camphor oil
Castor oil
Cocoanut oil
Cottonseed oil
Fish oil
Peanut oil
Rapeseed oil
Soya bean oil
Porcelain

SHERBROOKE, CANADA—461
Asbestos
Chromate of iron
Copper ore
Hides
Maple sugar
Paper
Pulpwood
Wood pulp

UNITED KINGDOM—520
Rubber
Tin
Hides
Artificial silk
Liquors
Ammonium sulfate
Paper stock
Gum copal
Castor beans
Ferromanganese
Palm oil
Leather
Clay
Steel
Pottery
Copper
Nickel sulfate

AMSTERDAM—417
Diamonds
Hides
Cinchona bark
Quinine
Rags
Paints
Rubber

BRITISH INDIA—787
Hides
Kadaya gum
Myrabolam gum
Manganese ore
Saltpeter
Castor seeds
Turmeric
Coconut oil
Indigo
Nux vomica

BORDEAUX—607
Aloxite
Potassium bitartrate
Rubber
Olive oil
Paper
Wine

RUSSIA—610
Hides
Licorice root
Sugar-beet seed
Casein
Birch tar oil
Cantharides
Ergot
Lycopodium
Gum tragacanth
Fusel oil

ITALY—627
Hides
Tartar
Zinc ore
Liquors
Artificial silk

LONDON—657
Rubber
Platinum
Tin
Hides
Indigo

BOOK REVIEWS

A German-English Dictionary for Chemists. By Austin M. Patterson, Ph.D., formerly editor of *Chemical Abstracts.* xvi + 316 pp. John Wiley and Sons, Inc., New York, 1917. Price, $2.00 net.

Dr. Patterson has performed a public service in the compilation of his German-English Dictionary for Chemists. His extended experience as Editor of *Chemical Abstracts* has given him exceptional qualifications for such an undertaking and the work shows the same painstaking care which characterized his successful work as Editor.

All chemists will understand the particular value of such a dictionary if they will recall their early efforts to read the German chemical journals, following a general two years' collegiate course in German and with the aid of the usually available German-English dictionaries. What a host of words and abbreviations presented themselves for the significance of which dictionaries gave no assistance. These old friends for whom we so long and fruitlessly sought are present in this new volume ready at hand and easy of access. So too for older chemists, already familiar with the German language, the book will prove of great value wherever accurate translation of any passage is required.

The printing is good, the covers are flexible, and the size is suited to the coat pocket. It meets a real need and it is safe to predict its general use.

Chas. H. Herty

How to Build up Furnace Efficiency. By Joseph W. Hays, Combustion Engineer. Tenth Edition. 154 pp., 26 illustrations. Joseph W. Hays, Rogers Park, Chicago, Illinois. Price, $1.00.

In the preface of this book the author explains that he has been led to write this rather technical subject of combustion in a really popular way, such as the public would want. The present tenth edition contains many new features. There are new charts, diagrams and illustrations to make clear some of the things that are hard to explain in the printed page. The author endeavors to show the manager, superintendent, engineer and fireman of the power plant how they may proceed actually to work a real reduction in the coal bills.

The object of the book is to make clear to engineers and firemen the proper way of operating a boiler furnace most economically, and the means suggested are not new, but the mode of expression is interesting and simple and as the author confesses "rather unvarnished," and he knows that the manager and engineer will accept his criticisms with the same good nature in which they are offered.

The subject discussed deals principally with the relation of the percentage of carbon dioxide in the flue gas, the draft in the furnace, stack temperature, leaks due to faulty boiler setting and how these affect the conditions for proper combustion.

The subject of fuel waste is enumerated and each loss is explained; it is further shown what the possible economies may be, how the wastes occur and how to overcome them.

In the appendix a number of charts are presented showing in a graphic way the relation between the constituents of the air and the products of combustion when burning different fuels such as oil, gas, wood, refuse and other material.

The book is written in "Five Reels:" (1) Why Your Fuel Is Wasted; (2) How Your Fuel Is Wasted; (3) How to "Spot" Your Fuel Waste; (4) How to Stop Your Fuel Waste; (5) How to Keep the Waste Stopped. The book is of convenient size to have at hand and use as a guide.

Oscar W. Palmenberg

The Chemistry and Technology of Paints. By Maximilian Toch. Second Revised Edition. D. Van Nostrand Company, New York, 1916. xi + 366 pp., 83 illustrations. Price, $4.00.

The first edition of this book was published in 1907 and entitled "The Chemistry and Technology of Mixed Paints." It contained 166 pages as against 366 of the second edition, so that the enlargement is very material. Since the publication of the first edition there has been a large amount of attention devoted to the study of paint, and there are in consequence 28 chapters in this second edition as against 16 in the first, and such a subject as "Chinese Wood Oil" has 111 pages devoted to it whereas formerly it had 6, while considerable attention is given to the newer work on fish oil and soya bean oil. That portion of the work devoted to the analysis of paint materials has undergone most marked changes, for in the analytical methods applicable to paint materials, and especially to oils, the work done in recent years has been very extensive and the results are incorporated in this second edition.

One of the noticeable features of the book is the treatment in Chapter 10 of the inert fillers and extenders. Until comparatively recent years, these materials were regarded as adulterants of paint and are by many so regarded now. The author treats these as though, within their stated limitations, they were entitled to the same kind of consideration as the older pigments such as lead and zinc, and discusses their merits and demerits quite as fully and in a manner equally scientific and exact. It may be said of the work generally that it is up-to-date, that it covers the fields suggested by its title thoroughly, and that it is full of suggestions for further research and improvement.

P. C. McIlhiney

Engineering Chemistry. By Thomas B. Stillman. Fifth Edition. 743 pp., 8vo., with 150 illustrations. The Chemical Publishing Company, Easton, Pa., 1916. Price, $5.00.

The appearance of five editions of this book since the first issue shows that it has been extensively used. On account of the death of the author in August 1915, when this edition was approaching completion, its final publication has been carried out by Messrs. Albert L. and Thomas B. Stillman. The book has been considerably enlarged and modified, but the main features of the previous editions have been retained.

The sub-title of the work describes it as "a manual of quantitative chemical analysis for the use of students, chemists and engineers," but it is to be observed that descriptions of many physical tests, copies of specifications, and other topics not dealing strictly with chemical analysis are included. On the other hand the book deals with only a restricted field of analytical chemistry, confining itself practically to the testing of such materials as are used in civil or municipal engineering.

It does not deal with mineral analysis or organic analysis in general, nor does it deal with the analysis of the important products of chemical industry, such as acids, alkalies, salts, bleaching materials, dyes, medicinal products, etc. However, the book presents much that is useful in its particular field.

Among the subjects most extensively treated are the proximate analysis of fuels, their colorimetry and their physical examination, the analysis of iron, steel and a number of nonferrous alloys, the analysis and physical tests of cement, concrete, clay, sand and building stones, the examination of asphalt and other bituminous road materials, of coal tar, lubricating oils, illuminating oils and fuel oils, soap, paint and varnish analyses, the chemical and physical examination of paper, the analysis and treatment of potable waters and boiler waters, the analysis of flue gases, illuminating gases, etc., the manufacture of producer gas, water gas and acetylene, photometry and pyrometry. Many official methods are quoted and many interesting details of manufacture are given. The book is to be highly recommended to those interested in these lines of examination.

The book contains several condensed tabular schemes of analysis, which, while useful to experienced analysts as aids to memory, give hardly sufficient details for the use of beginners. One of them, dealing with the analysis of potassium cyanide, has a misprint of "K T" for "K I" and it is certain that the inexperienced analyst would fail to determine cyanogen if he should use potassium tartrate in place of the iodide.

H. L. Wells

Vinegar: Its Manufacture and Examination. By C. A. Mitchell. 201 pp. and 54 illustrations. Published by C. Griffin & Co., London, and by J. B. Lippincott Co., Philadelphia. Price, $2.75.

The first third of this volume is devoted to the history of vinegar making, the second to the manufacture of vinegar, and the last to the methods of examination and characteristics of the various kinds of vinegar. So far as the book is concerned with modern practice, it deals almost exclusively with the English practice which is based on an acetic fermentation taking place at 105 to 110° F., while the rest of Europe, and America, ordinarily use bacteria which have their maximum activity at about 90° F.

The reviewer wishes to take issue with the opinion (p. 117) that the more rapid the vinegar formation the greater will be the clogging of the quick vinegar generator by "mother of vinegar."

The relation of the amount of oxygen available in the quick vinegar generator to the growth of the vinegar eel does not seem to be appreciated (p. 120) and the common method of getting rid of this pest by completely shutting off the air supply for a few days is apparently unknown in the English vinegar factories.

The rapid destruction of the acetic bacteria by the larvae of the vinegar fly seems to have been overlooked by the author, for it is stated (p. 128) that this fly "does not in any way affect the manufacture" of vinegar.

Taken as a whole the volume is one written by an Englishman for the English public and deals mostly with strictly English procedure. The book is of little value to American readers and is not to be compared with the standard works on vinegar which are available in German and in English.

Ralph H. McKee

Modern Chemistry and Its Wonders. By Geoffrey Martin, Ph.D., D.Sc., London. xvi + 351 pp. D. Van Nostrand Co., New York. Price, $2.00.

In the preface of Dr. Martin's latest book he states: "My recently published book, 'Triumphs and Wonders of Modern Chemistry,' met with such an enthusiastic welcome by the chemical reading public. . . . that when my publishers approached me with the request to write a companion volume to that work, treating of matters omitted for want of space in the first book, I gladly acceded to their proposal. The present book is the result. The treatment is popular, technicalities being avoided as much as possible. However, in it I suppose the reader to be familiar with the ordinary conceptions of chemistry, such as have already been explained in a popular manner in the first book. The book is not intended for students wishing to study for one or other of the innumerable examinations of our somewhat chaotic examination system. Rather it is intended to interest the cultured, general reader in some of the really wonderful achievements of scientific chemistry."

The author has accomplished the above in this, his latest work. To the reviewer, a teacher of General Inorganic Chemistry, the reading of the book was such a pleasure and an inspiration that it was read from cover to cover. Such a variety of interesting facts of every-day chemistry was presented in a manner and language that made one realize that the language of the chemist should not be foreign to the cultured layman. To a teacher the book is invaluable with its suggestions for presenting in clear concise manner the fundamental facts and principles of every-day chemistry. This is especially true for beginners' classes and popular lectures.

The average, dyed-in-the-wool chemist, or chemistry teacher is apt to undervalue books of this type (and we have too few of them); these are the very books we need, both for the teachers, our students and more especially for the cultured public.

Text-books are for the most part incomprehensible to an intelligent reader without the teacher, the classroom, and the laboratory. Should a layman of average education have the misfortune to pick up the average chemistry text-book, even a book intended for beginners, he proceeds only a few pages and closes it in disgust, concluding that chemistry is fit only for highbrows. The text-books have their place and we have a deluge of them, but we have too few of the popular type books.

The reviewer felt that the main worth of the book rested with its value to students of chemistry, and more especially the layman of average education. A class of sixteen freshmen, who had just finished their first half-year of college chemistry, and had elected a sequence in honors chemistry, were assigned summer reading consisting of a history of chemistry, Robert Kennedy Duncan's books, "The New Knowledge," and the "Chemistry of Commerce," and Geoffrey Martin's books. At the opening of the fall term, the class was unanimous in that "Modern Chemistry and Its Wonders" was the most instructive and inspiring of the list. With the layman in view, the book was placed in the hands of a friend who had never studied chemistry. The results were that the book was not only read, but was read on until the small hours of the morning. In a few days when he was asked how he liked the book, the reply came—"That is the first chemistry book I could understand and really enjoy."

The topics are varied, and each chapter is in itself a short story not dependent on preceding chapters. The Romance of Coal Tar, the Romance of Salt, Artificial Precious Stones, The Romance of Alcohol, of Explosives, of Hydrocarbons, are some of the live topics of every-day chemistry treated in a lucid manner. The author has even been bold enough to devote a chapter to Radium, and one to the Mystery of the Periodical System.

What the science of chemistry needs to-day is expansion in research. Research is expensive, and who carries the financial burden of research? The poorly endowed college or university? The chemist? The chemistry teacher? The University does her share, the chemist and teacher are usually too poor. It is the well-to-do reading public, and you cannot make the public interested in research in chemistry unless you have some means of letting them know what chemistry is, what it has accomplished for mankind, and an insight into its possibilities, if fostered by well endowed scientific colleges and schools or endowed private enterprises. Let us have more books of this type and may their circulation be enormous, with the end that they may replace to a considerable extent the trashy light stuff found too frequently in our public libraries and the libraries of the reading public.

The book has a neat appearance, the cuts and illustrations are well chosen and of good workmanship, and the volume is free from errors in chemical equations and chemical facts.

Arthur C. Neish

LITERATURE OF THE NITROGEN INDUSTRIES, 1912-1916

By Helen R. Hosmer, Research Laboratory, General Electric Company

INTRODUCTION

In the following general review of the literature of the Nitrogen Industries it is attempted to give in convenient form the essential statements of papers published during the last five years. The earlier literature is very general and often vague in nature, and is sufficiently well covered by a number of books. Moreover, it is the recent material with its more specific treatment of technical and cost details which is now of particular interest in connection with the attempts being made to establish an adequate domestic supply of nitrogen compounds for the United States.

The purpose has been to present an outline giving the salient features of the subject, as stated by various authorities, together with a bibliography of such a kind that the original articles need not be consulted in order to find which contain the particular information desired. The aim has not been exhaustiveness but rather the listing of references generally available in this country. It is believed, however, that the field is fairly well covered by these and that extension of the list would but lead to duplication, or to the inclusion of trivial articles.

The arrangement is inversely chronological except where entire consistency might have separated related items. The appendix contains material not properly a part of the subject but of possible use to those interested in the present-day problem. In this latter no effort is made to cover the fields at all completely.

It should be kept in mind that in all cases the statements made are those of the authors quoted. This accounts for some repetition and for contradictory data on some points. In cases where the material of different writers was obviously taken from the same authority this fact is noted and only one is quoted in detail.

In regard to the fact that the testimony given favors certain processes very markedly it must be remembered that certain industrial interests now prominent in this country have contributed disproportionately to the literature. It may well be that some of the processes not praised at all highly here, may yet prove to be cheaper and more efficient.

Very recently information of a fragmentary nature seems, for instance, to indicate that the Germans have been placing their reliance upon the Haber process, which may well have been much improved and developed during the last two years. In all cases, the data given here should be taken for what they are worth and not as authoritative.

I—DESCRIPTION AND CHEMISTRY OF PROCESSES

GENERAL*

Washburn[13] (1916) discusses in some detail the factors having bearing upon the problem before the United States of establishing a domestic supply of nitrates adequate to war demands. He analyzes the various proposals made. Gilbert[14] gives similar data in a condensed form.

Norton[17] (1916) discusses the various water powers in the United States which are available and adaptable to the nitrogen fixation industry. He favors the establishment of three plants to supply the needs of the sections of the country having the largest demands. He also mentions the possibility of getting 7,400,000 horse power during 14 hours of the day from complete harnessing of Niagara Falls. The details of this plan are given by Dunn[40] (1915): see also References 15 and 127.

Merrill[16] (1916) gives similar data for Western water powers.

Skerrett[23] (1916) gives a very general and brief treatment of the nitrogen situation, mentioning the importance of its consideration in connection with preparedness, and outlining very briefly the arc and cyanamide processes. He quotes from Norton, and most of his other data are to be found in Washburn's articles and statements.

Cushman[26] (1916), in an article entitled "Rôle of Chemistry in War," has discussed, among other things, the status of our nitrogen supply and the methods available for remedying this situation. His data on this point are taken from Summers[52] (1915), and Baekeland[58] (1914).

Cresap[38] (1915) gives in very general terms the compositions and characteristics of some 15 of the more common military explosives. It is to be noted that nitric acid is required for the preparation of all.

Baekeland[58] (1914) gives a brief history of the nitrogen industries and their present status, explaining the cause of failure of the Bradley and Lovejoy process. He mentions that a French Company has taken up the application of the Serpek process.

Merrill[48] (1915) gives full statistics of the water power resources and electric power development and control in the United States. The conclusions of his report are, however, severely criticized in Reference 31 (1916).

Martin and Barbour[1] (1916) in their book on "Industrial Nitrogen Compounds and Explosives" present a general review of the whole subject with references. They describe the most important processes and give diagrams and photographs of the apparatus. They also discuss the more general aspects of the subject and include statistics and many patents.

Roeber[149] (1910) gives a good general review of the nature of the various processes for nitrogen fixation, and their present status.

Summers[52] (1915) discusses in detail the physical chemistry and thermodynamics of the endothermic reaction between nitrogen and oxygen, giving the results obtained by Nernst from investigation of the equilibrium at temperatures between 1500 and 3500° C., by Nernst and Jellinek on rate of dissociation of NO at various temperatures and by Haber and Koenig working at reduced pressures. He computes that owing to the extreme dilution of the product there is a loss of some 95 per cent of the energy employed. He also mentions briefly the physico-chemical factors involved in the Cyanamide and Serpek processes.

The only arc processes in actual operation according to Landis[46] (1915) are the Birkeland-Eyde, the Schönherr, and the Pauling, all of which give as a product a gaseous mixture containing from 1 per cent to 2 per cent by volume of nitric oxide, from which the present well standardized condensation plants recover nearly 95 per cent in the form of 30 to 35 per cent nitric acid. This can be concentrated to 50 per cent by utilizing the waste heat of the process, but must then be further concentrated by special processes, or else converted into calcium or ammonium nitrate, before it is available for commercial purposes. The ammonia for such conversion is obtained in most cases from cyanamide.

These arc processes require enormous quantities of cheap electrical energy[46] (1915).

For a detailed discussion of the reactions involved and the thermodynamics of the case, Knox[67] (1914) should be consulted. He gives a full and critical review of the literature down to 1913, devoting over 86 pages to the chemistry of the processes, with references to the original articles.

Knox also describes the commercial processes and furnaces, taking up the Birkeland-Eyde, Pauling, Schönherr, Haber, Serpek, Cyanamide, and some other less important ones. The book is an extremely good résumé of the subject but lacks entirely yields, cost data, and technical details.

Haber[64] (1914) mentions the thermodynamical conditions limiting the yields of the arc and synthetic ammonia processes

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* Numbers refer to References in Bibliography, pages 437 and 438.

for fixing nitrogen. He believes that each process has its own field in which it may be successfully operated.

In his book, Perlick[65] investigates the general economic bearing of the nitrogen fixation industry and its relation to other industries and to agriculture, especially from the point of view of Germany's producing the nitrogen compounds necessary for her own consumption. The contributions to be expected from each of the processes available are discussed. From a consideration of costs he concludes that the demands of the chemical industries can be satisfied either by the arc process or by the Ostwald process of ammonia oxidation. The problem of supplying the needs of agriculture without increasing the cost is still unsolved. The Haber and Serpek processes seem to offer the most promise for this purpose. Statistics of consumption and production of various nitrogen sources are given.

The chemistry and reactions involved in the oxidation of nitrogen and the absorption of the acid formed are discussed by Scott[127] (1912) who gives the equations. He also discusses the theories for the process of oxidation, mentioning particularly the probability that ozone is an intermediate product and very essential to the course of the reaction.

Norton's[123] (1912) book like Knox's is a résumé of the nitrogen situation, including material collected from the literature, patents and personal observation. It is extremely full and comprehensive, and supplements Knox's book just where the latter is lacking, *i. e.*, on the technical and commercial side. The development of the industry and the various plants are given special attention. Methods of producing the materials required by the various processes are considered in their bearing upon an American industry. The properties and applications of the products are taken up. The organization of the European industry is described.

The chemistry of the processes and the possibilities for improvement are mentioned. He discusses the probable future of the industry particularly with regard to the effect of the cost of power and price of Chilean nitrate.

Norton also takes up the thermodynamics of the various processes. He describes also the less well-known patented processes and furnaces such as those of Guye, Von Kowalski and Moscicki, Thorsen and Tharaldsen, and Albihn. In fact he pays especial attention to patents. He includes non-electrical processes such as that of Häusser.

The uses of the various products, the syntheses of related products such as cyanides, statistics of the world's supply and consumption of nitrogen compounds, recovery of waste nitrogen products are all reviewed.

Norton's book is, in fact, the most complete treatise on the subject that has been published. Relatively few references to the literature are given, though many patents are reviewed.

OXIDATION PROCESSES

ARC PROCESSES

Summers[52] (1915) describes with diagrams the comparative operation of the three commercial types of furnace for direct combination of the oxygen and nitrogen of the air: the Häusser, and the Birkeland-Eyde, Schönherr, and Pauling. The three last, which are arc processes, take alternating-current at voltages of from 4000 to 5500 between the electrodes.

The Birkeland-Eyde furnace, which has had the most extensive application, employs a series of semicircular arcs rapidly expanded by means of a powerful direct-current magnet against the incoming air. The products are withdrawn at a temperature of about 1250° C. and contain about 2 per cent of NO. The recent furnaces have a 3000 kw. capacity and give a yield of 580 to 600 kg. of nitric acid per kw. yr. or 65 to 70 g. per kw. hr.

Scott[51] (1915) states that some furnaces take over 4000 horse power. At Notodden there are 32 furnaces using from 600 to 1000 kw. each and at Saaheim 8 of 3500 kw. each.

The Schönherr furnace uses a quietly burning arc some 23 feet long, around which the air circulates with a vortex motion. The gases pass over a water-cooler, and are withdrawn at about 850° C. after having given up a further part of their heat to the incoming air. The NO concentration is about 2.25 per cent. The largest furnaces have 800 kw. capacity, and yield 550 to 575 kg. of nitric acid per kw. yr. or 65 g. per kw. hr.

Scott[51] (1915) states that the Christianssand works have twelve 450 kw. furnaces of this type, and the Saaheim ninety-six 1000 kw. furnaces.

The Pauling furnace makes use of a series of rapidly succeeding arcs, driven upward by the blast of incoming air, and broken by the diverging horns of the electrodes. The effect is an arc flame 30 in. high in intimate contact with rapidly moving air. The yield of NO is from 1.25 to 1.5 per cent in the 400 kw. furnace, with yields of from 525 to 540 kg. per kw. yr. or 60 g. per kw. hr.

Scott[51] (1915) says that this furnace is employed in factories at Gelsenkirchen, Innsbruck, Milan, Roche-de-Rame, and in South Carolina. The last plant is stated to be merely experimental.

Scott[51] (1915) describes the Birkeland-Eyde, Schönherr-Hessberger, and Pauling furnaces and operation in considerably greater detail than Summers, and gives a comparison of their disadvantages.

Scott[127] (1912) gives the temperatures of the flames and escaping gases respectively as 3500 and 800–1000° C. for the Birkeland-Eyde furnace, 3000 and 1200° for the Schönherr, and —— and 1000° for the Pauling. The current supplies required for each furnace are as follows:

Birkeland-Eyde—Direct-current for magnetic field of 4500 lines of force per sq. cm.
—Alternating-current 5000 volts, 50 periods, 600–3000 kw.
Schönherr —Alternating-current 4200 volts, 50 periods, 600 H.P.-1000 kw.
Pauling —Single-phase alternating-current 4000–6000 volts, 50 periods, 400 kw.-1000 H.P.

Eyde[117] (1912) gives similar values for his furnace which he states is the only type used at Notodden. Both Birkeland-Eyde and Schönherr systems are used at Rjukan. He also gives cuts, diagrams, and photographs of plants and discusses power developments. Scott's (1912) article and this are very similar in context.

Scott[127] (1912) gives the most detail concerning the construction of the furnaces, conditions of operation, layout of plants, yields, etc., for the arc and cyanamide process with photographs from the plants. He also describes the absorption methods. He states that the power-factor for nitrogen fixation processes is about 0.6.

He also discusses the relative advantages of the three arc processes, and describes the electrical equipment with its guarantees, used by the Birkeland-Eyde plant at Rjukanfos. This last is described in considerable detail.

Scott also[51] (1915) describes the Kilburn-Scott arc furnace and process for oxidizing nitrogen. The apparatus employs a three-phase current giving, under the blast of air, an inverted cone of flame. Air enriched with oxygen is to be used cyclically, whereby it is expected to increase the yield of NO 20 per cent. Direct absorption in water is claimed to give a 50 per cent nitric acid.

The process does not appear to have been applied commercially as yet. Operating factors and their effect upon yields are mentioned but no data given.

The design of a commercial furnace, similar to the experimental one, is given for which the advantages of simplicity, conservation of heat, low first and maintenance costs, etc., are claimed.

Patents of methods for the fixation of atmospheric nitrogen by arc processes issued in recent years are reviewed in Reference 54 (1915).

Lamy[141] (1911) gives a general review of the cyanamide and arc processes for nitrogen fixation. His description of the Birkeland-Eyde, Schönherr, and Pauling processes, illustrated with diagrams, is very good.

Auzies[111] (1912) discusses the theory of nitrogen oxidation and gives tables showing the relation between temperature and yield. The catalysis of the reaction by oxides of cobalt, magnesium, chromium, nickel, platinum, palladium, barium, lead, cerium, and thorium has been effected. Cerium works best. Work has also been done on the catalysis of the reaction between nitrogen and hydrogen.

Tausent[131] (1912) shows the advantage of vertical arcs over horizontal, both in stability and yield of nitric acid.

Ehrlich and Russ[139] (1911) conclude from experiments on mixtures of nitrogen and oxygen that ozone is an important factor in the oxidation of nitrogen. They give the variation of per cent of nitric oxide formed, with the oxygen in the original mixture.

Vanderpol[145] (1911) gives a detailed description with diagrams for the Pauling process and absorption towers at La-Roche-de Rame, Hautes-Alpes, France.

Haber, Koenig, Platou and Holwech[147] (1910) have studied the effect of high voltage, high frequency alternating-current, cooled direct-current arcs, and pressure upon the oxidation of nitrogen and give their experimental data in considerable detail.

Holwech[148] (1910) has studied the formation of nitric oxide in the short direct-current arc at various temperatures with a cooled anode. He obtained the best results with the shortest arc and the highest field strengths compatible with the proper temperature, getting yields as high as 80 g. of nitric acid per kw. hr. at a maximum concentration of 9 per cent of NO.

Wolokitin[151] (1910) has studied the formation of nitrogen oxides in the flame of hydrogen and discusses the thermodynamics of the reaction.

Zenneck[152] (1910) gives a general discussion of the various methods for oxidizing nitrogen in the arc.

Koenig[44] (1915) discusses rather fully the subject of active nitrogen and its relation to nitrogen fixation. He reviews the literature and gives the results of work of his own upon the activation of nitrogen, oxygen, and hydrogen.

Hene[66] (1914) got a higher yield from sparking oxygen before mixing it with nitrogen than from sparking the nitrogen. He concludes that ozone is formed.

The reaction of active hydrogen and oxygen has been studied by Koenig and Elöd[68] (1914) and the conclusion reached that the electric discharge must also produce an active form of oxygen.

Lowry[70] (1914) finds spectroscopically that when active nitrogen and ozonized air are mixed, nitric oxide is produced, and suggests that the fact may throw light upon the molecular condition necessary for the oxidation of nitrogen.

Koenig[91] (1913) criticizes the conclusion of Fischer and Hene[118] (1912) that the electrical discharge activates the oxygen and not the nitrogen.

Fischer and Hene[118] (1913) conclude from a study of the effect of subjecting nitrogen and air separately to the action of electric discharges, that the oxidation of nitrogen in the arc flame is dependent upon the dissociation or activation of the oxygen and not of the nitrogen. In Reference 87 (1913) they reply to Koenig[91] (1913) and give their experimental data in detail.

Lowry[121] (1912) got increased yields of nitrogen peroxide from mixing air which had been subjected to the action of a series of spark gaps, with ozone.

Russ[126] (1912) discusses the evidence of various investigators that the reaction is not purely thermic but may involve electronic factors and points out that the formation of active nitrogen might be harmful.

Strutt[129] (1912) states that active nitrogen is not oxidized by oxygen but that the latter probably acts as a catalyzer to destroy the active modification.

Strutt[143] (1911) has studied the flame arising from the nitrogen-burning arc and concluded that it, like the afterglow phenomena in vacuum tubes containing air, is due to the oxidation of oxides of nitrogen by ozone.

Dary[39] (1915) states that Nodon has been able to obtain nitric acid very economically by electrolyzing peat under 10 volts. Peat contains 2 per cent by weight of nitrogen, which is converted into nitric acid by the combined action of nitrogen bacteria, the oxygen of the air, water, and heat from the electric current. The yield of nitric acid per ampere hour is 1 g., or 432 kg. in 24 hours per ha consumes 180 kw. hr. The yield per year on 150 ha is 100,000 tons of nitrate.

HÄUSSER PROCESS

The Häusser process[52] (1915), of which a single commercial installation has been made in Germany, employs coke oven gases mixed with air under pressure in an explosion bomb, fired by a high tension spark. The products are cooled at once by a high pressure spray of water. The temperature attained is 2100° Å. and the concentration of NO, 0.5 per cent. The maximum yield is 99 g. of nitric acid per cu. m. of gas equal to 6.2 lbs. per 1000 ft.

Dobbelstein[116] (1912) has experimented with the Häusser process using coke oven gas in a bomb of 100 liters capacity. Diagrams of the plant are given as well as curves showing the relation of yield to pressure, temperature of gas, and per cent of oxygen. The advantages and costs are compared with other processes.

Häusser[119] (1912) gives a detailed account of investigations upon nitrogen fixation by the explosion of gas mixtures and the influence of the various factors of pressure, etc. Increase in size of bomb gave larger yields.

ABSORPTION

The NO mixtures[52] (1915) produced by all these processes are cooled, passed into a gas holder, where time is allowed for the reaction

$$2NO + O_2 = 2NO_2$$

and are then sent to counter absorption towers, where they react with water, according to the equation

$$2NO_2 + H_2O = HNO_3 + HNO_2.$$

The nitrous acid is oxidized by the excess oxygen. An acid of 30 to 50 per cent concentration is thus obtained. The residual gases are circulated through towers containing weak alkaline solutions yielding nitrite-nitrate salts. About 2 or 3 per cent of the original NO gas is discharged with the waste gases.

Scott[51] (1915) discusses his absorption system and compares its operation and the concentration and nature of the products with those of the ordinary systems.

Briner and Durand[115] (1912) have studied the equilibria of nitrous and nitric acids formed when oxides of nitrogen are absorbed in water and conclude that increase in the pressure of NO and lowering the temperature favor the formation of nitrous acid.

Lewis and Edgar[142] (1911) have also studied the equilibrium between nitrous and nitric acids in aqueous solution and get as the value for the dissociation constant for

$$\frac{(HNO_2)^3}{(H)\ (NO_3)} = K = 0.0267 \text{ at } 25^\circ \text{ C.}$$

REDUCTION PROCESSES

HABER PROCESS (SYNTHETIC AMMONIA)

The Haber process depends upon the direct combination of nitrogen and hydrogen at temperatures of about 500° C. under the influence of uranium as a catalyzer, and is carried out under pressures of 200 atmospheres. The 8 per cent of ammonia formed is condensed out by cooling the mixture. The power expenditure is about 1.5 kw. hr. per kg. of nitrogen, the lowest of any of the fixation processes. The preparation of the nitrogen and hydrogen, and the compression required, increase the costs very considerably[52] (1915).

Haber[42] (1915) and his co-workers have made extended investigations of the heat of formation of ammonia at temperatures from 659° C. to 466, and at ordinary temperatures, and have determined its specific heat.

They[41,43] (1915) have also determined the equilibria at various temperatures, at ordinary pressures, and at 30 atmospheres.

Landis[46] (1915) doubts whether even the Badische Company, with its supply of waste sulfuric acid and hydrogen, is able to supply ammonium sulfate at a profit in normal times. The process, while not requiring very much electric power, does demand a great deal of skilled labor, and so probably has no future in the United States, in competition with the cyanamide processs, which provides the same end product, ammonia.

Crossley[61] (1914) gives a brief outline of Haber's synthetic ammonia process.

Haber[63] (1914) discusses in detail the history of the development and thermodynamics of the process for the production of synthetic ammonia.

Reference 89 (1913) gives the report of Haber and Le Rossignol, presented to the Badische Anilin- und Soda-Fabrik in 1909, which led that company to take up the large scale development of the process for synthetic ammonia. The thermodynamics of the reversible reaction between hydrogen and nitrogen are discussed and the reasons for working the process between 500 and 700° C. and under 200 atmospheres pressure are explained.

Bernthsen[112] (1912) gives a detailed but general review of the history of the development of the process for making synthetic ammonia. He mentions the various catalyzers tried, their adaptability and the effect of poisons and "promoters."

Billiter[113] (1912) finds that the rapid exhaustion of cerium hydride and nitride, which are quite active catalysts at 200–300° C., is due to gradual oxidation.

Serpek[73] (1914) discusses the general problem of inorganic ammonia synthesis taking up the chemistry of each of the several processes known. He quotes his material mainly from patents.

CYANAMIDE PROCESS

The fixation of nitrogen by the cyanamide process depends upon reactions that are generally expressed by the equation

$$CaC_2 + N_2 \rightleftharpoons CaCN_2 + C$$

which is not only reversible, but so complicated that its equilibrium constants have not yet been established. Landis[46] (1915) points out a few of the difficulties and special problems to be met and solved in preparing satisfactory grades of carbide and nitrogen, and then combining them on a commercial scale.

Summers[52] (1915) discusses the thermodynamics of the reactions involved in making calcium cyanamide from the elements, giving figures to show that the yield per unit of electrical energy is 4 to 5 times that of the direct oxidation methods, but this advantage is partly offset in practice by other costs, such as that of the preparation of nitrogen.

A history of the development of the cyanamide industry in America, with descriptions of operations, and illustrations of the apparatus and buildings of the American Cyanamide Company is given in the *Engineering News*[55] (1915). The output of the various factories of the world is given. (See CYANAMIDE PROCESS, p. 431.)

Landis[47] (1915) also describes the various subsidiary installations, such as the calcium carbide, lime, and coal gas plants, necessary to the operation of a cyanamide plant. Photographs are given, and capacities stated.

Reference 80 (1914) describes in great detail the electrical equipment and water power development employed in making calcium carbide and cyanamide in Norway and Sweden, under the control of the Nitrogen Products and Carbide Co., Ltd., which also owns plants in Belgium for making ammonium nitrate by the Ostwald process. The history of the development of the business is also outlined.

Reference 82 (1914) is a short general article describing with photographs the coal-gas and lime plants of the American Cyanamide Company's works at Niagara Falls.

Pranke[98] (1913) gives a brief history of the development of the process and its chemistry, and mentions the uses of the material.

Pranke's book[99] (1913) discusses very fully the history and chemistry of cyanamide, its preparation, conversion products and uses, and their reactions, and its action in the soil. Reports of tests and analyses are also given. Over two-thirds of the book is devoted to its agricultural value and properties. Extremely little manufacturing or cost data is given.

Foerster and Jacoby[146] (1907) have studied the reaction between calcium carbide and nitrogen with especial attention to the lowering of the temperature required, produced by the admixture of calcium chloride or fluoride.

AMMONIA FROM CYANAMIDE

Calcium cyanamide[25] (1906) is readily and almost quantitatively (98–99 per cent) converted into ammonia by treatment with steam, in accordance with the reaction

$$CaCN_2 + H_2O = CaCO_3 + 2NH_3.$$

This reaction is exothermic, evolving from 200 to 300 lb. cals. of heat per pound of ammonia, and to realize the advantage of this fact the commercial process (U. S. Patent 1,149,633, Aug. 10, 1915) is carried out in autoclaves. Lime nitrogen is fed slowly and with constant agitation into water, or mother liquor from a previous run, with ventilation to carry off the acetylene evolved from unconverted carbide, soda and lime added, the autoclave closed, and steam admitted up to a pressure of 3 or 4 atmospheres, at which temperature the reaction starts at a fair rate, generating ammonia and steam so rapidly as to necessitate relief of pressure by special valves. Even then the pressure generally reaches 12–15 atm. in 20 minutes, then falling off again. The steaming operation is repeated once or twice more to expel the ammonia from the solution, which is then filtered from the mud, the latter going to the dump.

The course of the reaction is illustrated by curves, showing the variation of pressure, rate of discharge, and percentage of ammonia in the ammonia-steam mixture, with time for quantities of from 7000–8000 lbs. of lime-nitrogen. Less than 0.2 per cent of ammonia remains in the sludge.

The mixture of ammonia and steam may either be absorbed directly, producing a high-grade ammonium sulfate, or passed through a simple rectifying column, giving an ammonia gas which is stated to be so pure that it can even be oxidized directly with no trouble from poisoning of the catalyzers.

Reference[106] (1913) gives a brief description of the method for obtaining ammonia by treating cyanamide with steam and states that ammonia of 99.8 per cent purity is thus obtained. Figures are given showing the completeness of decomposition.

Landis[25] (1916) considers it certain that the process for the preparation of ammonia by treating cyanamide with steam is already in successful operation in Norway, France, Switzerland, Italy, and Japan, and was installed in Belgium, before the war. The bulk of the product is used, in the form of ammonium sulfate, by the chemical and fertilizer industries. Norway produces large quantities for absorption of nitric acid from its Birkeland-Eyde plants. Germany is making enormous quantities for oxidation to nitric acid.

The American Cyanamide Company has had a small plant in successful operation in the United States, for six months, and is producing several tons per day of pure ammonia gas.

SERPEK PROCESS

The Serpek process is typical of the methods depending upon the formation of a nitride from which ammonia may be obtained by treatment with steam. The reaction which it involves is represented by the equation

$$Al_2O_3 + 3C + N_2 = 2AlN + 3CO$$

and is carried out at a temperature of from 1800 to 1900° C. in a revolving barrel type of electric resistance furnace which affords the constant agitation necessary. Bauxite and coal from a producer type of furnace are fed into this and the product is discharged as aluminum nitride containing from 26 to 34 per cent of nitrogen.

Summers[52] (1915) calculates that under the most favorable conditions 9 to 10 kw. hrs. of electrical energy will be required per kg. of nitrogen, besides the heat from the coal and producer gas. The cyanamide process requires about 16.2 kw. hr. per kg. of nitrogen, or if all energy be supplied by the electrical current, the two processes will have practically the same power consumption. The Serpek process is hampered by the necessity for disposing of the by-product alumina.

Reference[72] (1914) discusses the nitride reactions and the chemistry of the Serpek process mentioning the catalytic effect of hydrogen and iron.

Reference[84] (1914) gives briefly the history of the reactions fixing nitrogen by the formation of metallic nitrides. Of these, the only one to find commercial application is that involving the production of by-product alumina which has been developed by Serpek.

The starting point is impure oxide, or bauxite, which is mixed with carbon and heated in the presence of nitrogen. Combination occurs at about 1550° C. without any carbide formation, and is hastened by the presence of certain catalyzing reagents such as iron, silica, titanium oxide, nickel, and manganese, of which the first is most effective. The reaction temperature is further lowered by the presence of hydrogen, and aluminum nitride may thus be prepared at from 1250 to 1300° C. provided a large excess of nitrogen be used. At higher temperatures this is unnecessary, and the rate of the reaction is much increased. At 1900° the alumina is completely converted into nitride in 5 minutes, and recently Serpek has reduced the time to a fraction of a second by suitable control of the reaction mixture and of the nitrogen supply.

The nitride is easily decomposed into aluminum hydrate and ammonia by heating under several atmospheres pressure for 3 or 4 hours. Pure alumina may be produced as a by-product. The yield is 2 tons of alumina and 500 kg. of fixed nitrogen per kw. yr.

The process is in operation only in an experimental installation at Saint Jean de Manrieme in Savoy, though other plants are under construction at Arendal, in Norway, and in the United States.

Fraenkel[88] (1913) has investigated the progress of the reaction for the formation of aluminum nitride from alumina, carbon, and nitrogen, which he finds begins under suitable conditions at 1400° C. He has determined the effect of various factors upon the velocity.

Richards[100] (1913) gives the history of the reactions involved in the Serpek process, and outlines the process as patented.

Ross[101] (1913) has carried out some preliminary experiments upon the fixation of nitrogen by the alumina in feldspar, as a by-product in the preparation of potash. Larger percentages of nitrogen were fixed than corresponded to the aluminum present.

Russ[102] (1913) has been able to demonstrate the exothermic formation of aluminum nitride from the elements.

Tucker[105] (1913) has studied the chemistry of this process and concludes that it is of commercial interest only where the by-product of pure alumina may find use in the aluminum industry. He compares the advantages and disadvantages of this and the cyanamide process for ammonia.

Reference 107 (1913) gives an abstract of the patent (U. S. 1,040,439) discussing the chemistry of the Serpek method for decomposing aluminum nitride by means of alkaline aluminates.

Tucker and Read[132] (1912) have studied the reaction between nitrogen, alumina, and carbon, and state the necessary conditions for a good yield.

Stähler and Elbert[103] (1913) have studied the reaction for the formation of boron nitride by heating boron oxide or borocalcite with carbon in the presence of nitrogen at various pressures. From the mixture containing oxide a yield of more than 85 per cent of BN was obtained under increased pressure at temperatures between 1500 and 1700° C. Using instead of oxide, borocalcite (CaB_4O_7), a nearly theoretical yield was obtained between 1400 and 1800° C. without effect from pressure.

OXIDATION OF AMMONIA (OSTWALD PROCESSES)

Zeisberg[4] (1916) reviews the history of the process and development of the industry for the catalytic oxidation of ammonia to nitric acid with estimates of costs for American conditions. (See p. 433.) He reviews recent patents and other literature. He states that a successful plant in Westphalia built in 1909 had an annual production of 2400 tons of 53 per cent nitric acid. From Jan. 1911 to Aug. 1912, the efficiency was 89.6 per cent on a monthly production of 130 tons of ammonium nitrate. The efficiency of conversion was 83 per cent and of absorption 97 per cent. This plant operates on coal-tar ammonia. It is stated that this product has never appeared in the market. In 1912 and 1913, 8 per cent dividends were paid to stockholders. In 1910 the process was purchased by a London company capitalized at £2,000,000 and a new plant was erected in Belgium.

It is stated that the diagrams of the converter given by Schüphaus[29] (1916) are the only ones ever published. It is not possible to ascertain actual dimensions used. A few other details of the probable methods of operation of the process are mentioned.

According to Schüphaus[29] (1916) the nitric acid needed for the manufacture of sulfuric acid by the chamber process was supplied in Germany, after cutting off of other sources at the beginning of the war, by oxidation of ammonia from ammonia water. He describes the process and the apparatus which is manufactured and sold by the Berlin-Anhaltischen Maschinenbau-Aktiengesellschaft in Berlin.

The ammonia gas is liberated by treating a spray of its 3 per cent solution, mixed with milk of lime, with steam. The gas is passed through coolers to condense the water-vapor and then through caustic soda scrubbers to a gas holder.

The ammonia gas is thoroughly mixed with air and passed over very fine meshed platinum gauze heated by electric current (24 to 26 v., 120–125 amp.) to about 700°, where almost quantitative reaction forming nitrogen oxides and water occurs. The oxides then go to the lead chambers.

The apparatus is illustrated by cuts and a photograph, showing the arrangement of the parts of the system. Details of construction are given, but no exact dimensions nor capacities.

Reference 106 (1916) mentions that this process has been in successful commercial operation for some time in Belgium and probably has a great future.

The process for the oxidation of ammonia gas to nitric acid (generally known as the Ostwald process) is described in detail in Reference 109 (1913) with the history of its development. Cuts show the arrangement of a plant capable of converting 25 tons of ammonia per month into about 150 tons of 36° Bé. commercial nitric acid. The reaction

$$NH_3 + 4O = HNO_3 + H_2O$$

is brought about by passing the mixture of gases over spongy platinum, platinum, or platinum black as a catalyzer at a temperature of about 300° C. at a velocity of 1 to 5 meters per second. The time of contact between gas and catalyzer should not exceed $^1/_{100}$ of a second, or decomposition of the product into nitrogen and water will cut down the yield very seriously. Under properly adjusted conditions the yield is very nearly the theoretical.

The condensation plant is also described in detail, and costs are estimated. See Reference 109 (1913).

The successful development[110] (1913) of the process using platinum for a catalyst is mentioned with outline of its development at Odda and other places in Norway, Iceland and England.

Meneghini[94] (1913) has investigated the oxidation of ammonia by various oxides as catalysts. His efficiency was highest with increased rate of gas flow and with those oxides that were effective only at the higher temperatures, exceeding 95 per cent for burnt pyrites, chromic oxide, and oxides of rare earths. Values are given for various temperatures.

Kochman[120] (1912) mentions the oxidation of ammonia by metallic contact agents at relatively low temperatures as a practical problem and gives a description and drawing of a furnace.

Meneghini[122] (1912) had previously studied the catalytic action of electrically heated platinum and found that no reaction occurred below 350° C. Rapid action occurs between 400 and 450° C. The principal product was nitrous acid.

Reinders and Cats[125] (1912) also studied the conditions for this catalysis using platinum, ferric oxide, platinized copper, thoria. With the first two 80–90 per cent of the ammonia was oxidized to nitric acid and nitrogen trioxide. The velocity of the gas current is very important, there being an optimum for each catalyzer. The best temperature found for platinum was 500° C. and for ferric oxide 650–700° C.

II—PRODUCTION

GENERAL

Kubierschky[69] (1914) gives the average yearly increase in production of fertilizer materials during the past few years. The figures for several items are as follows:

	Years	Av. Annual Increase Per Cent
Cyanamide	1907–12	212.0
Norway saltpeter	1903–11	170.0
Ammonium sulfate	1901–11	10.5
Chile saltpeter	1901–11	6.8

The world's production in 1913 is given by Reference 83 (1914) as follows:

	Metric Tons
Ammonium sulfate	1,365,000
Chile saltpeter	2,740,000
Lime nitrogen	80,000
Norwegian nitrate, $Ca(NO_3)_2$	30,000

CHILE SALTPETER

Summers[52] (1915) gives the present annual output of Chile nitrate as 2,500,000 tons, of which the United States takes from 600,000 to 700,000 tons. The government tax has netted Chile about $500,000,000 in the last 30 years.

Reference 96 (1913) gives the yearly production from 1902 to 1912.

Bernthsen[112] (1912) gives figures for the exports, price, and value of Chile nitrate for each year from 1900 to 1912, and for the world production, etc., of ammonium sulfate for certain years, during the same period.

Scott[127] (1912) gives the annual exportations of nitrate from Chile at intervals during the years 1830 to 1911, in which time it has increased from 935 tons (long?) to 2,420,400 tons.

AMMONIUM SULFATE

Turrentine[6] (1916) advocates reliance by the United States upon the coke-oven by-product for both the war time and agricultural consumption of nitrogen products, and gives statistics of the present and probable future production. He states that the 68 per cent wasted in 1914 equals 350,000 tons of ammonia from which 300,000 tons of 100 per cent nitric acid might be made. He also estimates that from the surplus coal gas now wasted 800,000 continuous horse power could be generated with which 1,400,000 tons of ammonium sulfate could be produced by nitrogen fixation processes in time of emergency. He mentions special measures that should be taken which would further increase this production.

In a later Reference (5) he discusses the matter in much greater detail, giving statistics of the past development of the coke-oven by-product industry and estimates of its future. He gives the production of ammonium sulfate in the United States for each year from 1900–17 and both the probable and possible increase by 1920. He states that at the present (1916) rate of increase the total production from coke-ovens alone will be 800,000 tons of ammonium sulfate. In time of emergency he would withdraw all of the supply going into fertilizers. From the output at the rate normal on April 1, 1916, nitric acid could be made by the Ostwald process equivalent to 271,000 tons of sodium nitrate (the importation of sodium nitrate during 1915 was 577,000 tons) which would more than supply the needs for explosives, in times of peace. His conclusion is that such a supply of nitrogen compounds is adequate for the United States for both times of peace and of war.

Lymn also[27] gives curves showing the consumption and production of ammonium sulfate in the United States between 1900 and 1913, together with imports and word production.

Reference 11 (1916), a pamphlet issued by the by-products interests, gives data on the rate of production, and arguments intended to show that the ammonium sulfate produced is sufficient to insure a supply of nitric acid in time of war. The objections to depending upon such a supply are not mentioned, far less answered. The pamphlet objects to government manufacture of nitrates on the ground that it will lower the price of sulfate and discourage the by-product industry.

Porter[2] gives almost the same data and conclusions as Turrentine[6] and continues with arguments against recent legislation for the government's establishing a plant for nitrogen fixation. He gives a list of the by-product coke plants in the United States in September, 1916. In connection with Porter's statement that at the outbreak of the war, Germany had almost reached the limit in the production of by-product ammonia, it is of interest to note that Reference 7 says that at that time only $^1/_6$ of her coal was coked. The coking industry has been much extended since but yet it has been found necessary to make ammonia by the Haber process in quantities placed at 300,000 tons per year. In other words, the proposal made by Turrentine[6] that the United States Government should meet an emergency by going into the coke business does not seem to have been economical there.

Washburn[13] (1916) discusses the availability of by-product coke oven ammonia as a source of nitric acid in time of war, and points out that its extreme variability, depending upon the fluctuations of the iron industry, and the fact that the supplies must be gathered from scattered localities, are important drawbacks. The present maximum output, from 21 widely scattered points, is equivalent to only about 120,000 tons of concentrated nitric acid, which is perhaps two-thirds of a minimum safe reliance for war: 37 per cent of this total production is used for refrigeration and so could not be diverted, particularly in time of war: 10 per cent is already used in explosives and chemicals, and the remaining supply is used in agriculture, where it could be ill spared at a time when imported fertilizer materials were cut off.

Germany, with the greatest metallurgical industry in Europe, and making 90 per cent of her coke supply in by-product ovens, has to turn to atmospheric nitrogen for war supplies.

Childs[30] (1916) gives the probable increase in production of ammonium sulfate in the United States during 1916 as 30,000 to 40,000 tons. He gives the statistics of production, imports and consumption, in the United States from 1902 to 1915, and states that the present production from coking is only 29 per cent of that possible if by-product ovens were universally used. He discusses the future of coke by-products, mentioning the probable competition after the war of German products from their highly developed fixation processes. He states that the semi-direct method is the one used mostly in the United States. He also discusses the uses and demand for various by-products.

Landis[46] (1915) points out that the supply of ammonia from coke ovens has the disadvantages inherent in by-product sources. A ton of coal yields only 5 to 6 lbs. of ammonia. Any industrial depression, and particularly such as results from war [see *Mineral Industry*, 23 (1914), 412–13, 417–22], cuts down the supply at once. In Germany, regulations prohibiting the use of coal were passed, in order to force the production of coke and its by-products.

Clarke[9] (1915) gives an up-to-date list of by-product coke ovens built or under construction in the United States. He states that tar and ammonia yields are much lower here than in Europe.

The annual production of ammonium sulfate is now about 1,250,000 tons, practically all coming from by-product coke ovens or from gas-house retorts. The production in the United States per year is equivalent to about 70,000 tons, and is increasing annually at the rate of some 15 per cent[49] (1915).

In discussing Peacock's[49] (1915) paper, Johnson states that the production of ammonia possible in the United States, if all coking were done in by-product ovens, is about 225,000 tons annually. Only 30 per cent of this amount is saved at present.

American coals[52] (1915) contain from 0.9 to 1.4 per cent or 18 to 28 lbs. of nitrogen per ton, of which 20 per cent, or from 4$^1/_2$ to 7 lbs. of ammonia per ton of coal distilled is recovered. This yields 18 to 28 lbs. of ammonium sulfate per ton of coal.

Lymn[27] (1916) gives a table of the nitrogen content of coals from different parts of the United States.

The Mond producer gas system recovers 75 per cent or from 15 to 20 lbs. of nitrogen, or 60 to 80 lbs. of ammonium sulfate per ton of coal consumed. This plant, although installed abroad, is not very extensively used in America, as the expense of installation is relatively high.

Wagner[34] (1916) gives the yields per ton of various American coals in tar, ammonia, sulfur and naphthalene. The ammonia yield varies from 4.33 per cent for Alabama coal to 9.60 for Oak Creek, on the basis of ash and moisture-free coal. He discusses the subject of coke and coal and furnaces for coal distillation, etc., very fully but says little about by-products.

The world production for 1914 is estimated by the American Coal Products Company[57] (1915) to have been 1,300,000 to 1,350,000 metric tons against 1,409,000 in 1913. England produced 426,413 tons, or about 6200 tons less than in 1913. Figures could not be obtained for Germany. (See Consumption, Ammonium Sulfate, p. 432.)

In the United States, 183,000 tons, or 12,000 tons less than in 1913 were produced. This decrease was mostly during the last six months, and was due to the depression in the iron and steel trade caused by the war. The recovery possible from the coal now coked is 700,000 tons[57] (1915).

The principal source, and the one promising the greatest extension in the near future, is the by-product coke oven. The Coal Gas Works have the next largest total output, though the unit production is much smaller and widely scattered. Other sources are the by-product recovery gas producer, shale oil distillation, and the English blast furnaces using splint coal[57] (1915). Statistics of production for the years from 1900–14 for the different countries are given, with sources in each.[57]

Tutwiller[74] (1914) gives a table showing the rate of production and value of coke, tar, ammonium sulfate, etc., from 1903–1908.

Reference 83 (1914) gives the world's production of ammonium sulfate in 1913 as 1,365,000 tons, compared with 1,214,000 tons (metric) in 1912. The production of the various countries in tons was as follows:

	1913	1912
Germany	549,000	492,000
England	420,000	379,000
United States	177,000	151,000
France	75,400	69,000
Belgium	48,600	50,000

In 1913[81] (1914) the production of ammonia in terms of ammonium sulfate in the United Kingdom was about 420,000 tons (long). The exports were 325,000 tons.

Canada produced in 1913[76] (1914) 10,608 tons of ammonium sulfate from coke ovens.

The production in 1910 and 1911 in the United Kingdom[114] (1912) calculated as sulfate was 367,500 and 378,500 tons (long).

The production of Great Britain in 1911 and 1912, calculated as sulfate, was, according to Bradbury and Hirsch[85] (1913), as follows, in long tons:

	1911	1912
Gas works	169,000	166,000
Iron works	20,000	20,000
Shale works	61,000	61,000
Coke, carbonizing works and producer gas plants	135,000	132,000
	385,000	379,000

The figures given in Reference 108 (1913) are:

	1912	1911	1910
Gas works	172,094	168,783	167,820
Iron works	17,026	20,121	20,139
Shale works	62,207	60,765	59,113
Coke oven works	104,932	105,343	92,665
Producer gas and carbonizing works	32,049	29,964	27,850
	388,308	384,976	367,587

Scott[127] (1912) gives similar data for 1906, 1909 and 1910.

A comparison of the export trade of England and Germany during 1912 and 1913 gives the following totals in metric tons:

	1912	1913
Germany	56,897	74,318
Great Britain	285,134	270,697

The amounts exported to each country are given in Reference 78 (1914).

Tufts[144] (1911) reviews briefly the various commercial sources of ammonia. He believes that the by-product coke oven cannot long be a leading factor in the situation as the world's demand for ammonia is increasing at a rate that in seven years will take almost all the production possible if all the world's coke were made in by-product ovens. A corresponding rate of increase in coke consumption cannot be expected.

OXIDATION PROCESSES

Washburn[13] (1916) states that the world's yearly fixation of nitrogen by the arc process is some 32,000 net tons compared to 200,000 tons by the cyanamide process. The former process is practically confined to Norway, while the latter has been applied in Norway, Sweden, Germany, Austria, France, Japan, and Canada.

He (1916) also states[18] that there are employed in the World's Nitrogen Fixation industry 1,000,000 continuous horse power, and gives the distribution as follows:

Canada	30,000
Germany	350,000
Norway	450,000
Dalmatia, Italy, Switzerland, Japan, France	150,000
	980,000

From the condition of operating no arc processes, Germany has developed in 18 months an industry producing nearly 10,000 tons of nitric acid per year[21] (1916).

James B. Duke[32] (1915) is accredited with the statement that the Southern Electrochemical Company will shortly be producing at Great Falls, S. C., by the Pauling process, nitric acid at the rate of 4 tons per day. The product will be placed on the market at a price lower than that of acid made from sodium nitrate.[23] The plant uses 3000 kw. and is the only nitrogen fixation plant in the United States.

Reference 133 mentions that operation of a plant using the Pauling process with an estimated capacity of 8 tons of calcium nitrate has been begun by the Southern Electrochemical Company at Nitrolee, S. C.

Earlier press notices [134] (1912) stated that this plant, which was designed to use the surplus power of the Southern Power Company, would turn out 5 tons of nitric acid or 8 tons of calcium nitrate per day with a possible later development to a capacity of 50 tons.

Baur[36] (1916) in a table of the power consumption of the electrochemical industries of the world gives the following figures for nitrogen fixation:

PROCESS	Power Kw.	Yearly Production Metric Tons	YIELD PER KW. HR.
Nitric acid from air..........	295,000	180,000 =40,000 N =310,000 $Ca(NO_3)_2$ =270,000 $NaNO_3$	1 kg. N = 65 kw. hr. or 1000 kg. N as nitrate = 7.5 kw. yr.
Lime nitrogen..	55,000	150,000 =30,000 N	1 kg. N = 17.5 kw. hr. or 1000 kg. N as lime nitrogen = 2 kw. yr.

(1 kw. yr. = 8760 kw. hr.)

Installations of the arc process at Rjukanfos have already reached 185,000 kw. and with the completion of the works at Tyin and Matre nearly 300,000 kw. will be applied to the production of calcium nitrate. Plants for the production of nitric acid by the Moscicki process using 74,000 kw. are being installed in Switzerland. The arc process, because of the relatively small power consumption of each unit, and the ease of starting and stopping, is especially applicable to intermittent water powers.

Calcium nitrate will probably soon disappear from the market as it cannot compete with Chile nitrate, nor with ammonium sulfate, even when the latter is made from cyanamide[46] (1915).

Scott[51] (1915) states that in Norway alone nearly a quarter of a million horse power is employed for making nitric acid from the air: one factory uses 140,000.

Washburn[53] (1915) gives the annual productive capacity of the oxidation processes as over 30,000 tons of fixed nitrogen, worth at the normal average value about $250 per ton. This is about half of the amount of nitrogen fixed by the cyanamide process. The single factory at Niagara Falls has a capacity equal to one-half of the total world's installed capacity by arc processes.

Baekeland[58] (1914) states that the Norway factories alone are using, for the production of nitrates, over 200,000 electrical horse power with a capital investment of $27,000,000 and are contemplating an expansion to 500,000 horse power.

Scott[127] (1912) estimates the horse power consumption of the successive installations of the Birkeland-Eyde process year by year as follows:

Year	H. P.	INSTALLATION
1903....................	25	Experimental plant, Frognerkilens
1903....................	160	Experimental plant, Ankerlökken
1904....................	660	Arendal
1905....................	45000	First Notodden (Svaelgfos)
1910....................	15000	Second Notodden (Lienfos)
1912....................	140000	First Rjuken Installation
1913....................	120000	Second Rjuken Installation
1914....................	70000	Vamma
1915....................	80000	Matre
1916....................	70000	Tyin

Scott[127] (1912) states that (in 1912) Great Britain was not fixing an "ounce" of nitrogen.

REDUCTION PROCESSES

HABER PROCESS

It is claimed that the Badische factory is at present producing ammonium sulfate at the rate of 300,000 to 350,000 tons a year, an increase of 200,000 tons over the usual rate.[27]

References 8 and 23 (1916) confirm this figure and estimate that the total production by the Haber process in 1917 will be 500,000 tons, compared with 30,000 tons in 1913.

It is also stated that at the beginning of the war the German Government subsidized the Badische factory to the amount of 100,000,000 M. to avoid a shortage[28] (1916).

It was estimated in Reference 78 (1914) that the minimum production for 1914 would be 30,000 metric tons.

It was stated[77] in 1914 that the Badische Anilin- und Soda-Fabrik was increasing its capital by £900,000 to cover the cost of erecting a plant to be capable of producing 130,000 tons of ammonium sulfate annually by the Haber process.

CYANAMIDE PROCESS

The Canadian factory of the American Cyanamide Company has a capacity for fixing nitrogen equivalent to 90,000 lbs. of ammonia per day, and is increasing its capacity up to 110,000 lbs. in 24 hours[25] (1916).

Two plants in Germany, one in Bavaria, and another near Cologne, are producing 45,000 tons between them[28] (1916). Another plant is being erected in Westphalia, which will use 10,000 h. p. and is expected to produce 200,000 tons of concentrated nitric acid per year[28] (1916).

Landis[21] (1916) states that at the beginning of the war, Germany had three factories, with a total capacity of about 50,000 tons of cyanamide per year, but within 18 months was producing almost 500,000 tons. (See also Baur, above, under Oxidation Processes.)

During 1914 the world production of cyanamide in 14 factories was some 300,000 tons, averaging over 20 per cent nitrogen[46] (1915).

An article in the *Engineering News*[55] of January 1915 gives a list of the factories of the world and the output of each. The total product is given as 333,500 short tons.

The cyanamide industry[58] (1914) represents an investment of $30,000,000 in 14 factories, three in Germany, two each in Norway, Sweden, and Italy, and one each in France, Switzerland, Austria, Japan and Canada. The horse power employed is 200,000, and the annual amount was valued at $15,000,000. An English Company was contemplating installations of 600,000 H. P. in Norway, and 400,000 in Iceland.

Kubierschky[69] (1914) in a lecture on artificial fertilizer materials gives the cyanamide production for each year from the beginning of the industry in 1906 at 500 tons to 208,000 tons in 1914. The average yearly increase between 1907 and 1912 was 212 per cent.

Haber[6] (1914) gives the amount of nitrogen fixed by this method as 36,000 tons.

Pranke[98] (1913) states that the world's production in 1913 was estimated at 120,000 tons per year in 16 factories, four each in Germany and Italy, two in France, and one each in Austria, Norway, Sweden, Switzerland, Japan and Canada.

Scott[127,128] (1912) gives a list of the factories and outputs therefrom of calcium cyanamide in 1912.

AMMONIA AND NITRIC ACID FROM CYANAMIDE

Washburn[53] (1915) states that no ammonia is being made from cyanamide in America outside of the American Cyanamide Company's laboratory. European plants are producing it at the rate of 15 tons per day, and there is ready for operation in Norway a plant designed to transform 60 tons of cyanamide per day into ammonia to be combined with the nitric acid from the Birkeland-Eyde factories.

Kaiser[33] (1916) states that the B. and A. Masch. A.-G. built during 1915 over 30 plants for the oxidation of ammonia from the Frank-Caro process, capable of handling over 12,000,000 kg. of ammonia, and have under construction apparatus for 17,000,000 kg.

The foundation in England of a company with a capital of $10,000,000 to manufacture nitric acid from ammonia, the latter being derived from calcium cyanamide, by the Ostwald process, is mentioned in Reference 109 (1913).

It is stated[110] (1913) that the plant at Odda is capable of consuming 80,000 tons (long) per year of calcium cyanamide. Plants are projected with the following capacities:

Aura, Norway................................. (Controls power for 2,000,000 tons)	200,000 tons $CaCN_2$
Dagenham, England.............................	12,000 HNO_3
Trafford Park.................................	12,000 HNO_3
Manchester, Scotland..........................	9,000 HNO_3
Ireland.......................................	3,000 HNO_3

III—CONSUMPTION

GENERAL

In the year before the war[35] (1916) Germany consumed 217,000 metric tons of inorganic nitrogen as follows:

Chile saltpeter (imported)	100,000
Calcium nitrate (imported)	5,000
Ammonium sulfate (domestic production)	95,000
Calcium cyanamide ($^1/_3$ imported)	17,000

During the first year of the war only 12$^1/_2$ per cent of this quantity was obtained or produced. By the aid of a government grant of £7,500,000 large quantities of cyanamide and ammonium salts were made for military purposes[35] (1916).

England's consumption of ammonium sulfate in 1914 was 106,000 tons and exports 313,877 tons. German sales of the Deutsche Ammoniak-Verkaufs-Vereinigung for home consumption was 321,404 tons. Her exports for the year were 75,868 metric tons, and imports 34,628 metric tons[57] (1915).

In 1913[81] (1914) the United Kingdom consumed ammonia calculated as ammonium sulfate to the amount of 97,000 tons (long). The estimated home consumption in Great Britain was 90,000 tons[108] (1913). The consumption[114] (1912) of ammonia in the United Kingdom in 1911, calculated as sulfate, was 85,500 tons.

The consumption in the United States was 272,000 tons, compared with 262,000 in 1913[57] (1915).

The world consumption in 1913 is given[83] (1914) as follows:

	Metric Tons
Germany	460,000
United States	235,000
Japan	115,000
England	97,000
France	90,000

The world consumption of sodium nitrate[95] (1913) for 1910–12 is given as follows in long tons:

	1910	1911	1912
Shipments from South America	2,300,000	2,412,000	2,478,000
Consumption in U. K.	120,000	132,000	130,000
Consumption on Continent	1,531,000	1,564,000	1,778,000
Consumption in U. S.	501,000	556,000	481,000
Consumption in other countries	89,000	103,000	115,000
Consumption in world	2,241,000	2,355,000	2,504,000

Reference 96 (1913) gives the yearly consumption from 1902 to 1912.

Bernthsen[112] (1912) discusses the increasing demand for nitrogen compounds, giving the world production, increase, and price for sodium nitrate, and ammonium sulfate during the ten years from 1900.

Lamy[141] (1911) gives the growth in exports of nitrates from South America as follows:

1830	800 tons	1880	300,000 tons
1835	7,000 tons	1890	800,000 tons
1850	20,000 tons	1900	1,300,000 tons
1860	70,000 tons	1905	1,500,000 tons
1870	150,000 tons	1909	2,000,000 tons

The approximate consumptions (tons) in 1910 were:

France	Great Britain	Germany	Belgium	United States
250,000	100,000	500,000	200,000	400,000

USES

Washburn[13] (1916) states that even the Allies are employing 500,000 continuous horse-power in the fixation of nitrogen for explosive materials.

Washburn[13,18] (1916) estimates that a war supply of nitric acid for the United States should amount to at least 180,000 tons per year, which is[24] (1916) two-thirds of the estimated consumption of the German army.

He also points out what Germany has accomplished by the liberal use of fertilizer, that is, in quantities seven times as large per average acre cultivated as is the practice in the United States. From an area less than 80 per cent that of the State of Texas, she now raises 95 per cent of the food for a population nearly 70 per cent as large as that of the United States. In ten years our exportation of wheat and flour has fallen from 31 to 13 percent of the production, and general crop production has increased only 10 per cent, while the population increased 21 per cent. From less than one-half the area Germany harvested in 1907 over double the quantity of grain and potatoes. While cost of food rose 80 per cent in the United States it increased only one-half as much there.

Reference 7 (1916) gives the German consumption of nitrogen for 1913 as follows:

	Tons	Tons of Nitrogen
Ammonium sulfate	460,000	92,000
Nitrate of lime (Norwegian)	35,000	4,500
Nitrate of lime	30,000	6,000
Ammonia, Haber process	20,000	4,000
Nitrate of soda	750,000	116,000

The consumption of Chile nitrate increased from 155,000 tons in 1885 to 747,000 tons in 1913; of ammonium sulfate, from 125,000 tons in 1900 to 460,000 tons in 1913. The yield of wheat per hectare had doubled in Germany while increasing only $^1/_{10}$ in France in which latter country only $^1/_{15}$ as much potash and $^1/_2$ as much nitrate of soda is used per hectare as in Germany.

Figures giving the yields per acre of five principal crops in different countries are given by Harris[8] together with data showing Germany's large consumption of nitrogen fertilizers. The material seems to come from the same original source as Reference 7.

Landis[21] (1916) gives the present annual nitric acid consumption of Germany as 250,000 to 300,000 tons for munitions, besides the equivalent of 850,000 tons of sodium nitrate, 40,000 tons of nitrate of lime, and about 20,000 tons of Norwegian cyanamide, for agricultural and manufacturing purposes. The last items are estimated from the normal importation, which is now wholly cut off, and replaced by domestic production. The investment involved is over $100,000,000. It is quite possible, however, that the agricultural consumption is curtailed.

During 1912 Germany consumed 750,000 tons of Chile saltpeter, 425,000 tons of ammonium sulfate, 50,000 tons of lime nitrogen, and 50,000 tons of Norwegian saltpeter[20] (1916).

The imports of nitrates into Germany and Austria amount to about 750,000 tons annually. The consumption during the war is estimated at 750,000 tons of nitric acid for each side. This is based on an average consumption of 5 tons (3 to 10) of nitric acid per ton of explosives made, and 150,000 tons of explosives used per year[20] (1916).

Christopher[86] (1913) mentions that in Germany practically the whole production of ammonium sulfate is used on the soil, while in England, out of a production of 369,000 tons a year, only 70,000 tons are so used.

Sodium nitrate and ammonium sulfate constitute 80 to 85 per cent of the value of the raw nitrogen compounds produced in the world amounting in 1913 to nearly $200,000,000. Of this it is estimated that 80 per cent went for agricultural purposes. The farmers' purchases of nitrogen used east of the Mississippi during 1914 came to about $75,000,000, of which more than 90 per cent was in the form of ammonia. The normal annual consumption of nitric acid in the same region is about $7,000,000. The price per unit of nitrogen and the present rate of increase of consumption (10 per cent) is about the same for the two forms[53] (1915).

The fertilizer question is one of great importance to the United States[53] (1915). In the ten years from 1900 to 1910 population has increased 21 per cent, and the crop production only 10 per cent. Beef production fell 32 per cent, and the importation of foodstuffs more than doubled, with a marked decrease in the exports. Foodstuffs advanced in cost by 80 per cent between 1896 and 1912, and the increase in the cost of living was 59 per cent.

These figures indicate the necessity for increasing yields, as has been done in Europe, where the yield per acre is from 50 to 100 per cent greater than the United States, chiefly because of the use of fertilizers, which in Germany is, for instance, per acre, 15 times, in value in the United States, the average used on cultivated lands east of the Mississippi. Experiments in Indiana and Illinois have shown an increase in yield of wheat valued at from 2 to 3 times the cost of the fertilizer.

The present artificial fertilizers, however, contain from 85 to 90 per cent of material having no fertilizer value. To meet the conditions of long distance transportation and haulage over roads nearly impassable in the spring, it is essential that for the present mixtures should be substituted a concentrated substance of the proper composition and with the required physical and chemical properties.

Peacock[49] (1915) emphasizes the necessity of lowering the present prohibitive price of nitrogen products to check this increase in price of farm products.

Washburn[53] (1915) points out that arc methods of fixation cannot supply ammonia, and so must be limited to supplying the relatively small demand for nitric acid. The ammonia processes, on the other hand, supply a product for the conversion of which into nitric acid processes have already been sufficiently developed to leave little doubt of their ultimate success, even though as yet no thoroughly workable commercial plant is perfected, or in entirely satisfactory operation (in the U. S.).

Furthermore, the product of the arc processes, nitric acid, is not suited to the long-distance transportation from the remote localities where power is cheap enough to permit of its manufacture. Calcium nitrate is too hygroscopic for fertilizer purposes.

Washburn tends to the conclusion that the most promising solution of the fertilizer problem lies in the production of an ammonium phosphate compound deriving its ammonia from the cyanamide process.

Peacock[49] (1915) gives the annual nitrogen consumption of the fertilizer industry in the United States as equivalent to more than 100,000 tons of ammonia, increasing by about 8 per cent each year.

About 50 per cent of the Chile nitrate imported into the United States is used in the manufacture of explosives, and another 25 per cent in the arts requiring nitric acid[52] (1915).

IV—COSTS

PRICE OF NITROGEN

The price of combined nitrogen[52,49] (1915) is fixed by the price of Chile saltpeter, of which the 95 per cent pure contains about 15.5 per cent of nitrogen. When the latter sells for 2 cents per lb. for the 15 per cent grade, the price of nitrogen is 13.2 cents per lb. and the price of ammonium sulfate containing 21 per cent of nitrogen should be 2.7 cents per lb. The cost of converting nitrate into nitric acid increases its value 50 per cent. Hence, there is this added margin for the direct production of acid by other processes.

The price of Chile saltpeter has averaged since 1909, $35 to $40 per ton f. o. b. Chile, or $45 f. o. b. Liverpool. The present cost of production is from $10 to $20 per ton, leaving a profit on the mining of $5 to $10 after paying a tax to the Chilean government of $12.25 per ton.

The Liverpool price of ammonium sulfate approximates that of sodium nitrate, varying from $45 to $60 per ton. The nitrogen content is about 21 per cent.

The cost of converting ammonia into ammonium sulfate is about $15 per ton of the salt, and the cost to the by-product coke oven of producing the ammonia required for a ton is about $10.

Peacock[49] (1915) considers that it will be necessary to get the production cost at the factory down to 4 cents per lb. of ammonia, in order to have any process of nitrogen fixation compete successfully with by-product ammonium sulfate. This seems to necessitate a process giving other by-products of value. A low-priced ammonia once obtained, oxidation processes will follow easily. A concentrated end-product such as potassium or ammonium nitrate, or ammonium phosphate, with a factory cost not exceeding 5 cents per lb. of combined nitrogen in the form of ammonia will probably be necessary in order to meet the competitive resources of by-product ammonia.

Summers[52] (1915) also believes that the solution of the problem must be sought through improvement of processes.

Carlson[59] (1914) gives the value of a kilogram of nitrogen in the various forms showing the increase from the value as element up to a complex drug like veronal.

FIXATION COSTS

Washburn[13] (1916) claims that the arc process is at a great disadvantage compared with the cyanamide. For the fixation of a unit of nitrogen the former requires from five to six times as much power as the latter. The production of 180,000 net tons of concentrated nitric acid per annum requires 540,000 continuous horse power by the former and 100,000 continuous horse power by the latter method. At the moderate American cost of installation of $100 per continuous horse power, the total installation cost of the arc process for the above rate of production would be $80,000,000—and for the cyanamide process, $30,000,000. Even at an installation cost of $60 per continuous horse power on the switchboard, concentrated nitric acid costs a third more by the arc process. Even with power at the abnormally low figure of $10 operative cost per continuous horse power on the switchboard, the pound of nitrogen by the arc process costs for power alone as much as the total cost of the pound of nitrogen by the cyanamide process, including power, materials, labor, interest, amortization, and depreciation.

He also states that the cost of production of nitric acid by the cyanamide process as it is being established by an English Company throughout the allied countries is substantially 70 per cent of the cost of production from Chilean nitrate.

Gilbert[14] gives a comparative cost analysis of the arc and cyanamide processes. He does not state his authorities but his conclusions coincide with those of Washburn and others.

The German nitrogen monopoly agrees to sell nitrogen after the war at a maximum price of less than half what farmers normally pay[24] (1916) in the United States.

Germany has expended on her nitrogen fixation industry since the beginning of the war, $100,000,000[24] (1916).

Washburn[18] gives the cost of Chilean nitrate as $2.40 to $2.60 per unit of ammonia (20 lbs.) (= $50 a ton), and of cyanamide as 80–90 cents per unit of ammonia.

Norton[17] (1916) believes from observation of European practice that the minimum-sized plant for economical fixation of nitrogen is about 30,000 horse power.

He also states that in order to compete with the cyanamide process using power at $20 per horse power, the arc processes must get power at $3 or $4 a horse power, but if the final product desired be nitric acid, the arc process can compete at $7, $8 or $10 per horse power.

Summers[52] (1915) considers in detail the relative costs of the various processes for fixing nitrogen. From certain initial estimates of costs of labor, etc., he concludes that under the best conditions the manufacturer cannot meet expenses and pay more than $15 per kilowatt year. Hence the acid cannot find application in fertilizers, and the process can be utilized only if it may be coupled with some other product.

He computes that the electrical power requirements of the various processes are as follows:

Direct oxidation processes require per kg. of nitrogen.......	65.0 kw. hr.
Cyanamide process, aside from preparation of nitrogen gas, requires per kg. of nitrogen..........................	16.6 kw. hr.
Serpek process, besides energy from coal, requires per kg. of nitrogen..	12.0 kw. hr.
Haber synthetic ammonia process, besides preparation of nitrogen and hydrogen, compression and refrigerating, requires per kg. of nitrogen............................	1.5 kw. hr.

Baur[36] (1915) gives the yields and costs of the various arc processes as follows:

	Yield, g. of HNO_3 per kw. hr.	Price in Centimes per kw. hr.	Cost in Pfennigs per kg. N
Moscicki......................	..	0.30	15
Pauling......................	60	0.60	30
Birkeland......................	70	1.20	60
Schönherr......................	75	..	..

Hence at a market price of 1.23 M. per kg. of nitrogen as calcium nitrate, this substance can only be made at a profit, where power can be obtained in sufficient quantities at a price less than 0.5 centime per kilowatt hour.

The lime-nitrogen process requires about 2 kw. yr. per ton of nitrogen fixed, and the Haber or synthetic ammonia process, 3 kw. yr. per 1000 kg. of nitrogen.

Washburn[53] (1915), while giving no specific cost data, draws comparisons which he states are derived from actual working records, between the costs of the various processes.

Under the most favorable conditions the factory cost, exclusive of all power costs, of nitrogen in the form of commercial nitric acid, made by the arc process, is greater than the total cost of nitrogen as cyanamide, including power used at $10 per continuous horse-power year. Hence the cyanamide process can fix nitrogen, with power at $10 per horse-power year, cheaper than the cheapest of the arc processes with power free, or with all labor, raw materials and supplies free, and a charge of from $8 to $10 per horse-power year. The total cost of nitrogen in nitric acid from the arc process cannot by any chance be less than double that of nitrogen in cyanamide, thus giving the latter form a wide margin for its conversion into nitric acid, if desired. The indications are that weak nitric acid can be made by the cyanamide process for about $^3/_4$ of the cost by the arc process, but as power is brought below $10 per continuous horse-power year, the production cost of the latter process will diminish until it becomes about the same as for the former at $4 per horse-power year.

The cost of producing ammonia gas by the Haber process under the most favorable conditions, is nearly double that by the cyanamide process.

The investment necessitated by the arc process per unit of nitrogen as weak nitric acid, assuming the investment for power to be between $50 and $75 per horse power upon the switchboard, is about three times that per unit of nitrogen as ammonia, or twice that per unit of nitrogen as nitric acid derived from cyanamide. The fixed investment for ammonia production for the cyanamide process may be as low as one and one-half times the market value of the annual product compared with three times for the Haber process. For nitric acid by the cyanamide process the investment may be only one and one-fourth times the annual product, while for the arc process, with a power investment of $75 per continuous horse power, the fixed investment would be from three to four times.

In the United States the majority of manufacturing concerns vary in fixed investment from one to one and a half times the market value of the annual product, exceeding this proportion only in very special cases. The most reliable class of investments, such as public utility corporations do not exceed $4 to $6 investment per dollar of gross revenue.

Washburn[53] (1915) points out that though the Haber process demands relatively little power, yet the cost in the vicinity of New York of the electrical energy demanded is as much as the total power cost for cyanamide at other available sites. Its successful employment by the Badische Company is due to their pressing need for a way of disposing of large quantities of by-product sulfuric acid.

Peacock[49] (1915) believes that synthetic ammonia processes such as that of Haber may have local application, but will never become commercially important.

The plant investment required for the production of cyanamide ammonia is about half that for Haber, or synthetic ammonia. The cyanamide plant costs per unit of nitrogen fixed, about one-quarter as much as the arc process plant, and even the cyanamide-ammonia-nitric-acid plant costs only from one-third to one-half as much to install as the arc. The electric power required per unit of nitrogen fixed is one-fifth and the labor about the same as that of the arc process. The further conversion of the ammonia into nitric acid requires only a small fraction of additional power and labor. Moreover, the cyanamide is readily transported, and can be easily and economically converted into ammonia and nitric acid by small units at the point where used[46] (1915).

Haber[64] (1914) states that the Frank and Caro or cyanamide process fixes 50 g. of nitrogen per kw. hr. including all power.

The energy consumption in the fixation of one ton of nitrogen as calcium cyanamide is given by Pranke[99] (1913) as about three horse-power years including manufacture of carbide and all subsequent factory operations.

Kroczek[92] (1913) gives the horse-power consumption of the various processes as follows:

	H. P. hr. per kg. (2.2 lb.)
Kawalsky-Pauling	97
Birkeland-Eyde	84
Schönherr	80
Calcium cyanamide	33
Aluminum nitride	16

Scott[127] (1912) gives the nitrogen content and comparative prices of various artificial fertilizers as follows:

	Per cent Nitrogen	Price per Ton (Long)
Ammonium sulfate from gas works	19.75	£13
Chile nitrate	15.50	£ 9 15s
Norwegian calcium nitrate	12.75	£ 8 10s
Calcium cyanamide	18.00	£10

Roeber[149] (1910) gives the yields of the various processes as:

Schönherr (Badische Co.)	75 g. HNO_3 per kw. hr.
Birkeland-Eyde	70 g. HNO_3 per kw. hr.
Pauling	60–75 g. HNO_3 per kw. hr.
Cyanamide	76 g. HNO_3 per kw. hr.

Scott[127] (1912) gives the yield of the Birkeland-Eyde process as 500–550 kg. of nitric acid or 853–938 kg. of calcium nitrate per kw. yr. The best yield at Notodden has been 900 kg. of 100 per cent nitric acid per kw. yr.

The Pauling process guarantees 60 g. of 100 per cent nitric acid per kw. hr. and a cost of 120 francs per kilowatt as cost of the electrochemical plant itself.

Dobbelstein[116] (1912) gives the costs of installation and operation for a plant employing the Häusser method with coke oven gases.

Reference 84 (1914) gives the yields of the Serpek process as 2 tons of alumina and 500 kg. of fixed nitrogen (as ammonia) per kw. yr.

Beckman[135] (1911) describes the general financial status of the nitrogen fixation industry as being "well paying" and gives income figures. He makes a mistake, however, in stating that the Birkeland-Eyde process has been abandoned. [See Reference 130 (1911).]

Franklin[140] (1911) gives a very general review of the status of nitrogen fixation processes, considering only the Birkeland-Eyde, Schönherr, and cyanamide processes, and their relative costs, with data taken from other authors.

Roeber[149] (1910) gives a good general review of the various processes for nitrogen fixation, with costs, and present status of industry.

Voorhees[150] (1910) discusses the relative costs and actual value to the farmer of the various constituents of artificial fertilizers, and shows where economy should be effected.

AMMONIA FROM CALCIUM CYANAMIDE

Landis[25] (1916) gives estimates on the plant and operating costs for the production of 30,000 lbs. of ammonia per day, based on designs made by the American Cyanamide Company, in the light of European practice, and after six months' experience in America with a small plant, imported from Germany. These involve the use of an autoclave unit of nine shells requiring a continuous motor load of about 200 h. p.

The plant, without power or pumping plants, equipped to put out as final product an ammonia gas saturated with moisture at the temperature of the condenser water available may be erected for $120,000. This does not include cost of land, foundations, or sludge disposal. The cost of operation, including the items of power, steam, water, labor, chemicals, repairs, interest, depreciation, etc., comes to $451.43 per day, or $0.01505 per pound of ammonia. The detailed items are given in the original.

Laboratory experiments by Manuelli[71] (1914) have shown the yield to be from 90–99 per cent of the theoretical. The cost should be about 20 centimes per kilo of nitrogen.

OXIDATION OF AMMONIA

Zeisberg[4] (1916) gives costs deduced for American conditions from the costs given in Reference 109 and compares them with estimates from other sources for small and large plants.

He gives the cost of making nitric acid from sodium nitrate as at least 1.75 cents per lb. for labor, repairs, and sulfuric acid and with sodium nitrate at 2.64 cents per lb. the cost of the nitrogen used per lb. of nitric acid would be 3.750 cents compared with 4.280 cents for the Ostwald process. But the Ostwald process will become increasingly more profitable as the price of Chile nitrate and consequently of ammonia becomes less. These estimates are based on an 85 per cent efficiency for the Ostwald process and a 97 per cent efficiency for the retort method of making nitric acid. Zeisberg concludes that ammonia itself is so valuable that there is little hope that the Ostwald process can ever compete successfully with the arc processes for the production of nitric acid.

Kaiser[33] (1916) claims to be able to oxidize ammonia to nitric acid with a 90–95 per cent yield at a cost of 1.25 kg. of coke per kg. of ammonia, besides the power for driving fans.

Dieffenbach[62] (1914) computes that at the selling price existing, oxidation of ammonia to nitric acid is less profitable than conversion to sulfate. But in factories producing dilute nitric acid, absorption by nitric acid should be yet more economical.

In Reference 109 (1913)the cost of manufacture of nitric acid from ammonia from gas liquor is given for a plant capable of producing monthly 148.4 tons of 53 per cent nitric acid from 25 tons of nitrogen in the form of ammonia. The cost of plant is estimated at $55,000, and the items are given. Operating costs per month should be as follows:

Power, 14,400 h. p. hrs. at 3 cents....................	$ 437.50
Steam, 20,000 kg....................................	337.70
Total operation including above and interest, labor, etc.	2,187.50
Costs per ton of 100 per cent HNO_3..................	39.94

These figures include the plant and cost of production of ammonia gas from gas liquors. Detailed items are given with estimates of profits. The estimates are based on English conditions.

V—APPENDIX

RECOVERY OF NITROGEN COMPOUNDS

BY-PRODUCT COKE OVENS

Christopher[86] (1913) gives a history of the development of ammonia recovery from coke ovens with the yields at various periods, descriptions of the types of ovens, with comparative working costs and values of the products. A bibliography is included.

The yields obtained in 1870 are given as 10 gallons of tar and 16 lbs. of ammonium sulfate per ton of coal in gas works, and 5 to 11 gallons of tar and 4 to 6 lbs. of ammonium sulfate from coke ovens. This had been increased in 1881 by the Simon-Carves plant to 6.12 gallons of tar and 28 lbs. of ammonium sulfate.

PRODUCER GAS PLANTS

A further resource for the recovery of nitrogen compound is the ammonia-recovery producer-gas plant. The Lymn apparatus is a recent system based upon the general principles of the Mond process, but with the high and bulky towers replaced by vertical washers. The form and operation is fully described and illustrated. Operating costs are given for a plant producing from 2812 to 2830 kw. hr. per hour, with a consumption of from 64.6 to 70.2 tons of coal yielding from 1.76 to 1.94 tons of ammonium sulfate in 24 hours. The nitrogen content of the coal used was 0.8 per cent, and the cost $3.00 to $3.25 per ton. Including a 10 per cent depreciation charge, the cost of gas is 0.14 per kw. hr. Reference 56 (1915) gives further details.

COAL GAS MANUFACTURE

Wagner[75] (1914) describes and gives the costs, etc., for recovery of ammonia and other products in coal gas distillation by the Feld system. The raw liquor usually contains from 1 to 2 per cent of ammonia from which all but about 0.005 per cent is recovered.

The operating costs, without depreciation and interest, for the ammonia recovery from a plant carbonizing 300 tons of coal per day should be for a 250-day year:

$32,530 if aqua ammonia, and
$12,811 if ammonium sulfate be the final product.

With ammonia at 8 cents per lb., aqua ammonia of 26° at $102 a ton, and ammonium sulfate at $60 a ton, the annual profits for the two processes should be $47,030 and $30,809, respectively.

If the Bueb process for the extraction of cyanogen be combined with the above Feld process, the operating expenses will be $11,546 and the profit $48,039.

Tutwiller[74] (1914) describes in detail the methods of coal gas manufacture and by-product recovery, giving cuts and diagrams of apparatus. He gives analyses, proximate and ultimate, of a typical coal. He also describes in detail the concentration of ammoniacal solutions, illustrating with cuts and diagrams. His article is very full.

Rittman and Whitaker[50] (1915) give a bibliography of the chemistry of gas manufacture of 274 references covering the headings:

Carbonization and distillation of coal.
Gas producers, water-gas.
Petroleum oil distillation.
Oil gas.
Reactions of hydrocarbons.
High temperature and high pressure reactions.
Low temperature carbonization.
Chemical equilibrium and catalysis.
General literature.
Books.

PEAT PRODUCER-GAS PLANTS

Lymn[27] (1916) gives an historical résumé of the development of producer-gas by-product recovery in Europe and outlines the latest features of his own system. He mentions the systems and improvements of Young and Beilby, Mond, Duff, Grossley and others, describing each and discussing the advantages of each. The article is very fully illustrated with diagrams, etc. He gives detailed costs of operation and estimates on three different types of installation. He gives the yield of a Lymn plant as 61 lbs. of ammonium sulfate per ton of coal, which is a "nitrogen efficiency of 70 per cent." He also discusses the adaptability of various fuels and states that peat containing 60 per cent of water can be used. Plants burning peat have been in operation in Europe for several years.

Nature[19] (1916) in the course of an article discussing the distillation of peat in producer-gas plants gives figures on the recovery of by-products. Peat contains from 0.5 to 2.5 per cent of nitrogen, almost all of which may be liberated as ammonia by passing steam over the material heated to 350–550°. The following yields have been obtained from large-scale experiments:

	Germany	Italy	England	
Nitrogen content in per cent........	1.0	1.58	2.3	2.2
(Moisture content)..................	(40–60)	(15)	(58)	(63)
Ammonium sulfate recovered per ton of theoretically dry peat..........	70 lbs.	115 lbs.	215 lbs.	168 "

Producer-gas plants treating peat are in successful operation at Portadown, Ireland (400 brake horse power), near Osnabruck, Germany (3000 H. P.) and at Orentano, Italy (700 metric H. P.). The last two recover ammonium sulfate. The German plant consumes 210 tons of peat (60 per cent moisture) in 24 hours. The Irish plant using peat at 5s. a ton obtains power at 1/16 penny per H. P. hr. It is stated that the amount of combustible matter in the world's peat deposits exceeds that in all the known coal fields.

MISCELLANEOUS

Ammonia Recovery from Waste Liquors—Knoedler[45] (1915) has been able to recover 28 per cent ammonia from waste liquors of the Welsbach Company containing about 1 per cent, by a distillation plant which he describes in detail, at a cost of operation of $2.24 per 1000 lbs. The output of his plant was 3000 lbs. of 26 per cent ammonia per day.

Ammonium Chloride from Recovery Plants—A process has been patented and is being applied by the Berlin-Anhaltische Maschinenbau Aktien-Gesellschaft or the manufacture of ammonium chloride instead of ammonium sulfate from by-product ammonia, with the idea of supplying the market for the pure salt, and also avoiding a future overproduction of sulfate[79] (1914).

Wagner[75] (1914), in the course of an illustrated article on coal gas residuals and the Feld system, describes processes and apparatus for the recovery of ammonia gas by continuous stills and its conversion into ammonium sulfate.

The results obtained by slow distillation of coal in vacuum at various temperatures are discussed by Cobb, Burgess and Wheeler[60] (1914).

A tar scrubber for the direct process[104] (1913) for ammonia recovery from gases, avoiding the customary absorption and redistillation, is described, with cuts, by Strommenger. A good sulfate containing 25 per cent of NH_3 is obtained.

Heck[90] (1913) describes in some detail the operation of the Brunck direct, and the Koppers semi-direct, processes, with estimates of the relative saving effected by each.

Ohnesorge[97] (1913) outlines the history and recent development of the direct process for recovery of ammonium sulfate.

The direct process using a Pelouze extractor is briefly described by Pfudel[124] (1912).

Brown[137] (1911) gives working directions for the operation of a waste ammonia recovery plant and for concentration and testing of the product.

Cooper[138] (1911) has carried out some experiments upon the direct recovery of ammonia, and gives the diagram of his tar extractor.

PRODUCTS MADE FROM CYANAMIDE

Cyanamide is capable of a number of conversions to products, such as urea, dicyanamide, creatinin.

Washburn states that the United States imports annually for the celluloid industry $50,000 worth of high-grade urea which can now be supplied from this source. Urea is also applicable in the manufacture of explosives, when not prohibitively expensive[53] (1915). Its nitrogen can be converted almost quantitatively into cyanides by fusion with salt, giving a yield equal to nearly 25 per cent of the weight of the cyanide equivalent.

Clennell[37] (1915) discusses the chemistry of this reaction, and of others for making cyanides, as given by the literature and patents.

Cyanamide itself is an excellent agent for case-hardening, and hundreds of tons are being used abroad in the manufacture of war materials, and will probably find extensive use here when the peculiarities of the trade have been overcome[46] (1915).

Sulzer[130] (1912) makes ammonia and formic acid from calcium cyanamide by fusing with charcoal and sodium carbonate, and then heating with water in an autoclave.

Carlson[59] (1914) discusses in a general way the use of cyanamide as a raw material for the manufacture of other products such as cyanides, urea, veronal and other drugs. He gives the value of a kilogram in the various forms from element to complex drug.

NOMENCLATURE OF CYANAMID INDUSTRY

The following definitions of terms used in the Cyanamid industry are given by Pranke[99] (1913):

Lime-Nitrogen—Crude calcium cyanamide, ground to a fine powder after removal from the ovens in which it is formed. It contains about 55 per cent calcium cyanamide, CN.NCa, about 2 per cent calcium carbide, and about 20 per cent free calcium oxide.

Cyanamid—This is a trade name for the completely hydrated material prepared for use as a fertilizer in the United States. It contains about 45 per cent calcium cyanamide, 27 per cent calcium hydroxide and no carbide. The name is always capitalized and has no final "e."

Cyanamide—The compound represented by the formula $CN.NH_2$. It is sometimes referred to as acid cyanamide, or free cyanamide.

Calcium Cyanamide—The chemical compound of the formula CN.NCa, or $CaCN_2$, as it is frequently written.

Calcium Cyanamid—The name used by the United States Department of Agriculture and by some State Departments of Agriculture to designate the commercial Cyanamid. It is sometimes used to indicate the substance represented by the formula CN.NCa, but for the sake of clearness the compound CN.NCa will be called calcium cyanamide in the present paper.

Nitrolim—The trade name for the material sold in England for agricultural purposes. It is a lime-nitrogen to which has been added just enough water to destroy the carbide. Practically all the free lime is present as calcium oxide.

Kalkstickstoff—The commercial material manufactured in Germany for use as a fertilizer. It is similar to nitrolim.

Stickstoffkalk—A crude calcium cyanamide made by nitrifying a calcium carbide which contains about 10 per cent of calcium chloride. Its manufacture in Westergeln, Germany, under the Polzeniusz patents was discontinued in 1910.

Calciocianamide—The Italian commercial product, completely hydrated.

Cyanamide de Calcium—The French commercial product, completely hydrated.

EQUIVALENTS

1 M. (Mark) = $0.238
1 (pfennig) = 1/100 M.
1 £ (pound) = $4.8665
1 s. (shilling) = 1/20 £
1 fr. (franc) = $0.193

1 (centime) = 1/100 franc
1 kg. (1000 g.) = 2.205 lbs. (Av.)
1 kw. hr. = 1.359 H. P.
1 long ton = 2240 lbs.
1 metric ton = 2204.62 lbs.

POWER COSTS

The average coal consumption per kw. hr.[3] (1916) was found to be 2.77 lbs. (bituminous) at a modern 18,500 kw. steam turbine plant at Worcester, Mass. The unit cost of production per kw. hr. was 5.3 mills for fuel ($4.28 per ton) and 1.12 mills for operating labor cost. The cost analysis is given.

Dunn[10] (1916) discusses the relative construction and operation costs of hydro-electric and steam plants for the generation of electricity. He gives comparative unit analyses of cost of operation.

Stillwell[12] (1916) gives similar data and also shows the variation in total cost of power for various costs of coal.

Scheuer[22] (1916) gives the cost of power from hard and soft coal at different prices in Germany, with and without by-product recovery. He also gives statistics of coal production and by-product yields of various kinds.

Baekeland[15] (1916) states that at $1.25 a ton for good steam coal power can be obtained cheaper than the price now paid at Niagara.

In Reference 24 (1916) Washburn discusses the relation of the water power problem to nitrogen fixation, describing the difference between Norwegian and United States water powers. He gives estimated costs of installing plants, etc.

There is considerable interest in the possibility that certain of these processes might be adapted to utilized off-peak and off-season loads[52] (1915).

In figuring the cost[84] (1914) of water power, it is the tendency abroad to include only operating costs, and not the investment on the plant, contrary to the practice in the United States. This should be taken into consideration in making comparisons. There are many plants in operation in the chemical industries abroad, whose real costs of power production are no lower than many of the more favored locations in this country.

Scott[127] (1912) discusses the power question as it affects Great Britain, and goes into comparison and details in regard to the cost of installation of hydro-electric, and steam plants, and the relative advantages of coal and gas-fuel, and of surface combustion. He gives the capital and running costs for a producer-gas engine power station for 3000 brake horse power.

In Norway[127] (1912) the electric horse-power year costs $4 to $6 compared with $10 to $15 in the U. S.

Lyon and Keeney[93] (1913) give the cost of power used for various electrochemical processes in 25 different localities from hydro-electric and steam plants.

VI—REFERENCES

1—Martin and Barbour, "Industrial Nitrogen Compounds and Explosives." (D. Appleton & Co., N. Y. 1916.)

2—Porter, *Metallurgical and Chemical Engineering*, **15** (1916), 470–5.

3—*Electrical World*, **68** (1916), 671.

4—Zeisberg, *Metallurgical and Chemical Engineering*, **15** (1916), 299–304.

5—Turrentine, This Journal, **8** (1916), 923–6.

6—Turrentine, *Ibid.*, **8** (1916), 584–5.

7—*Frankfurter Handelsblatt*, May 29, 1916, Abstract, *Engineering* (L.), **101** (1916), 576.

8—Harris, *American Fertilizer*, **45** (1916), 32–5.

9—Clarke, Abstract, *Metallurgical and Chemical Engineering*, **14** (1916), 601–3.

10—Dunn, *Proc. Am. Inst. Elec. Eng.*, **35** (1916), 575–90.

11—H. Koppers Co.,Pittsburgh,Pa.,"By-products of the Coking of Coal in America," **1916**. (Pamphlet issued to oppose government nitrate plant.)

12—Stillwell, *Proc. Am. Inst. Elec. Eng.*, **35** (1916), 561–74.

13—Washburn, "The Facts in the Nitrogen Case," **1916**.

14—Gilbert, "Sources of Nitrogen Compounds in the United States," Smithsonian Publication No. 2421 (1916).

15—Baekeland, Statement before Senate Committee on Agriculture and Forestry, **1916** (S. 4971).

16—Merrill, Statement before Senate Committee on Agriculture and Forestry, **1916** (S. 4971).

17—Norton, Statement before Senate Committee on Agriculture and Forestry, **1916** (S. 4971).

18—Washburn, Statement before Senate Committee on Agriculture and Forestry, **1916** (S. 4971).

19—*Nature*, **97** (1916), 19–23.

20—*Scientific American*, **112** (1916), 216.

21—Landis, *Metallurgical and Chemical Engineering*, **14** (1916), 260.

22—Scheuer, *Elektrotechn. Z.*, **37** (1916), 64–7.

23—Skerrett, *Iron Age*, **97** (1916), 359–62.

24—Washburn, Statement before House Committee on Military Affairs, Feb. 11, 1916; Statement before House Committee on Agriculture, Feb. 1, 1916.

25—Landis, This Journal, **8** (1916), 156–60; *American Fertilizer*, **44** (1916), 21–6.

26—Cushman, *J. Frank. Inst.*, **181** (1916), 163–90.

27—Lymn, *J. Am. Soc. Mech. Eng.*, **37** (1915), 253–66.

28—*Nature*, **96** (1916), 537.

29—Schüphaus, *Met. und Erz*, **13** (1916), 21–8; Abstract, *Metallurgical and Chemical Engineering*, **14** (1916), 425–6.

30—Childs, *Amer. Iron and Steel Institute*, May **1916**; Abstract, *Metallurgical and Chemical Engineering*, **15** (1916), 38–41.

31—*Electrical World*, **68** (1916), 10–2, 69–70.

32—Duke, *Engineering and Mining Journal*, **101** (1916), 149; *Manufacturers' Record*, **68** (1915), 54.

33—Kaiser, *Chem.-Ztg.*, **40** (1916), 14; Abstract, *Chemical Abstracts*, **10** (1916), 806.

34—Wagner, "Coal and Coke," **1916** (McGraw-Hill Book Co.).

35—Vogel, *Chem.-Ztg.*, **40** (1916), 12–3; Abstract, *J. Soc. Chem. Ind.*, **35** (1916), 431.

36—Baur, *Schweizerische Wasserwirtschaft*, **7**, Nos. 16 and 17; *Elektrotechn. Z.*, **36** (1915), 694–5.

37—Clennell, *Metallurgical and Chemical Engineering*, **13** (1915), 756–8.

38—Cresap, *Iron Age*, **96** (1915), 752–3.

39—Dary, *Revue d'Electrochimie et d'Electrometallurgie*, **8** (1914), 70–2; Abstract, *Elektrochem. Z.*, **21** (1915), 226.

40—Dunn, *Scientific American*, **113** (1915), 492–3, 505–7.

41—Haber, Maschke, *Z. Elektrochem.*, **21** (1915), 128–30.

42—Haber, Tamaru, Oeholm, *Z. Elektrochem.*, **21** (1915), 191–245.

43—Haber, Tamaru, Ponnaz, *Z. Elektrochem.*, **21** (1915), 89–106.

44—Koenig, *Z. Elektrochem.*, **21** (1915), 267–86.

45—Knoedler, This Journal, **7** (1915), 1061–4.

46—Landis, This Journal, **7** (1915), 433–8; *Metallurgical and Chemical Engineering*, **13** (1915), 213–8.

47—Landis, *Metallurgical and Chemical Engineering*, **13** (1915), 218–20.

48—Merrill, Report upon Electric Power Development in the United States, etc., in response to Senate Resolution of Feb. 13, 1915. Part **2**, Doc. 316, 485 pp.

49—Peacock, *Trans. Am. Electrochem. Soc.*, **27** (1915), 409–17.

50—Rittman, Whitaker, "Bibliography of the Chemistry of Gas Manufacture," Bureau of Mines, *Technical Paper*, **120** (1915).

51—Scott, *J. Soc. Chem. Ind.*, **34** (1915), 113–26.

52—Summers, *Trans. Am. Electrochem. Soc.*, **27** (1915), 339–83; *Proc. Am. Inst. Elec. Eng.*, **34** (1915), 337–81; Abstract, *Metallurgical and Chemical Engineering*, **13** (1915), 241–4.

53—Washburn, *Trans. Am. Electrochem. Soc.*, **27** (1915), 385–402; *Metallurgical and Chemical Engineering*, **13** (1915), 309–14.

54—*Elektrochem. Z.*, **21** (1915), 211–21.

55—*Engineering News*, **73** (1915), 16–21.

56—*Metallurgical and Chemical Engineering*, **13** (1915), 456–8.

57—*Metallurgical and Chemical Engineering*, **13** (1915), 638–9; *American Fertilizer*, **43** (1915), 37–42.

58—Baekeland, This Journal, **6** (1914), 769–78; *Metallurgical and Chemical Engineering*, **12** (1914), 559–60.

59—Carlson, *Z. angew. Chem.*, [3] **27** (1914), 724–5.

60—Cobb, *J. Gas Lighting*, **126** (1914), 329–31; Abstract, *J. Soc. Chem. Ind.*, **33** (1914), 541; Burgess, Wheeler, *J. Chem. Soc.*, **105** (1914), 131–40.

61—Crossley, *J. Soc. Chem. Ind.*, **33** (1914), 1140.

62—Dieffenbach, *Chem. Ind.*, **37** (1914), 265–9.

63—Haber, *Z. angew. Chem.*, **27** [1] (1914), 473–7.

64—Haber, *J. Soc. Chem. Ind.*, **33** (1914), 52–4.

65—Perlick, "Die Luftstickstoff Industrie in ihrer volkswirtschaftlichen Bedeutung" (Dr. Werner Klinkhardt, Leipzig, 1913).

66—Hene, Dissertation der Berliner Technischen, Hochschule, **1912**, p. 48; Abstract, *Elektrotechn. Z.*, **35** (1914), 745.

67—Knox, "Fixation of Atmospheric Nitrogen," D. Van Nostrand Co. 1914. 110 pp.

68—Koenig, Elöd, *Ber.*, **47** (1914), 516–29.

69—Kubierschky, This Journal, **6** (1914), 692.

70—Lowry, *Trans. Faraday Soc.*, **9** (1914), 189–92.

71—Manuelli, *Ann. chim. applicata*, **1** (1914), 388–96; Abstract, *J. Soc. Chem. Ind.*, **33** (1914), 690–1.

72—Matignon, *Chem. Z.*, **38** (1914), 894–5; Abstract, *J. Soc. Chem. Ind.*, **33** (1914), 829.

73—Serpek, *Z. angew. Chem.*, [1] **27** (1914), 41–8.

74—Tutwiller, *J. Franklin Inst.*, **178** (1914), 383–416.

75—Wagner, *Scientific Amer. Supplement*, **80** (1915), 316–9; *Metallurgical and Chemical Engineering*, **12** (1914), 696–702; *Amer. Gas Inst.*, **1914**.

76—*Chemical Trade Journal*, May 9, 1914; Abstract, *J. Soc. Chem. Ind.*, **33** (1914), 541.

77—*Chem.-Ztg.*, Apr. 23, 1914; Abstract, *J. Soc. Chem. Ind.*, **33** (1914). 590.

78—*Chem.-Ztg.*, **38** (1914), 593; Abstract, This Journal, **6** (1914), 597.

79—*Chem.-Ztg.*, **13** (1914), 117; Abstract, This Journal, **6** (1914), 778–9

80—*Engineering* (London), **98** (1914), 267–72, 294–6, 351–3, 465–8.

81—*J. Soc. Chem. Ind.*, **33** (1914), 134.

82—*Metallurgical and Chemical Engineering*, **12** (1914), 265–8.

83—*Z. Ver. deut. Ing.*, **58** (1914), 980.

84—*Z. Ver. deut. Ing.*, **58** (1914), 66–7.

85—Bradbury, Hirsch, Abstract, *J. Soc. Chem. Ind.*, **32** (1913), 84.

86—Christopher, *J. Soc. Chem. Ind.*, **32** (1913), 115–24.

87—Fischer, Hene, *Ber.*, **46** (1913), 603–17.

88—Fraenkel, *Z. Elektrochem.*, **19** (1913), 362–73.

89—Haber, Le Rossignol, *Z. Elektrochem.*, **19** (1913), 53–72; Abstract, *Metallurgical and Chemical Engineering*, **11** (1913), 211–4; *J. Soc. Chem. Ind.*, **32** (1913), 134–8; This Journal, **5** (1913), 328–31.

90—Heck, *Stahl u. Eisen*, **33** (1913), 777–82.

91—Koenig, *Ber.*, **46** (1913), 132–4.

92—Kroczek, *Gas World*, **59** (1913), 378; *Chemical Abstracts*, **7** (1913), 3922.

93—Lyon, Keeney, *Trans. Am. Electrochem. Soc.*, **24** (1913), 119–47.

94—Meneghini, *Gazz. chim. ital.*, [1] **43** (1913), 81–90; Abstract, *J. Soc. Chem. Ind.*, **32** (1913), 230.

95—Montgomery & Co., Report, Abstract, *J. Soc. Chem. Ind.*, **32** (1913), 84.

96—Montgomery & Co., Report, Abstract, This Journal, **5** (1913), 260; *Chem. Eng.*, **17** (1913), 78.

97—Ohnesorge, *Z. angew. Chem.*, **26** (1913), 593–6.

98—Pranke, *Chem. Eng.*, **12** (1913), 113–5.

99—Pranke, "Cyanamide," Chemical Publishing Co., Easton, Pa., 1913, 106 pp.

100—Richards, *Chem. Eng.*, **17** (1913), 196–9.

101—Ross, This Journal, **5** (1913), 725–9.

102—Russ, *Z. Elektrochem.*, **19** (1913), 923–5.

103—Stähler, Elbert, *Ber.*, **46** (1913), 2060–77.

104—Strommenger, *Stahl u. Eisen*, [2] **33** (1913), 1694–5.

105—Tucker, *J. Soc. Chem. Ind.*, **32** (1913), 1143–4; This Journal, **5** (1913), 191–2.

106—*Coal Trades Review* (L) May 23, 1913; *Coal Trades Review* (L), **11** (1913), 476.

107—*Engineering Mining Journal*, **95** (1913), 602.

108—Forty-ninth Annual Report on Alkali. Proceedings during the year 1912; Abstract, *J. Soc. Chem. Ind.*, **32** (1913), 786–8.

109—*Metallurgical and Chemical Engineering*, **11** (1913), 438–42.

110—*Times Engineering Supplement*, Oct. 15, 1913; Abstract, *J. Soc. Chem. Ind.*, **32** (1913), 1008.

111—Auzies, *Rev. gén. chim.*, **15** (1912), 233–41; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 919.

112—Bernthsen, *Trans. 8th Intern. Cong. Appl. Chem.*, **28** (1912), 182–210; This Journal, **4** (1912), 760–7.

113—Billiter, *Nernst Festschrift*, **1912**, 86–9; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 919.

114—Hirsch, Bradbury, *J. Soc. Chem. Ind.*, **31** (1912), 71, 716.

115—Durand, Briner, *Compt. rend.*, **155** (1912), 1495–7.

116—Dobbelstein, *Stahl u. Eisen*, **32** (1912), 1571–7; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 982.

117—Eyde, *Trans. Intern. Cong. Appl. Chem.*, **28** (1912), 169–81; Abstracts, *Chemical Engineer*, **16** (1912), 188–91; This Journal, **4** (1912), 771–4.

118—Fischer, Hene, *Ber.*, **45** (1912), 3652–8.

119—Häusser, *Z. Ver. deut. Ing.*, **56** (1912), 1157–64.

120—Kochmann, *Arbeit. Pharm. Institut. Berlin*, **8**, 81; Abstracts, *Chem. Zentr.* [1] **1912**, 169; *Chemical Abstracts*, **6** (1912), 2295.

121—Lowry, *J. Chem. Soc.*, **101** (1912), 1152–8.

122—Meneghini, *Gazz. chim. ital.* [1] **42** (1912), 126–34; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 383.

123—Norton, "Utilization of Atmospheric Nitrogen," Dept. of Commerce and Labor, Bur. of Manufacturers. Special Agents Series, 52, 1912.

124—Pfudel, *J. Gasbel.*, **54** (1911), 1272–3; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 64–5.

125—Reinders, Cats, *Chem. Weekblad*, **9** (1912), 47–58; Abstracts, *Chem. Zentr.*, [1] **83** (1912), 708; *J. Soc. Chem. Ind.*, **31** (1912), 280.

126—Russ, *Z. angew. Chem.*, **25** (1912), 586; *J. Soc. Chem. Ind.*, **31** (1912), 383.

127—Scott, "Manufacture of Nitrates from the Atmosphere." Smithsonian Report for 1913, pp. 359–84 (1914). (Publication 2291.) Reprinted from *J. Roy. Soc. Arts* (*London*), **60** (1912), No. 3104.

128—Scott, *Nature*, **89** (1912), 463; Abstract, This Journal, **4** (1912), 619.

129—Strutt, *Proc. Roy. Soc.* (*A*), **86** (1911), 56–63; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 70–1.

130—Sulzer, *Z. angew Chem.*, **25** (1912), 1268–73; Abstract, *J. Soc. Chem. Ind.*, **31** (1912), 682.

131—Tausent, *Z. Elektrochem.*, **18** (1912), 314–9.

132—Tucker, Read, *Trans. Am. Electrochem. Soc.*, **22** (1912), 57–66.

133—*Metallurgical and Chemical Engineering*, **10** (1912), 126.

134—Newspaper clippings, *Times*, Raleigh, N. C., June 14, 1912, *Wall Street Journal*, July 25, 1912.

135—Beckman, *Metallurgical and Chemical Engineering*, **9** (1911), 340.

136—Birkeland, Garfield, *Metallurgical and Chemical Engineering*, **9** (1911), 436, 485.

137—Brown, *Chemical Engineer*, **14** (1911), 456–61.

138—Cooper, *Chemical Engineer*, **13** (1911), 111.

139—Ehrlich, *Russ. Monatsh. Chem.*, **32** (1911), 917–6; Abstract, *J. Soc. Chem. Ind.*, **30** (1911), 1393–4.

140—Franklin, *General Electric Review*, **14** (1911), 472–5; *Chemical Engineer*, **14** (1911), 453–6.

141—Lamy, *Metallurgical and Chemical Engineering*, **9** (1911), 99–104.

142—Edgar, *J. Am. Chem. Soc.*, **33** (1911), 292–9.

143—Strutt, *Proc. Roy. Soc.*, **85** (1911), 533–6.

144—Tufts, This Journal, **3** (1911), 295–9.

145—Vanderpol, *Metallurgical and Chemical Engineering*, **9** (1911), 196–8.

146—Foerster, Jacoby, *Z. Elektrochem.*, **13** (1907), 101–7.

147—Haber, Koenig, Platou; Haber, Platou; Holwech, Koenig; Haber, Holwech, *Z. Elektrochem.*, **16** (1910), 789–813.

148—Holwech, *Z. Elektrochem.*, **16** (1910), 369–90.

149—Roeber, *Mineral Industry*, **19** (1910), 58–67.

150—Voorhees, This Journal, **2** (1910), 153–5.

151—Wolokitin, *Z. Elektrochem.*, **16** (1910), 814–26.

152—Zenneck, *Physik. Z.*, **11** (1910), 1228–33; Abstract, *Metallurgical and Chemical Engineering*, **9** (1911), 73–5.

ADDITIONAL MATERIAL AND COMMENT

The galley proof of the above article was sent to thirty different libraries, firms and individuals for criticisms and suggestions of further material. The following items were obtained in this way:

F. C. Zeisberg and F. G. Liegenroth, of the E. I. du Pont de Nemours and Company state that the gases from the Birkeland-Eyde furnace are withdrawn at 1100° C. and contain about 1.25 per cent of NO. The concentration of NO in the product of the Schönherr furnace is only about 1.75 per cent and the yield is the same as for the Birkeland-Eyde. The temperature of the escaping gases is 1200° C. for the latter and 800 to 1000° C. for the former. Both of these furnaces, as well as the Pauling, take single-phase current. The Schönherr uses 5000 volts and the Birkeland-Eyde is now built to take as high as 4000 kw. The power factor of the last has been raised to 0.8 in recent developments.

The enrichment of air with oxygen as done in the Kilburn-Scott process is an old idea.

At Notodden the strength rarely rises above 30 per cent HNO_3 by weight in the acid delivered.

The total power in Norway (Rjukanfos and Notodden) used for fixation processes is 350,000 H. P. (250,000 kw.). The Tyn, Matre and Vamma developments will not be so employed for sometime, at least.

H. G. H. Tarr of R. D. Wood and Co. writes: "I feel quite certain that the combination of a by-product gas and steam plant will produce cheaper power than can be attained in any other way. I am preparing an article which will be published in one of the periodicals in the next two or three months, in which I shall go more into detail." This article will appear in the *Metallurgical and Chemical Engineering*. Mr. Tarr has already published in *Power* for November, 1908, comparative analyses of the costs of operating water-power and gas-power plants.

C. W. Andrews of the John Crerar Library supplied the following references to books:

Georg Brion, "Luftsalpeter, seine Gewinnung durch den elektrischen Flammenbogen." Berlin & Leipzig (G. J. Göschen, 1912, 153 pp.).

Theodor Pfeiffer, "Stickstoffsammelnde Bakterien, Brache und Raubbau." (Ed. 2. Berlin, P. Parey, 1912, 100 pp.)

Wilhelm Schneidewind, "Weitere Versuche über die Wirkung verschiedener Stickstofformen aus den Jahren 1908–1911." (Berlin, Deutsch Landwirtschafts-Gesellschaft, 1912, 171 pp.)

The following books, some of which also were suggested by C. W. Andrews, belong to an earlier period than that covered by this paper, but may be of interest to those who wish to study the earlier phases of the subject:

Robert Huber, "Zur Stickstoff-Frage." (Bern, Stämpfli & Cie., 1908, 116 pp.)

Konrad Wilhelm Jurisch, "Salpeter und sein Ersatz." (Leipzig, Hirzel, 1908, 356 pp.)

Adolf Koenig, "Uber die Oxydation des Stickstoffes im gekühlten hochspannungsbogen bei Minderdruck." (Halle, Knapp, 1908, 76 pp.)

This book consists of a brief review of the chemistry of nitrogen oxidation and a detailed report of the author's experiments.

Wilhelm Schneidewind, "Die Stickstoffquellen und die Stickstoffdüngung." (Berlin, P. Parey, 1908, 139 pp.)

P. Vageler, "Die Bindung des atmosphärischen Stickstoffs in Natur und Technik." (Braunschweig, Vieweg, 1908, 132 pp.)

The greater part of this book is devoted to the fixation of nitrogen by bacteria, only 19 pages being given to technical methods. A diagram of the arc chamber of the Bradley and Lovejoy process is shown.

Eduard Donath, "Die technische Ausnutzung des atmosphärischen Stickstoffes." (Leipzig & Wien, F. Deuticke, 1907, 250 pp.)

This book is a good detailed treatment particularly of the chemical aspects of the subject, with descriptions of apparatus and many references to the literature. The Bradley-Lovejoy process is described quite fully.

Johannes Brode, "Ueber die Oxydation des Stickstoffes in der hochspannungs flamme." (Halle, Knapp, 1905, 63 pp.)

F. Lepel, "Die Bindung des atmosphärischen Stickstoffes, insbesondere durch elektrische Entladunge." (J. Abel Greifswald, 1903, 42 pp.)

NEW PUBLICATIONS

By Irene DeMatty, Librarian, Mellon Institute of Industrial Research, Pittsburgh

Analysis: A System of Qualitative Chemical Analysis. J. A. Gibson. 12mo. 44 pp. Price, $0.45. Herald Statesman Publishing Co., Columbia, Mo.

Applied Chemistry. F. B. Emery and Others. 4to. 212 pp. Price, $1.20. Lyons & Carnahan, Chicago.

Applied Science: Les Sciences physiques et naturelles avec leurs applications à l'agriculture, à l'industrie, etc. J. Dutilleul and E. Ramé. 8vo. 288 pp. Price, 1 fr. 50. Librairie Larousse, Paris.

Bauxite: L'industrie de la bauxite dans le département du Var. A. de Keppen. 8vo. 22 pp. Chaix, Paris.

Blast Furnace Construction in America. J. E. Johnson, Jr. 8vo. 410 pp. Price, $4.00. McGraw-Hill Book Co., New York.

Briquetting: A Handbook of Briquetting. Vol. 1. The Briquetting of Coals, Brown Coals and Other Fuels. G. Franke. 8vo. 631 pp. Price, $9.00. J. B. Lippincott Co., Philadelphia.

Chemical Control in Cane Sugar Factories. H. C. P. Geerligs. 8vo. 168 pp. Price, 10s. Norman Rodger, London.

Chemical Discovery and Invention in the Twentieth Century. W. A. Tilden. 8vo. 503 pp. Price, 7s. 6d.

Chemical Mathematics: Traité de mathematiques générales à l'usage des chimistes, physiciens, ingénieurs, etc. E. Fabry. 8vo. 480 pp. Price, 10fr. A. Hermann et fils, Paris.

Chemistry: Cours de chimie. P. Bourgarel. 18mo. 231 pp. Garnier frères, Paris.

Chemistry: Laboratory Manual of General Chemistry. A. G. Lamb. 4to. Price, 6s. Oxford University Press, London.

Chemical Directory: The First Annual Chemical Directory of the United States. Ed. by B. F. Lovelace. Williams & Wilkins Co., Baltimore.

Chemists' Yearbook for 1917. F. W. Atack. 2 vols. 3rd Ed. Price, 10s. 6d. Sherratt & Hughes, Manchester.

Chemistry for Photographers. W. R. Flint. 12mo. 205 pp. Price, $2.00. American Photographic Publishing Co., Boston.

Coal Mining Kinks. Compiled from Coal Age. 8vo. 104 pp. Price, $1.50. Hill Publishing Co., New York.

Compressed Air Practice in Mining. David Penman. 8vo. 253 pp. Price, 5s. Charles Griffin & Co., London.

Electricity: Qu'est-ce que l'électricité? A. Despaux. 8vo. 216 pp. Price, 7fr. 50. H. Dunod et E. Pinat, Paris.

Engineering Analysis of a Mining Share. J. C. Pickering. 8vo. 95 pp. Price, $1.50. McGraw-Hill Book Co., New York.

Engineering Data: The Pocket Diary and Year Book for 1917. A Collection of Useful Engineering Notes. 330 pp. Price, $0.40. Norman Remington Co., Baltimore.

Engines: The Fitting and Erecting of Engines. C. L. Brown. 8vo. 173 pp. Price, 3s. 6d. Emmott & Co., London.

English and Engineering. F. Aydelotte. 16mo. 390 pp. Price, $1.50. McGraw-Hill Book Co., New York.

Gasoline and How to Use It. G. A. Burrell. 281 pp. Price, $1.50. Oil Statistical Society, Boston.

German-English Dictionary for Chemists. A. M. Patterson. 12mo. 332 pp. Price, $2.00. John Wiley & Sons, New York.

Glass: A Memoir of British Resources of Sands Suitable for Glass Making. G. H. Boswell. 8vo. Price, 1s. 6d. Longmans, Green & Co., London.

Manufacturing Costs and Accounts. A. H. Church. 8vo. 452 pp. Price, $5.00. McGraw-Hill Book Co., New York.

Mechanical Pocket Book and Diary for 1917. 32mo. 786 pp. Price, 1s. Technical Publishing Co., Manchester.

Mechanics: Précis de mécanique théorique et pratique. E. Gabriel. 8vo. 244 pp. J. de Gigord, Paris.

Microscopic Examination of Steel. Henry Fay. 8vo. 82 pp. Price, $1.25. John Wiley & Sons, New York.

Minerals: Tables for the Determination of the Common Minerals and Rocks. W. A. Tarr. 16mo. 25 pp. Price, $0.40. University Cooperative Store, Columbia, Mo.

Operation of Gas Works. W. M. Russell. 8vo. 206 pp. Price, $2.00. McGraw-Hill Book Co., New York.

Ores: A Study of the Magmatic Sulfid Ores. C. F. Tolman, Jr., and A. F. Rogers. 4to. 76 pp. Price, $1.00. Leland Stanford, Jr., University.

Organic Chemistry: Leçons de chimie. B. Gauthier-Echard. 16mo. 250 pp. Deslis frères et Cie, Paris.

Organic Chemistry: A Text Book of Organic Chemistry. E. V. McCullum. 8vo. Price, 10s. The Macmillan Co., London.

Paraffin: The Vaporizing of Paraffin for High Speed Motors. Edward Butler. 12mo. 120 pp. Price, $1.25. J. B. Lippincott Co., Philadelphia.

Refining Industry in the United States. Oil and Gas Journal. Price, $1.00. *Oil and Gas Journal*, Tulsa, Okla.

Saws: Their Care and Treatment. H. W. Durham. 8vo. 272 pp. Price, 5s. Wm. Rider & Son, London.

Steam-Boilers: Their Theory and Design. H. D. Parsons. 5th Ed. 8vo. 377 pp. Price, $4.00. Longmans, Green & Co., New York.

Ventilation: Some Modern Methods of Ventilation. R. Grierson. 8vo. 202 pp. Price, 8s. 6d. Archibald Constable & Co., London.

Welding: A Practical Manual of Autogenous Welding. R. Granjon and R. Rosemberg. 8vo. 273 pp. Price, 5s. Charles Griffin & Co., London.

Wiring: Standard Wiring for Electric Light and Power. H. C. Cushing, Jr. 16mo. 360 pp. Price, $1.00. The Author, 63 Park Row, New York City.

NEW JOURNALS

Abstracts of Bacteriology. Published under the Direction of the Society of American Bacteriologists. Bi-monthly. Price, $5.00. Williams & Wilkins Co., Baltimore.

The Journal of Dairy Industry. Edited by J. H. Fransen. Bi-monthly. Price, $5.00. Williams & Wilkins Co., Baltimore.

The Journal of Urology. Edited by Hugh H. Young. Bi-monthly. Price, $5.00. Williams & Wilkins Co., Baltimore.

RECENT JOURNAL ARTICLES

Air Drying. Carl Hering. *Metallurgical and Chemical Engineering*, Vol. 16 (1917), No. 4, pp. 187–190.

Alloys: A Bibliography of Alloys: Binary, Ternary and Quaternary Systems: Clarence Estes. *Metallurgical and Chemical Engineering*, Vol. 16 (1917), No. 5, pp. 273–282.

Amino Acids: Sur quelques dérivés des amino-acides. J. T. Bornwater. *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. 36 (1917), No. 5, pp. 281–284.

Analysis of Light Oils. Gustav Egloff. *Metallurgical and Chemical Engineering*, Vol. 16 (1917), No. 5, pp. 259–263.

Atom: Structure of the Atom. Saul Dushman. *General Electric Review*, Vol. 20 (1917), No. 3, pp. 186–196.

Bleached Groundwood. Otto Schutz. *Paper*, Vol. 19 (1917), No. 23, pp. 64–66.

Brick Sewers. J. F. Springer. *Municipal Engineering*, Vol. 52 (1917), No. 2, pp. 47–52.

Carbonization of Kelp for the Recovery of Potash. J. W. Turrentine. *Metallurgical and Chemical Engineering*, Vol. 16 (1917), No. 4, pp. 196–199.

Cleaning the Blast Furnace Gas. L. Bradley and Others. *The Iron Trade Review*, Vol. 60 (1917), No. 9, pp. 517–520.

Concrete: The Progress of Reinforced Concrete. E. D. Andrews. *The Engineering Review*, Vol. 30 (1916), No. 6, pp. 168–170.

Dry Concentration of Gold Ore. Leonard Goodday. *Engineering and Mining Journal*, Vol. 103 (1917), No. 7, pp. 305–306.

Fertilizers: Permanent Soil Fertility. S. B. Haskell. *The American Fertilizer*, Vol. 46 (1917), No. 5, pp. 21–25.

Flotation, Past and Present. N. C. Bonnevie. *Mining American*, Vol. 74 (1917), No. 1826, pp. 8–9.

Flotation's Remarkable Advance in 1916. *The Mining and Engineering World*, Vol. 46 (1917), No. 1, pp. 29–32.

Germany's Manganese Supply. Frank Jovie. *The Iron Age*, Vol. 99 (1917), No. 8, p. 496.

Graphite Deposits in Burnet and Llano Counties, Texas. W. B. Phillips. *Manufacturers' Record*, Vol. 71 (1917), No. 8, p. 45.

Grinding Wheels and Grinding Machines. C. W. Blakeslee. *The Engineering Magazine*, Vol. 52 (1917), No. 5, pp. 697–710.

Hydrocarbons: Sur les points de fusion de quelques hydrocarbures. C. J. Enklaar. *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. 36 (1917), No. 5, pp. 247–249.

Hydro-electric Power and Electrochemistry and Electrometallurgy in France. C. O. Mailloux. *Metallurgical and Chemical Engineering*, Vol. 16 (1917), No. 5, pp. 265–273.

Manganese: On the Estimation of Manganese in High Speed Steels. C. T. Nesbit. *Chemical News*, Vol. 115 (1917), No. 2985, pp. 61–62.

Manganese Significance in Steel Metallurgy. F. H. Willcox. *The Blast Furnace and Steel Plant*, Vol. 5 (1917), No. 3, pp. 97–100.

Magnesite: The Origin and Geo-chemistry of Magnesite. S. H. Dolbear. *Mining and Scientific Press*, Vol. 114 (1917), No. 7, pp. 237–238.

Magnetic Properties of Sheet Steel. T. Spooner. *The Electric Journal*, Vol. 14 (1917), No. 3, pp. 90–97.

Metal Spraying with Oxy-Acetylene "Pistol." Lathrop Collins. *Acetylene Journal*, Vol. 18 (1917), No. 9, pp. 494–502.

Metallurgical Problems of the Rand. H. F. Bain. *Mining and Scientific Press*, Vol. 114 (1917), No. 7, pp. 227–235.

Metric System: The Adoption of the Metric System in the United States. *The Scientific Monthly*, Vol. 4 (1917), No. 3, pp. 193–219.

Mill and Smelter Construction in 1916. *The Mining and Engineering World*, Vol. 46 (1917), No. 1, pp. 1–28.

MARKET REPORT—MARCH, 1917

WHOLESALE PRICES PREVAILING IN THE NEW YORK MARKET ON MARCH 15

INORGANIC CHEMICALS

Acetate of Lime,	100 Lbs.	3.25	@	3.50
Alum, lump ammonia	100 Lbs.	4.00	@	4.25
Aluminum Sulfate, high-grade	Ton	65.00	@	70.00
Ammonium Carbonate, domestic	Lb.	10	@	10½
Ammonium Chloride, white	Lb.	18	@	18½
Aqua Ammonia, 26°, drums	Lb	5½	@	6
Arsenic, white	Lb.	14	@	15
Barium Chloride	Ton	90.00	@	92.00
Barium Nitrate	Lb.	11	@	11¾
Barytes, prime white, foreign	Ton	35.00	@	40.00
Bleaching Powder, 35 per cent	100 Lbs.	3.50	@	3.75
Blue Vitriol	Lb.	9¼	@	9½
Borax, crystals, in bags	Lb.	7½	@	8
Boric Acid, powdered crystals	Lb.	12½	@	12¾
Brimstone, crude, domestic	Long Ton	45.00		
Bromine, technical, bulk	Lb.	1.30	@	1.40
Calcium Chloride, lump, 70 to 75% fused	Ton	23.00	@	24.00
Caustic Soda, 76 per cent	Lb.	4.40	@	4.50
Chalk, light precipitated	Lb.	4½	@	4¾
China Clay, imported	Ton	18.00	@	30.00
Feldspar	Ton	8.00	@	15.00
Fuller's Earth, foreign, powdered	Ton	35.00		
Glauber's Salt, in bbls.	100 Lbs.	65	@	70
Green Vitriol, bulk	100 Lbs.	1.15	@	1.20
Hydrochloric Acid, commercial, 18°	Lb.	1½	@	1¾
Hydrochloric Acid, C. P., conc., 22°	Lb.	1¾	@	1⅞
Iodine, resublimed	Lb.	3.50	@	3.55
Lead Acetate, white crystals	Lb.	14	@	14½
Lead Nitrate	Lb.	15½	@	15¾
Litharge, American	Lb.	8½	@	9½
Lithium Carbonate	Lb.	1.02	@	1.05
Magnesium Carbonate, U. S. P.	Lb.	24	@	26
Magnesite, "Calcined"	Ton	67.50	@	70.00
Nitric Acid, 36°	Lb.	5½	@	5¾
Nitric Acid 42°	Lb.	6¼	@	6½
Phosphoric Acid, sp. gr. 1.750	Lb.	30	@	32
Phosphorus yellow	Lb.	80	@	90
Plaster of Paris	Bbl.	1.50	@	1.70
Potassium Bichromate, casks	Lb.	37	@	38
Potassium Bromide (granular)	100 Lbs.	1.00	@	1.05
Potassium Carbonate, calcined, 88 @ 92%	Lb.	45	@	75
Potassium Chlorate, crystals, spot	Lb.	61	@	62
Potassium Cyanide, bulk, 98–99 per cent	Mixture	1.50	@	1.60
Potassium Hydroxide, 88 @ 92%	Lb.	86	@	88
Potassium Iodide, bulk	Lb.	2.90		
Potassium Nitrate	Lb.	30	@	32
Potassium Permanganate. bulk	Lb.	3.80	@	4.00
Quicksilver, flask	75 lbs	115.00	@	120.00
Red Lead, American, dry	Lb.	10½	@	10¾
Salt Cake, glass makers'	Ton	18.00	@	20.00
Silver Nitrate	Oz.	45½		
Soapstone in bags	Ton	8.00	@	12.00
Soda Ash, 58%	100 Lbs.	3.10	@	3.15
Sodium Acetate	Lb.	9	@	9½
Sodium Bicarbonate, domestic	100 Lbs.	1.95	@	2.05
Sodium Bichromate	Lb.	16	@	16½
Sodium Chlorate	Lb.	24	@	25
Sodium Fluoride, commercial	Lb.	—	@	—
Sodium Hyposulfite	100 Lbs.	1.75	@	1.85
Sodium Nitrate, 95 per cent. spot	100 Lbs.	3.72½	@	3.75
Sodium Silicate, liquid. 40° Bé	100 Lbs.	1.05	@	1.25
Sodium Sulfide, 30%, crystals, in bbls.	Lb.	2⅛	@	2¼
Sodium Bisulfite, liquid, 32 s. g.	Lb.	.01¼	@	.01½
Strontium Nitrate	Lb.	28	@	30
Sulfur, flowers, sublimed	100 Lbs.	2.35	@	2.75
Sulfur, roll	100 Lbs.	2.20	@	2.25
Sulfuric Acid, chamber, 66° Bé	Ton	29.00	@	30.00
Sulfuric Acid, oleum (fuming)	Ton	38.00	@	40.00
Talc, American white	Ton	10.00	@	11.00
Terra Alba, American, No. 1	100 Lbs.	85	@	90
Tin Bichloride, 50°	100 Lbs.	13.50		
Tin Oxide	Lb.	56	@	58
White Lead, American, dry	Lb.	9¼	@	9½
Zinc Carbonate	Lb.	24	@	26
Zinc Chloride, commercial	Lb.	15	@	15¼
Zinc Oxide, American process XX	Lb.	12¼	@	12½
Zinc Sulfate	Lb.	6½	@	6⅝

ORGANIC CHEMICALS

Acetanilid, C. P., in bbls.	Lb.	45	@	50
Acetic Acid, 56 per cent, in bbls.	Lb.	7½	@	8
Acetic Acid, glacial, 99½%, in carboys	Lb.	24	@	26
Acetone, drums	Lb.	22	@	23
Alcohol, denatured, 180 proof	Gal.	66	@	67
Alcohol, grain, 188 proof	Gal.	2.78	@	2.80
Alcohol, wood, 95 per cent, refined	Gal.	1.05	@	1.07
Amyl Acetate	Gal.	3.50	@	4.00
Aniline Oil	Lb.	27½	@	28
Benzoic Acid, ex-toluol	Lb.	8.00	@	8.50
Benzol, 90 per cent	Gal.	59	@	60
Camphor, refined in bulk, bbls.	Lb.	90	@	90½
Carbolic Acid, U. S. P., crystals, drums	Lb.	43	@	45
Carbon Bisulfide	Lb.	5½	@	6¼
Carbon Tetrachloride, drums, 100 gals.	Lb.	15½	@	16
Chloroform	Lb.	60	@	61
Citric Acid, domestic, crystals	Lb.	72	@	75
Creosote, beechwood	Lb.	1.75	@	2.00
Cresol, U. S. P.	Gal.	1.25	@	1.30
Dextrine, corn (carloads, bags)	100 Lbs.	3.45	@	3.50
Dextrine, imported potato	Lb.	12¼	@	13
Ether, U. S. P., 1900	Lb.	15	@	20
Formaldehyde, 40 per cent	Lb.	13	@	13½
Glycerine, dynamite, drums included	Lb.	54½	@	55
Oxalic Acid, in casks	Lb.	45	@	46
Pyrogallic Acid, resublimed bulk	Lb.	3.25		
Salicylic Acid	Lb.	80	@	90
Starch, cassava	Lb.		—	
Starch, corn (carloads, bags) pearl	100 Lbs.	2.45	@	2.50
Starch, potato	Lb.	12½	@	12¾
Starch, rice	Lb.	8	@	8½
Flour, sago	Lb.	4¾	@	5
Starch, wheat	Lb.	5	@	6
Tannic Acid, commercial	Lb.	65	@	70
Tartaric Acid, crystals	Lb.	85	@	86

OILS, WAXES, ETC.

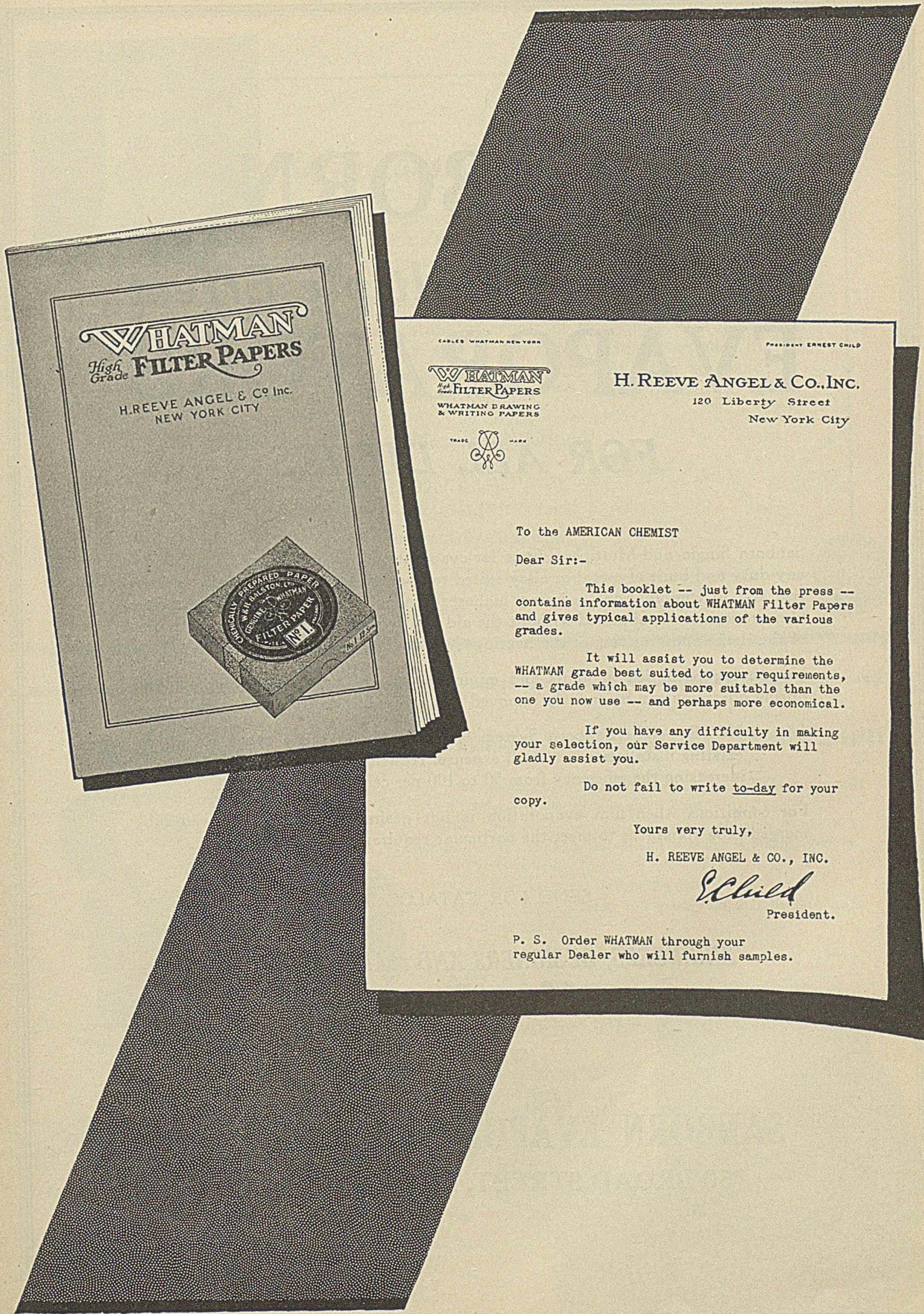
Beeswax, pure, white	Lb.	52	@	54
Black Mineral Oil, 29 gravity	Gal.	13½	@	14
Castor Oil, No. 3	Lb.	19¾	@	20
Ceresin, yellow	Lb.	14	@	18
Corn Oil, crude	100 Lbs.	12.25	@	12.50
Cottonseed Oil, crude, f. o. b. mill	Gal.	89	@	89½
Cottonseed Oil, p. s. y.	Lb.	13½	@	14
Menhaden Oil, crude (southern)	Gal.	nominal		
Neat's-foot Oil, 20°	Gal.	1.20	@	1.30
Paraffine, crude, 118 to 120 m. p.	Lb.	6½	@	6¾
Paraffine Oil, high viscosity	Gal.	29½	@	30
Rosin, "F" Grade, 280 lbs.	Bbl.	6.15	@	6.25
Rosin Oil, first run	Gal.	37		
Shellac, T. N.	Lb.	52	@	53
Spermaceti, cake	Lb.	24	@	25
Sperm Oil, bleached winter, 38°	Gal.	nominal		
Spindle Oil, No. 200	Gal.	24	@	25
Stearic Acid, double-pressed	Lb.	15½	@	16
Tallow, acidless	Gal.	1.04	@	1.05
Tar Oil, distilled	Gal.	30	@	32
Turpentine, spirits of	Gal.	52		

METALS

Aluminum, No. 1, ingots	Lb.	57	@	59
Antimony, ordinary	Lb.	32	@	33
Bismuth, N. Y.	Lb.	3.05	@	3.10
Copper, electrolytic	Lb.	36		
Copper, lake	Lb.	36		
Lead, N. Y.	100 Lbs.	9.75		
Nickel, electrolytic	Lb.	50	@	55
Platinum, refined, soft	Oz.	105.00		
Silver	Oz.	73		
Tin	Lb.	53½		
Tungsten (WO_3)	Per Unit	17.00	@	17.50
Zinc, N. Y.	100 Lbs.	10.00		

FERTILIZER MATERIALS

Ammonium Sulfate	100 Lbs.	5.25	@	5.50
Blood, dried f. o. b. Chicago	Unit	4.30		
Bone, 4 and 50, ground, raw	Ton	32.00	@	33.00
Calcium Cyanamid	Unit of Ammonia	3.25		
Calcium Nitrate, Norwegian	100 Lbs.	—		
Castor Meal	Unit	—		
Fish Scrap, domestic, dried, f. o. b. works	Unit	nominal		
Phosphate, acid, 16 per cent	Ton	11.50	@	11.75
Phosphate rock; f. o. b. mine:				
Florida land pebble, 68 per cent	Ton	2.00	@	2.10
Tennessee, 78–80 per cent	Ton	5.00	@	5.50
Potassium "muriate," basis 80 per cent	Ton	415.00	@	425.00
Pyrites, furnace size, imported	Unit	nominal		
Tankage, high-grade, f. o. b. Chicago	Unit	4.25	&	10



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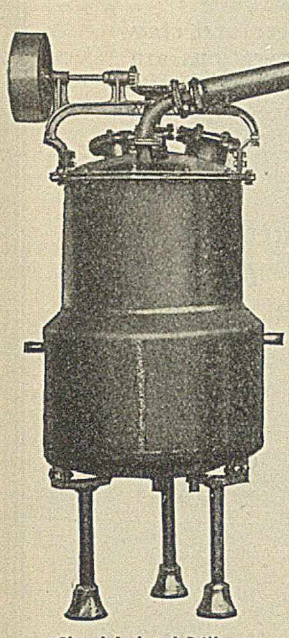

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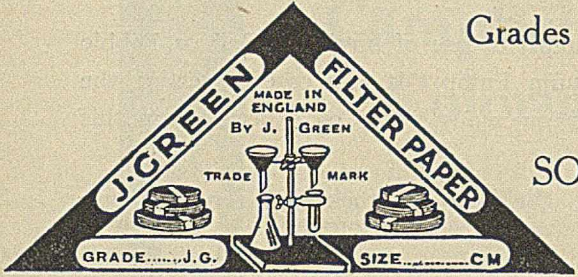

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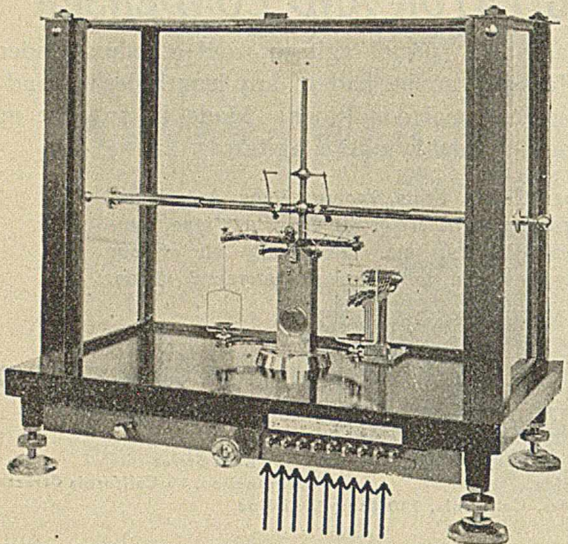

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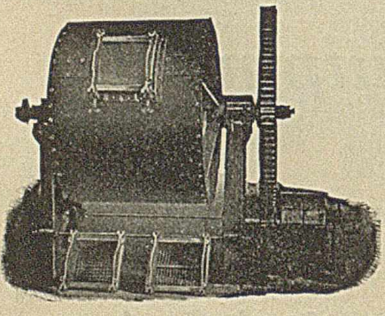

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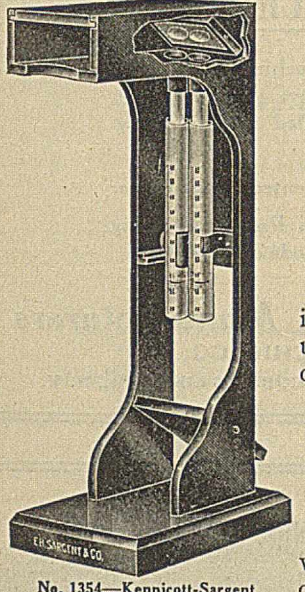

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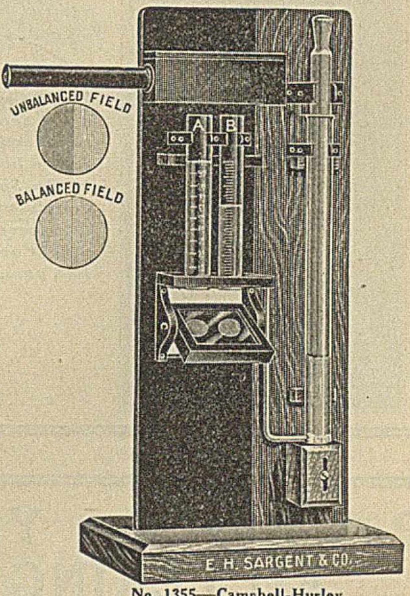

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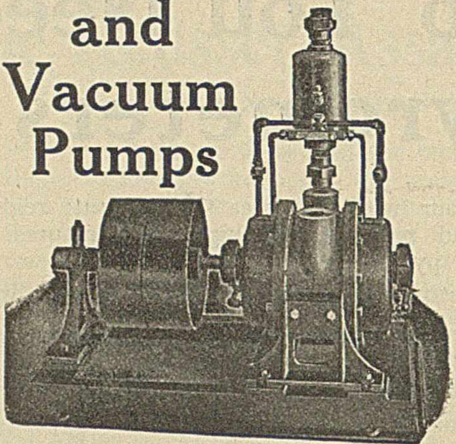

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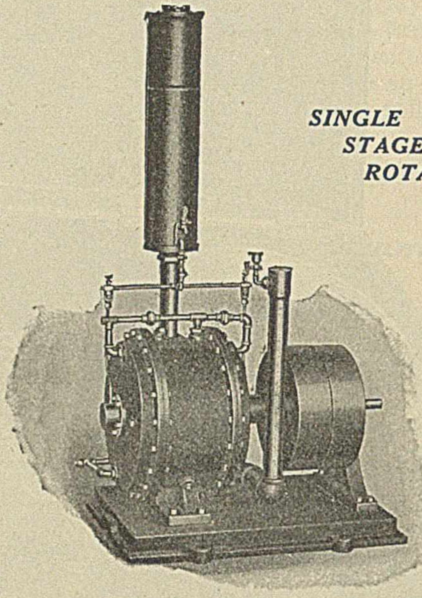

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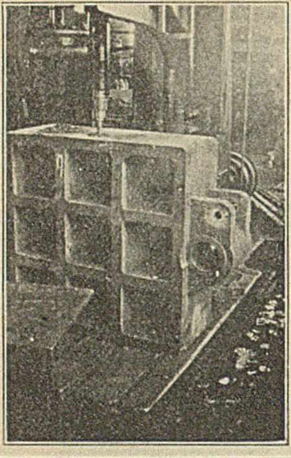

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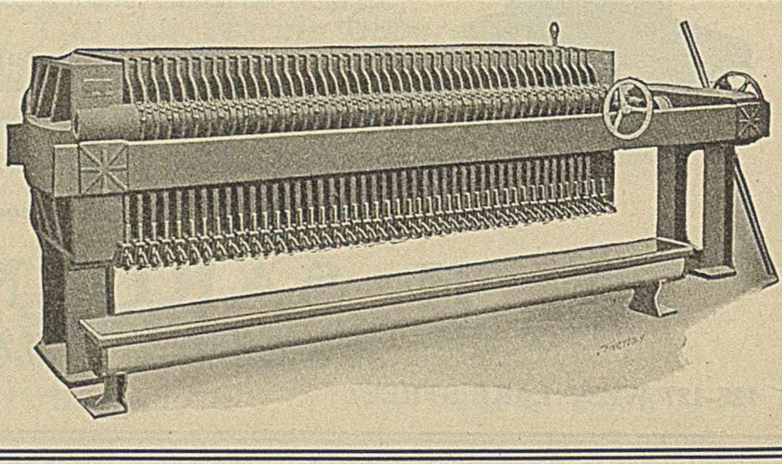

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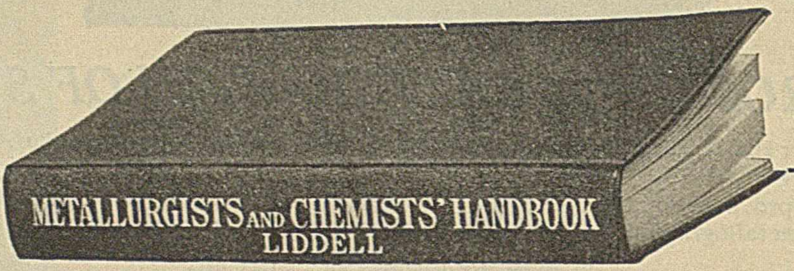

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