**For Release to Morning Papers of December 2, 1929**

# REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY AND SOILS,
*Washington, D. C., September 3, 1929.*

SIR: I have the honor to submit herewith the report of the work of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1929.

Respectfully,

HENRY G. KNIGHT,
*Chief of Bureau.*

Hon. ARTHUR M. HYDE,
*Secretary of Agriculture.*

## INTRODUCTION

The Bureau of Chemistry and Soils serves the producers and consumers of farm products and the manufacturers who convert these products into articles of commerce. Primarily a research and fact-finding organization, the bureau has as its objectives the gathering of information and the determination of scientific facts and principles through experimentation and research, to the end that these may be applied to the conservation of American soils and to crop-production and crop-utilization problems of national or regional importance.

The work of the bureau covers a wide range of subject matter pertaining to land utilization, soil fertility, fertilizer-resource development, and the utilization of agricultural products of various kinds. Within this organization are the soil survey, which is mapping soil areas and laying the foundation for the study of the Nation's soil resources; soil-erosion studies, which aim to aid in reducing losses from soil washing and in controlling flood water; soil-fertility studies, having for their purpose a better utilization of the soil; and finally the application of engineering and chemical technology to the study of fertilizer resources and the more economical and diversified utilization of the products of the soil.

The research work now in progress includes investigations in soil chemistry, soil physics, soil erosion, soil microbiology, soil fertility, nitrogen fixation, potash and phosphate resources, crop chemistry, fruit and vegetable chemistry, fermentation methods for the production of organic acids, the utilization of farm and industrial wastes, food microbiology, food deterioration and spoilage, dust explosions and farm fires, and improvements in the technic of producing sirups, sugars, vegetable oils, proteins, insecticides, fungicides, tanning materials, and a variety of other products.

For the purpose of administration three large units are recognized within the bureau: (1) Chemical and Technological Research, (2) Soil Investigations, and (3) Fertilizer Resources and Fixed Nitrogen Investigations. Each of the three units is under a chief scientist who not only directs the work of his unit but also serves as a member of an informal coordinating board within the bureau. By virtue of its broad field of activities and the coordinated effort within the bureau the organization is given the opportunity to attack problems along very broad lines.

The Bureau of Chemistry and Soils is actively prosecuting investigations and research upon 376 subprojects under 122 major lines of inquiry recog-

nized as projects. The major lines of inquiry to all intents and purposes are continuous or at least cover a period of years, while the subprojects, which represent the detailed activities of the bureau at any given period, have time limits placed upon them and when they are completed are succeeded by others usually in the same major line of inquiry.

In the main the appropriations are made to the bureau for the purpose of attacking specific problems, the solution of which is of interest to the business of agriculture and has therefore a utilitarian objective. However, direct attack upon some of these problems in the absence of essential fundamental knowledge is wasteful of funds and energy. Search for the necessary fundamental knowledge frequently leads the investigator into the realms of pure science, where a foundation is laid for the logical attack and final solution of the problem under consideration. Such a method of attack requires careful, thoughtful planning, the development of skilled technic, an intelligent and discriminating analysis of results, and ability of a high order to make the necessary practical applications.

The interest of the farmer should not terminate with the production of his crops, but he should be in a position to follow his products through to the ultimate consumer in order that he may intelligently adjust his production to the demands of the market. The Bureau of Chemistry and Soils, therefore, needs to function not only as a research agency to increase efficient unit production but should also be in position to follow the products of the farm through the industrial processes that make use of agricultural products.

The research activities of the bureau should result in a more economical utilization of farm products in the manufacture of articles of commerce and the production of more uniform final products, thus benefiting the farmer and the ultimate consumer. The widening of markets for farm products through the development of new channels for their industrial utilization is one of the most important functions of the bureau. This may be brought about only through painstaking research and the application of the results to the problems of industry. During recent years great strides have been made by the Nation as a whole through the development of new industries using as their raw materials the products of agriculture. The utilization of agricultural wastes and residues by industry is a subject which is receiving careful attention. The possibilities in this field appear to be very great. The wastes of to-day become important raw materials for the use of industry to-morrow. Numerous examples may be cited where waste has been converted into valuable commodities, but the greatest agricultural waste, the crop residues, consisting of stalks, straw, hulls, etc., are still awaiting wide industrial uses.

Something over one-half of the agricultural land area of the United States has been surveyed by the bureau. Land classification and effective land utilization upon sound principles await the completion of detailed and reconnaissance surveys of the remainder of the land area. Further, much of the soil-research work of the bureau is based upon the soil survey. There is an increasing interest on the part of the States in the whole subject of land classification, soil conservation, and soil fertility, which makes this field of work exceedingly important.

Results obtained in fertilizer and fixed-nitrogen investigations are being applied by industry as rapidly as conditions appear to warrant, thus reflecting direct benefit to agriculture in the form of cheaper and more satisfactory sources of plant-food materials. Advancement in this field depends largely upon the development of fundamental research and the application of the laws and principles thus discovered or verified to the technic of manufacture. Such researches are primarily functions of the Federal Government since they are directed to the development of a more efficient national agricultural program. At the present writing the nitrogen-fixation industry seems to be making satisfactory progress. The phosphate industry has been very well stabilized, based upon well-known practical methods, but new methods are being developed and put into use which will have a direct bearing upon the concentrated-fertilizer industry. Although the United States has rather large resources of potash, most of it is locked up in such form that it can not be made readily available. By an act of Congress at the last regular session funds were made available to the Bureau of Chemistry and Soils and to the Bureau of Mines for the purpose of making special investigations in an attempt to perfect commercial methods

for extracting potash from potash-bearing silicates, which are widely scattered over the country.

With the increased use of fertilizers in the agriculture of the United States, it is highly important that this country not only have sources of supplies of the raw materials, potash, phosphate, and nitrogen, but also that the most economic methods be developed for their preparation in satisfactory forms for use upon the land. Toward these objectives the fertilizer work of the bureau is steadily and effectively directed.

A total of 48 departmental publications from this bureau has been printed during the past year, including soil-survey reports, technical bulletins, farmers' bulletins, and circulars. In addition, 35 articles on the work of the bureau have appeared in the Yearbook of Agriculture, 1928. The number of soil surveys published during the year was more than double the number issued during the fiscal year 1928. This brings the published soil surveys much nearer current than has been the case for several years, but there is still need to bring the reports sufficiently up to date to meet the demand from all parts of the United States for prompter publication of the results of the soil surveys.

During the year 147 articles by scientific workers of the bureau have been published in technical and scientific journals, magazines, and other publications, giving other scientists and the public the latest information on the progress of various lines of work and research carried on by the three units of the bureau.

With the realization that its scientific work should be clearly reported to the public, by whom it is supported, the bureau in the past year has greatly increased its output of information to the press. Several hundred releases of timely interest have been prepared in the editorial office of the bureau and distributed through the press and radio services of the department to the special or regional groups to which they might prove of service.

## CHEMICAL AND TECHNOLOGICAL RESEARCH

C. A. Browne, *Chief*

### CARBOHYDRATE INVESTIGATIONS

#### CANE SIRUP

Experiments on methods of obtaining more profitable utilization of low-purity cane juice in sugar factories have been continued, with encouraging results.

These experiments proved that it is possible to make a sirup from a low-purity cane juice suitable to blend with corn sirup in the production of various grades of mixed sirups. By producing sirup instead of sugar from a low-purity last mill juice and preserving the juices of higher purity for sugar production it is possible that beneficial economies will result. Work in cooperation with a large sugar factory in Louisiana also proved that a good grade of sirup can be made by a process of combining the low-purity juices with one of the intermediate refinery products.

Substantial progress has been made in the investigation of "swells" in cans of sirup caused by a slow chemical reaction. Investigations indicate that the reaction between amino acids and reducing sugars, normal constituents of the juice, is partially responsible. The investigation is being continued to determine the other causes.

"Cane cream," a new product, developed by this bureau from sirup of low-purity juices, has been established on a production basis, and practically all technological problems of production and packaging have been solved. The work on cane sirup and cane cream is part of the general plan for the production of specialties which it is believed will benefit the Louisiana sugar and sirup industries and is directly in line with the bureau's program of developing commercial uses for agricultural by-products.

#### DIRECT-CONSUMPTION SUGARS

On the basis of information obtained, it is planned to conduct an investigation for the purpose of studying and improving juice clarification in connection with production of direct-consumption sugar and edible molasses, giving attention to the use of carbon in connection with the sulphur-lime process. It is possible that better grades of molasses may be produced without reducing sugar yield. This is part of the program for diversification of Louisiana sugarcane products and production of specialties particularly suited to the domestic cane-sugar industry of Louisiana and Florida.

Improvement in the quality of direct-consumption sugars is a matter which is now of very great interest to producers. Very small proportions of impurities derived from the juice have a

detrimental influence with regard to use in certain industries—for instance, in the candy industry. Many direct-consumption sugars give a poor candy test or undergo objectionable decomposition reactions when heated to a high temperature, as is necessary in certain industries. The nature of some of these impurities has been studied, as has also the distribution of organic colloidal material in the sugar crystal, and the nature of the salts present. As a possible means of improving the quality of direct-consumption sugars various proportions of different decolorizing carbons were used, and samples of the finished sugar were examined in the laboratory in comparison with refined sugars made by the customary process. An extensive examination revealed important effects of colloidal contaminants of sugar on foaming when sirups are prepared from the sugar. This was correlated with the surface-tension effect of the colloids in the sugar solution. Much information has been obtained which is valuable in indicating the most effective manner of using activated carbons and the proportions required.

### CANE SUGAR

Investigations on cane-sugar production are being continued. Particular attention is being given to difficult filtration of raw sugar and to the difficulties of refining with bone char. Results to date indicate that slow filtration is due chiefly to mechanical action of particles in the filter medium which are of somewhat greater than colloidal dimensions. These particles consist to a great extent of material which is originally in the juice and is not removed by clarification, and also material which flocculates as a result of concentration of the juice to sirup, and also during the cencentration of the sirup to massecuite. These different factors apparently vary in relative importance in different factories and in the same factory at different times. It has now been quite definitely established that these variations are due in part, at least, to variable factors as regards soil, fertilizer, and degree of maturity of the cane as they influence the clarification of the juice. The phenomenon in question is very similar to the variable occurrence of turbidity and separated flocculated material in cane sirup made on the farm in the Southern States. For instance, it is observed, in the case of cane sirup made from cane grown on soil which was heavily manured, that the sirup continued to deposit sediment for weeks after production. Even when the sirup was carefully strained and filtered after being drawn from the finishing pan, it became turbid and deposited flocculated material within a short time. On the other hand, sirup made from cane grown on light soils remains practically clear after being finished. Experiments are being made on selected lots of cane representing different cultural conditions, such as soil fertility, water supply, and drainage. A sugar company is cooperating by arranging factory runs of one to two days with lots of cane of selected types.

### BEET SUGAR

Some study has been made of diffusion from plant cells with respect to proper operation of a diffusion battery, as in producing beet diffusion juice. Plans have been drawn for the construction of an experimental beet diffusion battery to be located in the laboratories in Washington. With this equipment the influence of various factors on diffusion of beet cossettes will be studied with the idea of devising a possible method to "hold back" certain colloidal impurities. Such means, if successful, would undoubtedly be more effective than clarifying the juice subsequent to diffusion.

The perfection of a procedure of automatic pH control of second carbonation of beet diffusion juice was completed during the year. This procedure will probably be installed by one of the beet-sugar companies for use during the next season. It is anticipated that attention will also be given to adaptation of this procedure to third saturation of beet diffusion juice.

### MAPLE PRODUCTS

Suitably controlled maple sirup color standards are of great importance in the buying and selling of maple sirup. The standards in use in the industry during the last few years are based upon a caramel preparation prepared from granulated sugar as specified in Bulletin No. 134 of this bureau, Maple Sap Sirup; Its Manufacture, Composition, and Effect of Environment Thereon. We have been asked during recent years to prepare standards for distribution through the Extension Service. Investigation revealed that the colors obtained have varied by as much as one color grade (and in some cases more), according to the grade of refined granulated

sugar used. As a result of spectrophotometric study, color standards have been definitely fixed, thus making them reproducible and independent of the quality of refined sugar used. It was found that caramel prepared from different grades of refined sugar varied quantitatively but not qualitatively in color, thereby making it possible to use any caramel preparation made from refined cane sugar by diluting in the required proportions to give the various color standards.

State departments of agriculture, agricultural experiment stations, and extension services in the maple districts, particularly in Vermont, New York, New Hampshire, Maine, and Pennsylvania, cooperated with the bureau in the work of distributing master standards to the maple-sugar producers.

During the present year attention has been given to the diversification of maple products, particularly to the production of pure maple candies. For several years the production of maple candies in the maple districts has been increasing, but this development has been severely handicapped, owing to the poor keeping quality of the candy due to rapid drying out. During the present year formulæ were prepared whereby maple candies of a number of different types and of suitable keeping quality can be prepared by using a certain proportion of inverted maple sirup, made by inverting maple sirup with invertase. A mimeographed circular embodying this information was prepared and distributed through county agents.

### HONEY

In cooperation with the bee culture laboratory and honey producers and exporters, an investigation was made of the diastase content of honeys treated and processed in varying manner. The diastase content was also studied in relation to a number of chemical characteristics.

This subject is of great importance in connection with the requirements of certain European countries to which honey is exported from the United States.

### STARCH

A survey was practically completed on the utilization of cull sweetpotatoes, taking into consideration such factors as initial cost and operating cost of starch factories of varying size, distribution of sweetpotato production in the United States, variable transportation costs for raw material, and alternatives such as feeding cull potatoes to livestock.

Chemical and physical examination of sweetpotato starch produced at the Arlington farm plant was made and indicates that sweetpotato starch is on practically the same basis as white-potato starch with respect to general characteristics and methods of utilization. This conclusion, however, is by no means final, since much remains to be done in the study of dextrins and soluble starches produced from sweetpotato starch. A survey was made relative to the probable trend of use of domestic-potato starch in this country in competition with modified cornstarches and in competition with imported potato starch. Cooperation was established with a number of manufacturers of dextrins and modified starches for the purpose of obtaining suitable industrial tests. In cooperation with the first sweetpotato starch factory to be established in the United States much pertinent information was gained regarding the possible utilization of sweetpotato culls. A bureau representative was present during most of the period of operation and assisted the operating company by installing a system of chemical control and with suggestions as to procedure of operation.

### MISCELLANEOUS INVESTIGATIONS

It is anticipated that some of the results of the colloid investigations relating to sorgo sirup, which were suspended this year because of reduced personnel, may be utilized in improving the clarification of sorgo juices, producing sirup of improved and more uniform quality. It is planned to continue this work actively during the next fiscal year. Although no work has been done during the present fiscal year on corn sirup and corn sugar, some of the results of the colloid investigation which is being conducted in connection with the clarification of cane juice can in all probability be applied to this subject to furnish clues to be used in improving the clarification of starch conversion liquors.

### DUST EXPLOSION INVESTIGATIONS

Marked progress has been made in the reduction of the losses of life and property resulting from dust explosions in grain-handling operations.

Only 2 lives were lost, 29 persons injured, and property damaged to the extent of $888,000 in the 30 industrial-plant dust explosions investigated by our engineers since July 1, 1928. Studies of the causes of dust explosions in different types of industrial plants and methods for their control and prevention were largely responsible for the continued reduction in these losses during this year. Our work indicates very definitely that practically all types of combustible dusts are explosive when mixed in proper proportions with air and that nearly 30,000 industrial plants in the United States are liable to this risk. More than a million and a quarter people are employed in these plants, which manufacture products having an annual value of $10,000,000,000. As the only Government agency engaged in work for the prevention of industrial-plant dust explosions, the Bureau of Chemistry and Soils has received increasing calls for help as the leader in this undertaking in the United States.

### INERT GAS

A great increase in the use of inert gas for fire and explosion protection has followed the publication of Technical Bulletin No. 74, entitled "The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment," which describes the investigations made at Arlington farm that clearly demonstrated the value of inert gas for such purposes.

In addition to the previously reported inert-gas installations made at two hard-rubber grinding plants, a cork grinding mill, a Pyrethrum-flower grinding plant, and a number of sulphur grinding mills have adopted this method of preventing explosions and a feed-grinding plant, in the Middle West, is now installing one of the largest inert-gas systems in the country. The use of inert gas to provide protection in one of the large starch plants is being considered, and experiments are under way to develop methods of properly cleaning and conditioning the gas for such use. Fire extinguishers filled with inert gas under pressure, instead of chemicals, are now being produced and are finding a ready market.

Methods of cleaning and conditioning flue gas to render it satisfactory for use as a preventive of dust explosion and fires are now being developed at Arlington farm. Two types of washers employing wooden grids, limestone, and water sprays have already been tested. Experiments with silica gel and aluminum gel to develop a method of removing moisture and objectionable fumes are also being made. Preliminary plans have been made to carry on experimental work to determine the value of inert gas for fire protection in cotton gins. The introduction of electrical power has eliminated the possibility of using steam, which was formerly employed to extinguish fires in the lint flues. A reduction in insurance rate for an installation where steam was used for this purpose has been granted. It is hoped that inert gas can be used where steam is no longer available and a similar or larger reduction in insurance obtained. Data on fire losses in the various States have been obtained and conference held with manufacturers of inert-gas fire-protection equipment. Conferences with cotton ginners and insurance company representatives have been planned.

### LABORATORY RESEARCH

The work of the dust-explosion laboratory can be divided into two main divisions, research and service testing. Considerable attention was devoted to the development of apparatus for the determination of the relative degree of explosibility of various dusts.

The chief difficulty encountered in the development of dust-explosion testing apparatus has been the inability to obtain a uniform dust cloud in the bomb of the apparatus. A new type of dust-explosion apparatus has been designed which, it is believed, will overcome this difficulty to a great extent. Considerable time has been spent in making the design as simple and foolproof as possible.

Work is being done, using the new laboratory apparatus, to obtain fundamental data relating to dust explosions. These data will include information on such subjects as the following: The amount of dust actually burned; the amount of oxygen consumed with various concentrations of dust; time-pressure curves which show, in addition to the maximum pressure developed, the time required to reach maximum pressure with different dust concentrations; and possibly the rate of flame propagation in the bomb. To the best of our knowledge there is very little information in the literature covering any of the numerous relationships which may be deducted from such data. This work is being done with aluminum dust, because the product of combustion is a solid oxide. The partial-vacuum reading obtained after burn-

ing the aluminum is used to determine the amount of dust burned and the amount of oxygen consumed.

A number of tests were made to determine the oxygen dilution necessary to prevent explosion or propagation of flame in a dust cloud.

Tests to determine the lower explosive limit of ethylene oxide in an atmosphere containing ethylene oxide, air, and 10 per cent carbon dioxide were made. In preliminary tests it was found that the lower explosive limit of ethylene oxide in air is 3 per cent, which checks with the value obtained by another investigator; and the ignition of air-ethylene oxide mixtures where the ethylene oxide content is 3.2 per cent, or just 0.2 per cent above its lower explosive limit, produces very high pressure. Final tests showed that the use of 10 per cent carbon dioxide does not lessen the explosion hazard of ethylene oxide air mixtures, nor does it raise the lower explosive limit of ethylene oxide an appreciable amount. Care should be exercised in using ethylene oxide as a fumigant, even though the thoroughly mixed ethylene oxide-air mixture is nonexplosive, for explosive mixtures will exist in some parts of the room for certain periods until the gases are uniformily mixed.

### INDUSTRIAL-PLANT STUDIES

Whenever any unusual operating conditions or dust-explosion hazards have come to the attention of the bureau an effort has been made to investigate and suggest to the management, or develop, methods of overcoming the hazards. A visit was made during the past year to a grain elevator in Baltimore where an oil switch had exploded. Recommendations were made and adopted by the company. A visit to a wood flour plant where several dust ignitions had occurred resulted in the adoption of a fine water spray within the grinders and the frequent wetting down of the room in order to provide relief against the explosion hazard. Visits have been made to mills and grain elevators to observe new grain-handling equipment and dust-collecting apparatus in operation. A study was made of possible dust-explosion hazards in a large spice-grinding mill, and venting equipment was recommended at several points. Visits were made and assistance given to a number of other industrial plants during the year.

Addresses before conventions or meetings of trade associations are frequently used to announce or call attention to methods of dust-explosion prevention, in addition to departmental publications and contributions to technical or trade journals.

### DUST-EXPLOSION HAZARDS COMMITTEE

The bureau maintains close cooperation in dust-explosion-prevention work with the industries, insurance organizations, underwriting agencies, State commissions, and safety organizations. This makes possible very prompt application of the control and preventive methods developed by the bureau engineers. One of the most valuable contacts is that with the dust-explosion hazards committee of the National Fire Protection Association.

This committee under the leadership of the Chemical Engineering Division of the bureau is preparing safety regulations for the industries in which dust explosions have occurred. These regulations embody the results of the bureau's experimental work and become the basis of standards for State commissions, industrial companies, insurance associations, safety organizations, and other similar bodies. The committee has recently prepared regulations for dust-explosion control and prevention in the following lines of industry: Flour and feed mills; sugar and cocoa pulverizing systems; terminal grain elevators; pulverized-fuel installations; and starch factories. These regulations have been approved by the National Fire Protection Association and also adopted by the National Board of Fire Underwriters. They have been published by the United States Department of Labor as Bulletin No. 433, entitled "Safety Codes for the Prevention of Dust Explosions," in order to make them available for State labor departments, industrial boards, and similar State commissions intrusted with the protection of employees in manufacturing establishments.

### FARM FIRES

To decrease the huge loss from fires in rural America, which it is estimated take a toll of 3,500 lives and destroy $150,000,000 of property annually, the bureau has continued its study of the causes of fires and its investigation of methods of preventing farm fires. Research is progressing along engineering, chemical, bacteriological, and educational lines. Some results and findings of this work have been published during the year in

Farmers' Bulletin 1590, Fire-Protective Construction on the Farm and in Circular 76, Fires in Cotton Gins and How to Prevent Them. As the titles imply, these publications, which have been widely distributed, contain information on simple methods of constructing farm buildings whereby fire protection can be most readily and cheaply effected, outline the principal causes of farm fires and methods for their prevention, and deal with methods of preventing fires in cotton gins. The principal causes of farm fires which are emphasized are the following: Spontaneous ignition of hay, grain, feeds, and other agricultural products; lightning; defective chimneys and heating apparatus; sparks on combustible roofs; careless use of matches in smoking; careless handling and storage of gasoline and kerosene; and faulty wiring and improper use of electrical appliances.

### SPONTANEOUS IGNITION OF HAY

The spontaneous heating of wet hay stored in barns following the Vermont flood of 1927 was a striking demonstration of the importance of this factor in farm fires. The investigation of the causes and the chemical processes underlying the spontaneous ignition of hay and other agricultural products is intended to include as well the investigation of the heating of these products which does not of necessity lead to actual fires, but which nevertheless causes immense loss from deterioration and spoilage. Laboratory work on several phases of the subject of spontaneous heating has been carried on during the present year. As a requisite for the work on hay, an accurate method for the determination of its moisture content has been selected after careful experimental comparison of several methods.

Various theories which have been advanced to account for the self-ignition of hay are being investigated in the laboratory. One theory is that self-ignition of hay is due to "pyrophoric hay carbon" which resulted from an experiment by Ranke in which hay was heated to 250° to 300° C., carbonized, and shaken and poured out on a porous plate, following which it was observed to glow after a few minutes and finally to calcine. The theory advanced by Laupper contends that the ignition is due, not to pyrophoric carbon but to the pyrophoric iron present in it. Accordingly, "hay carbon" has been prepared and tested for pyrophoric property. That this exists has been confirmed, but whether it is due to the carbon or to other matter associated with the carbon, or to pyrophoric iron, remains to be determined. Further experiments are in progress looking to the solution of this problem.

Experiments have been started to determine the action and products, both bacteriological and chemical, of the heating of hay at comparatively low temperatures under anaerobic conditions. Tests will be made especially for unsaturated, unstable, and readily oxidized products.

### LARGE-SCALE EXPERIMENTAL WORK

Large-scale field experiments on the spontaneous ignition of hay are being conducted in a suitable structure 24 feet wide, 26 feet long, and 22 feet high to the ridge, erected on the Animal Husbandry Experiment Farm at Beltsville, Md. The spontaneous heating and ignition of hay is being studied here from the bacteriological, chemical, and engineering angles under conditions believed to be ideal and simulating as nearly as possible those on farms. The barn has a capacity of approximately 35 tons of hay. The initial research is being made on only 14 tons. An enlarged laboratory experiment is also being carried on in conjunction with the large-scale test, utilizing three-quarters of a ton of hay in a tightly constructed box. In both cases extensive temperature readings are being obtained by means of a large number of thermocouples, and samples of hay and gases are being collected from the hay under observation for analysis and examination. The results of the first experiments are not yet available. This work has been planned to cover a period of at least three years, and subsequently experiments will be conducted along expanded and modified lines suggested by the initial research.

A revolving, tubular hay sampler has been designed and constructed for use in these large-scale field experiments on the spontaneous ignition of hay.

Studies of the ignition and heating of hay and other agricultural products have included contacts with agricultural colleges engaged in similar investigations, and special investigations of serious farm fires where spontaneous combustion was regarded as the cause.

Studies are also being conducted on modern haying methods and machinery as affecting spontaneous ignition of hay.

### FARM FIRE PROTECTION COMMITTEE

Leadership of the farm fire protection committee of the National Fire Protection Association has devolved largely upon the Bureau of Chemistry and Soils in view of the fact that officials of this bureau have been appointed as chairman and secretary of the committee which is composed of 15 representatives of national organizations and 4 members from the United States Department of Agriculture. Two meetings were held during the year, one October 1, 1928, in Chicago, the other April 2, 1929, also in Chicago. Reports on rural fire departments and fire-protective construction on the farm contained, respectively, information on standards for rural fire-fighting apparatus and information on fire-department organization, personnel, duties, drills, etc.; instructions in bulletin form (Farmer's Bulletin 1590) as to fire-protective construction of homes, barns, and other buildings on the farm.

Representatives of this bureau are also taking an active part in the work of the agricultural committee of the National Fire Waste Council and of the farm fire-prevention and control committee of the American Society of Agricultural Engineers.

Six radio talks were delivered each to a potential audience of 400,000 listeners. Twelve articles were also published in the press and trade journals. A 7-panel, animated farm-fire booth was extensively shown at fairs, conventions, and meetings. Three addresses were made before gatherings of national prominence.

### EXHIBITS AND PUBLIC INFORMATION

Special booth exhibits were constructed to show the work on farm fires, naval stores, soil erosion, and leather and tanning materials, while other exhibits showed activities of the bureau in connection with food colors, making cellulose from peanut shells, gluconic acid and salts, dye intermediates, citrus products, rotenone as derived from Derris root, "Neo," a new nicotine spray, ethyl formin, methal chloroacetate, soil analysis, soil fertility, concentrated fertilizers, gas laws at high pressures, work of the division of physics, a stirring machine for phosphoric acid, and a shaking machine for phosphoric-acid determinations.

The bureau participated in exhibitions at the Association of Official Agricultural Chemists convention in Washington, the International Live Stock Show, and the American Farm Bureau Federation Meeting, at Chicago, the Inaugural exhibit in Washington, the Pacific Southwest Exposition, in Long Beach, Calif., the Chemical Industries Exposition, New York City, and the National Fire Protection Association meeting in Memphis, Tenn.

### COLOR AND FARM WASTE

The most successful contribution of the Color and Farm Waste Division to the chemical industry was the invention of the process for the production of phthalic anhydride by the catalytic oxidation of naphthalene. This process has been of inestimable value, both to the vat dye and to the lacquer industries. The 1927 dye census tells us that the phthalic anhydride output by American factories in 1927 was the highest on record, 4,549,825 pounds. The unit sales value of this product was 17 cents a pound as against an invoice value of 24 cents a pound in 1914 when our entire consumption was imported from Germany. With the working out of this process, the bureau established itself as one of the leaders in the field of catalytic oxidations and subsequently worked on the production of anthraquinone from anthracene in a similar manner. This process is also of great importance, although priority in the patent field has been granted to a German inventor.

### DYE INTERMEDIATES

A logical outgrowth of the bureau's work on phthalic anhydride is the investigation of the Friedel-Craft synthesis. The outstanding industrial example of the Friedel-Craft synthesis is the process for anthraquinone, by which this most important dye intermediate is manufactured from benzene and phthalic anhydride. instead of from anthracene. Similar processes may be developed, using other components in the place of benzene, by which the field of dye intermediates, with particular emphasis on vat dye intermediates, may be greatly enriched. For these reasons this particular project will be of great value to the dye industry.

During the past year our work on the synthesis of 2-aminoanthraquinone

from phthalic anhydride and chlorobenzene has been reported. It appears that several large dye industries are interested in this process, as it offers a more economic means of preparation than the older method of preparing anthraquinone, sulphonating, and separating the monosulphonic acid and then aminating.

Exhaustive experiments have been carried out on the preparation of naphthoyl-benzoic acid and naphthanthraquinone. A great part of the value of this process lies in the fact that naphthalene, as a raw material for dyes, is plentiful and cheap, whereas benzene and its homologs are likely to become more expensive with the development of their use in motor fuels.

Recently diphenyl has come on the market in large quantities and in a fairly pure state. It appears to offer an attractive raw material to build up a new series of vat dye intermediates and presents a field which is for all practical purposes a new one.

### BIOLOGICAL APPLICATION OF DYES

The question of the biological application of dyes is inextricably bound up with the problem of national health. Dyes are used internally and externally in the treatment of diseases, any they are used very widely in the diagnosis of pathological conditions. These applications are increasing all the time and it seems reasonable to predict that they will continue to grow in the future as rapidly as they have in the past. As an example, this bureau was recently consulted by representatives of a university in connection with the development of a differential stain for the cancer cell. Stains are now used in the diagnosis of cancer, but a highly developed technic and knowledge of the subject is required. If a stain could be developed which would stain not only the recognized but the incipient cancer growth in a way which would make it stand out from the healthier cells in its neighborhood, a distinct advance could be made in the treatment of this disease. The bureau has been asked to furnish, by synthesis or otherwise, the dyes which may be indicated as experiments progress.

### MISCELLANEOUS INVESTIGATIONS

The routine examination of stains has required a large amount of work during the past year owing to extensive collaboration with Army authorities as well as with the stain commission. Fully 35 per cent of the time of two workers has been devoted to this routine, and about 200 samples of stains have been reported on either verbally or in writing. This work has included the chemical part of the standardization of stains for the commission on standardization of biological stains, also extensive work in connection with the setting of stain standards for the Government purchase of these materials.

In the syntheses of biological stains and dyes of antiseptic or therapeutic value, the main problem to which this division has devoted itself during the past year has been a study of the different fuchsins and their homologs. It has been noted in the past that dyes of this class produced by different manufacturers under the same name have differed widely in their staining properties. Investigation of this phenomenon has shown us that while these dyes are supposed to be the same material they do in fact differ very widely. This division has synthesized a number of basic and acid fuchsins and is now studying them with a view to correlating their chemical and spectrophotometric characteristics. Later on these materials will be studied elsewhere from a staining standpoint.

In testing the fungicidal properties of dyes the inhibitory effect of about 25 representative dyes upon *Penicillium luteum-purpurogenum* has been investigated with interesting results.

### FARM-WASTE INVESTIGATIONS

Investigations as to the utilization of several kinds of farm waste have been conducted during the year. Lignin is one of the three great components of agricultural wastes. Thirty per cent of the dry material of all vegetation is lignin, and the annual production of this material has been estimated as being 40,000,000 tons. Most of this is at the present time wasted. A great proportion is lost in the waste liquor from the paper mills, and more is discarded on the farm in cornstalks, corncobs, straw, etc.

Lignin has been the subject of investigation for many years, and its exact composition is one of the great chemical enigmas. The industrial usefulness of a chemical compound in these days depends on a knowledge of its constitution, for with the development of modern methods of research, the day of empirical chemical manu-

facture is almost past. The project on lignin was originally formulated for the purpose of finding out the chemical structure of this material. With this in view the work on destructive distillation of lignin has been carried on by this bureau. When lignin was distilled destructively under reduced pressure, four products resulted. On the basis of lignin used, the yields of these products were as follows: Oily distillate, 30.5 per cent; aqueous distillate, 12 per cent; carbon residue, 43.5 per cent; and gas, 14 per cent.

The aqueous distillate contained 0.6 per cent of methyl alcohol, 1 per cent of acetone, and 0.4 per cent of acetic acid. Over 80 per cent of the oil was of phenolic character and eugenol and guaiacol were identified in this. This high yield of aromatic compounds obtained from lignin is believed to be significant from the standpoint of the structure of lignin, as it gives weight to the hypothesis that lignin is cyclic in structure.

The potential value of this phase of the lignin work is very great. Eugenol is the essential constituent of oil of cloves. In the latter form it is quite largely used pharmacologically, and the basic constituent itself is used in the manufacture of vanillin. Guaiacol is also used in pharmacological work. If we take into consideration the amount of lignin that goes to waste in the paper industry and elsewhere, it will be seen that the development of this process offers a potential cheap source of eugenol and guaiacol.

Study of the rôle of lignin in animal nutrition by experiments on dogs and cows and by investigations carried out in vitro with the juices from a cow's stomach and intestines, proves that the animal body is capable of breaking down lignin. In its passage through the system lignin suffers a loss of 30 per cent of its original methoxyl content. This breaking down takes place in the stomach of the animal and is apparently brought about by an enzyme.

In the study of the humification of lignin, analyses indicate that the effect of the action of ordinary soil organisms on cornstalks, oat hulls, corncobs, and wheat straw is to cause considerable decomposition of lignin along with the greater decomposition of the pentosan and cellulose. It has generally been assumed that lignin is not attacked by soil organisms, or at least only to a limited extent. The results obtained will throw new light on the general problem of the organic matter in the soil. There is some question as to whether or not the lignin from different vegetable sources is of the same composition. A study was made of lignin from oat hulls, by the same methods as those previously applied to lignin from corncobs, and the results obtained are quite similar to those obtained on the latter product.

### CATALYTIC OXIDATIONS

During investigation of the catalytic vapor-phase oxidation of p-cymene, tests have been made of a number of catalyst carriers, such as unglazed porcelain, asbestos, pumice, and silica gel. Several different types of apparatus have been built and tried out for the purpose of obtaining optimum rate of flow, time of contact, and condensing conditions. Most of the studies have been made using vanadium pentoxide as the catalyst, but a number of mixtures have also been tried. Both air and pure oxygen have been tried as oxidizing mediums. The reaction between p-cymene and oxygen takes place quite readily at a temperature of about 400° C. A number of products are formed. Those so far identified are as follows: Paratoluic acid, tere-phthalic acid, formaldehyde, formic acid, water, and carbon dioxide. Considerable p-cymene is recovered unoxidized.

Although p-cymene is produced in this country at the rate of about 10,000,000 pounds annually, little use for it has been found, despite the fact that a number of investigations on the subject have been carried on in this bureau and elsewhere. Some of the outlets suggested for p-cymene will be of value when the industry has been persuaded to recover and purify it in such amounts as will bring about the lowering of the price. If the catalytic oxidation is successful in producing organic materials of value to industry, an important step will have been taken along this line.

### INDUSTRIAL FERMENTATIONS

A marked feature in the progress of chemical industry in this country and elsewhere during the last 10 years has been the employment of microorganisms to perform large-scale chemical transformations. In many cases these organisms will carry through complete reactions in a way that is cheaper and simpler than the ordinary chemical process, and it has been felt that the application of this idea offered special promise in the utilization of agricultural products and wastes.

The study of industrial fermentations was begun in 1926. Following a preliminary survey of the action of nearly 200 molds on solutions of glucose, one organism was selected because of its ability to produce large quantities of gluconic acid, and intensive study has been given to this problem, both on a laboratory and semiplant scale. The past year has for the most part been devoted to a study of processes for mold fermentations, conducted on a semiplant scale, with particular reference to the production of gluconic acid by the action of fungi on corn sugar. Since no statements have been found in the literature regarding the commercial development of laboratory processes for the production of organic acid by mold fermentations most of this work has been of a pioneering nature.

During the past year 65 pounds of calcium gluconate has been sold at $2 per pound to various research centers interested in its physical, chemical, and physiological properties. Preliminary reports from some of these investigations indicate that calcium gluconate may find a wide and valuable use as a remedial agent in pathological conditions induced by calcium deficiency.

Preliminary experiments have indicated that high-production hens laying thin-shelled eggs may be helped in the production of thick-shelled eggs by the addition of small quantities of calcium gluconate to their feed. It is hoped that these investigations will be extended to high-production dairy cows which often suffer a severe strain on their calcium reserve due to the large amount of milk produced. While calcium salts of other organic acids apparently have little effect in maintaining a high calcium level in these cattle, calcium gluconate might prove highly beneficial. It is impossible at the present time to estimate in dollars the value of the industrial fermentation investigation. One firm has, however, taken up the process and is engaged in working it out on a small-plant scale. Another concern is giving it serious consideration and has requested and received a culture of our mold. Furthermore, the process and the possibilities of utilization of gluconic acid and its salts have been the subject of numerous written inquiries and personal interviews from those interested.

In taking up the study of the utilization of molds, the bureau has established itself in a field which is receiving much attention both here and abroad and which will probably in the future prove increasingly important to the chemical industry.

### CROP CHEMISTRY LABORATORY

The crop chemistry laboratory has continued scientific study of the factors which affect the quality of crops grown in the United States with the purpose of obtaining information on the interrelation of these factors, so as to make possible such modification of existing agricultural practice as will improve the quality of our food supply.

In the field study of increasing the protein content of wheat at the Arlington Experiment Farm, sodium nitrate has been the fertilizer chiefly used heretofore, but as other nitrogen compounds such as ammonium sulphate, calcium nitrate, urea, etc., are now coming into wide use, it seemed important to compare the results, which might be obtained with these, with those obtained previously. A series of plots for this purpose has been laid out and the fertilizers applied.

Work on increasing the phosphorus content of wheat has not yet reached the stage where plots can be laid out, but during the year further experiments were made on the absorption of phosphorus by wheat seedlings in culture solutions, and some analyses were made of crops grown during previous years as to phosphorus content.

In view of the interest shown in manganese as a constituent of foods, work on this element was continued. Improvements were made in the official method for determining manganese, and analyses made of a large number of samples of cereals and their products. Wheat seedlings were also grown in culture solutions containing manganese in various forms, and the principles of absorption of this element were worked out.

The study of the absorption of food constituents by young plants, which has been under way for several years, was continued, further observations being made on the effect of varying the conditions on the absorption of potassium and phosphorus by wheat seedlings.

## FOOD-RESEARCH INVESTIGATIONS

### FRUIT AND VEGETABLE CHEMISTRY

Important work has been accomplished during the past year on the effect of ethylene on the composition and physical condition of Bartlett pears to be used for canning and drying. The results obtained with

canning pears were so promising as to warrant an extension of this work during the coming season. An advantage to the canning industry in the application of ethylene to pears, and possibly other products, is to reduce the necessary storage period for the ripening and also to reduce considerably the labor cost which is incurred in the frequent sorting and handling of pears under present conditions. If further tests indicate the practicability of this method of handling pears it appears probable that the method will be rather generally adopted, especially by the larger commercial canners of pears. This method also promises beneficial results in connection with the canning of apricots and peaches, upon which work will be undertaken during the 1929 packing season.

Investigations of methods of sulphuring apricots, peaches, and pears have been actively continued during the present year. Two field laboratories are located at central points so that both the apricot and peach sulphuring could be studied in the producing sections of California.

In the fruit and vegetable by-products studies at Los Angeles, the laboratory work on the composition of California citrus oils was completed. In the same by-product field, a beginning was made of the study of the manufacture of pectin from grapefruit waste and also on the manufacture, utilization, and composition of grapefruit oil. The inheritance of composition through vegetative propagation has been studied in the case of Eureka and Lisbon lemons. Investigation has also been made on the effect of freezing on citrus fruits.

### FOOD SPOILAGE AND DETERIORATION

The commercial production of mayonnaise has reached the point where it is regarded as one of our major food-manufacturing industries. In the marketing of this product certain difficulties are encountered, such as the actual bacterial spoilage of the product, the development of rancidity, and the breaking down of the emulsion. These conditions render the product unfit for sales distribution.

Before undertaking a study of the spoilage of mayonnaise, it was necessary to develop a standard formula and standard methods for determining the quality. The standard methods adopted were as follows: A physical method for the determination of consistency, a physical method for the measurement of color, a chemical method for the determination of acidity, and a microscopic method for determining the character of the emulsion. The flavor was determined organoleptically.

In the substitution of acids for vinegar in the mayonnaise samples, pure acetic acid was found unsuitable because of a marked acid odor and an absence of sufficient preservative properties; lemon juice produced a product of good quality and of good stability, though no lemon flavor was noticeable. Lactic acid made a product of high quality. After three months' storage these samples were better in consistency and character of emulsion and showed less development of rancidity than did the samples made up with vinegar or other acids.

During the present year a new and peculiar type of molding of shell eggs in cold storage has been studied. The mold organisms were isolated and identified as species of Cladisporium and Penicillium. Preliminary indications point to the possibility of an initial oil treatment of the eggs as a possible method of combating this type of storage spoilage.

During the past year one of the large can-making companies announced the development of a new process for canning vegetables whereby the use of brine or water was eliminated. This process required the closure of the cans under a high vacuum before the processing operation was carried out. A number of tests have been made on a modification of this method whereby the high vacuum in the closed can is obtained by exhausting with steam. The flavors of vegetables canned by this method are markedly improved over those of the ordinary canned products—in fact, are closely comparable with the flavors of the freshly cooked materials. A number of different vegetables can be effectively canned by this method.

### MILLING AND BAKING

In the investigation on cake making different grades of flour made from different classes of wheat were used, both alone and with the addition of 20 to 25 per cent of other substances—for instance, white-corn flour, gelatinized-corn flour, various starches, soybean flour, and potato flour. Very successful results were obtained, especially with the use of corn flour and

cornstarch. A mixture of wheat and soybean flours likewise made cakes of very good quality, which on further study may prove of special interest to the trade. The importance of cake investigation is evident when it is realized that over 50,000,000 barrels of flour are used in making cake, the value of which product is over $1,000,000,000 yearly.

The use of flour made from germinated wheat, other cereals, legumes, etc., is giving interesting results. Most of the evidence seems to point to the fact that the use of a small amount of flour made from slightly germinated grain or seed mixed with ordinary flour improves the baking value of that flour. The volume of the loaf is larger, and the texture, and in some cases even the color, is improved.

### PHYTOCHEMICAL INVESTIGATIONS

From the investigations of this division it appears that susceptibility to surface scald in apples held in storage is correlated with the percentage of "oily fraction" in the total ether extract of the waxlike surface coating. The higher the percentage of this fraction the less permeable to gases is the natural coating of the apple. When this percentage is high a condition of abnormal respiration is brought about through the accumulation of carbon dioxide within the fruit, and this accumulation is directly responsible for the formation of acetaldehyde. This volatile product is considered the direct cause of skin browning, which is characteristic of scald. Differences between the respiratory activity of the sunny and green sides of the same fruit as well as between that of a fully colored and of an immature apple probably account for the fact that scald is more prevalent on the less-colored portions and on an immature fruit. Ventilation is believed to retard the accumulation of carbon dioxide within the tissues, which might otherwise occur as a result of the physical nature of the waxy coating. The use of oil wrappers for the control of scald has no effect in preventing a condition of abnormal respiration, but it may be that the mineral oil in the oil wrappers absorbs the toxic acetaldehyde formed under these conditions. During the year an exhaustive study has been made of ursolic acid, which is one of the three major constituents of so-called apple wax. As a result of this work it is possible to state more definitely than heretofore, the chemical identity of this substance.

### CHEMISTRY OF PLANT PRODUCTS

The results of previous investigators were confirmed as to the presence of formic, acetic, aconitic, malic, and lactic acids in sugarcane molasses. In addition to these, citric acid, not previously reported as a constituent of cane molasses, was identified.

Cane molasses "slop" was found to contain formic, acetic, succinic, tricarballylic, and lactic acids in considerable amounts with a very small amount of aconitic acid and a possible trace of citric acid.

Knowledge of the unstable acids resulting from the action of lime on glucose has been furthered. Winter's so-called glucic acid has been prepared and its properties studied. There is very strong evidence that it is the half aldehyde of malonic acid, described by Pinner as acrolactic acid. The great rise in temperature when its calcium salt is exposed to air simulates the phenomenon of "spontaneous combustion," and it becomes a pertinent question whether such an unsaturated compound as this may not play a part in the "heating" of agricultural products, especially of hay.

## INDUSTRIAL FARM PRODUCTS

### HIDES AND SKINS

As a part of the department's broad program of research on the conservation of hides and skins, field work with butchers, dealers, and tanners has been actively continued on the elimination of poor practices in skinning and curing, which cause a waste of essential raw materials estimated to be at least $20,000,000 a year. Two hide specialists, one in Pennsylvania and the other in Virginia, North Carolina, and Tennessee, have been continuously at work among producers and handlers of hides and skins, pointing out to them poor practices and correcting such practices whenever possible by demonstrations and advice. Many glaring examples of poor technic are being found, and many of the producers fail to understand just what such poor practices on hides and skins mean in terms of the quantity, quality, and appearance of the leather made from them. Educational work is being done to bring about a fuller realization of the consequences of such defects.

The best results from this work on hides and skins can only be realized

after standard grades have been set up and accepted as an essential part of trade practice. To establish standard classification and grading and to improve marketing conditions this division has cooperated closely with the Bureau of Agricultural Economics in assisting it to prepare tentative schedules for grades and classes of hides and skins and in other phases of its work. In this connection considerable time has been spent in the field interviewing hide dealers on the subjects of selective trading and improvement in the grades of hides and skins.

### SALT STAINS

Bacteriological researches have been started with particular reference to the origin and prevention of salt stains on hides and skins, a serious damage of long-recognized standing. The origin of salt stains is still a debatable matter, though they are believed to be the result, in part or entirely, of bacteriological action. Consequently bacterial studies are now being centered on salted hides and skins and on used and unused salts to isolate as many cultures as possible of halophilic or salt-tolerant organisms, and particularly those that are chromogenic or color producers. Several such organisms have been isolated, and the work is being continued.

### TANNING MATERIALS

Depletion of our forests by man and diseases, including particularly the blight of the American chestnut tree, is steadily bringing about a greater and greater shortage of domestic tanning materials. Looking to the future when the supply of vegetable tanning materials may become an acute matter unless provision is made in the meantime, special efforts are being put forth to secure or develop new sources of tannin. In cooperation with the Office of Forest Pathology, Bureau of Plant Industry, woods and barks from foreign sources are being examined for their tannin content. Of those so far examined, only the *Castanea crenata* has shown any considerable tannin content. The wood of this tree has, on the moisture-free basis, from 12 to 15 per cent tannin, and the bark 14.6 per cent tannin.

Also in cooperation with the Office of Forest Pathology data are being obtained on the vertical distribution of tannin in Chinese chestnut trees and roots grown at the experiment orchards at Bell, Md. These data will afford a means of comparing the tannin content of Chinese chestnut trees grown indigenously and in this country and can also be used in arriving at the tannin yield of an entire tree from a tannin analysis of only one part, such as the top branches.

### FERROCHROME TANNING

Public service patent applications have been prepared and filed in the United States Patent Office on ferrochrome as a tanning material, following laboratory experiments, which have indicated some interesting possibilities of a joint chrome-iron tannage by the use of certain ferrochrome solutions. Large-scale tanning experiments have been arranged but not yet carried out.

### LEATHER

Realizing the ultimate costliness and extravagances of the rapid deterioration of leather bindings, resulting primarily from the use of leathers of improper tannage, the bureau has collaborated with the United States Government Printing Office in examining chemically and physically for that office all of the leathers used in its public binding work. During the past year 40 leathers of both regular and special tannages have been examined, most of which were found not to be satisfactory for long-service bindings.

As a part of investigational work in securing composition data on available leathers and in drawing specifications for leathers, the bureau has collaborated with the Government Printing Office in a chemical and physical study of a special collection of English bookbinding leathers. The results of this study, with a discussion of their significance, have been published for the information of tanners and users of bookbinding leathers. All of the leathers of this special collection that were claimed to be acid free and pyrogallol tanned were found to be so and thus to comply with two of the essential requirements for durable bookbinding leather.

### DETERIORATION OF BOOKBINDING AND OTHER LEATHERS

Recently the Library of Congress brought to the attention of the bureau the fact that many thousands of its leather bookbindings were in an advanced stage of rotting. On the basis of data acquired over many years of

experimentation and research on the deterioration of leather, the bureau prepared and recommended several leather dressings, which if applied periodically would help to arrest further decay of old leather bindings and if applied before material decay has set in, would add years to the life of the bindings and thus save the Library of Congress many thousands of dollars in rebinding. These dressings are now being supplied to the library and systematically applied to its leather bindings.

### VEGETABLE AND CHROME-RETANNED SOLE LEATHERS

Because of an ever-increasing shortage of vegetable tanning materials and the consequent possibility of future developments hinging upon chrome tannages, experiments are being made to obtain fundamental data on the wearing quality and other properties of chrome-retanned sole leather as compared with the well-known, long-established, vegetable-tanned sole leather. The work is being done on leathers made from the same hides, which gives a strictly comparable basis that is so essential for work of this general nature and yet is so seldom obtained. A particularly interesting point brought out by the data is that the tensile strength of the chrome-retanned leather is less than that of the vegetable-tanned leather. It is also thinner than the latter unless heavily retanned. Actual wearing tests on these two leathers have been completed, but the detailed data have not yet been assembled and analyzed. The results so far show that on an average the chrome-retanned sole leather, if heavily retanned, wears longer than the vegetable-tanned leather. The chrome-retanned leather did not prove satisfactory, however, as regards water resistance and also in some cases did not afford sufficient protection to the bottom of the foot against uneven surfaces because of its soft nature.

### THE EFFECT OF OILS AND GREASES ON LEATHER

Because of the known wide difference in the efficacy of various oils and greases as leather dressings, an elaborate experiment on the preservative effect of 20 oils and greases on leather is under way. Complete chemical data on the oils and greases have been obtained for correlation, if possible, with their effect upon the leather after it has been aged by exposure both indoors and outdoors.

### NAVAL STORES

The work on turpentine, rosin, pine oil, pine tar, pine pitch, rosin oil, rosin spirits, and other resinous farm and forest products derived from the pine tree and generally known collectively as naval stores, which are produced to the extent of about $60,000,000 worth annually in this country, has progressed very satisfactorily during the year. These farm and forest products are recognized as materials essential to the paint, varnish, paper-size, soap, printing-ink, polish, and other major industries of the country, and in addition supply the needs of foreign countries for these materials. The need for research work of a fundamental and also of a practical nature is more pressing than ever, despite the bureau's past efforts to help both the producers and users of these products. Every improvement which the research work of the bureau introduces in process work or production gives the users of naval stores a better material and one less difficult to work with.

### BETTER SETTING FOR FIRE STILL

In the technological field work which the bureau has been conducting for a number of years, it has been the general observation that the working of the stills was inefficient in some particular: The gum was scorched and the rosin thereby degraded, the yield of turpentine was not as great as it should have been; fuel consumption was too high; the still ran irregularly and showed a tendency to go flat or boil over, or it took too long to work off a charge. Study of the problems presented revealed that in many, if not in most instances, the setting of the still was at fault. It could not be uniformly heated, there being portions of the still that were cold and other portions that were too hot. The still was found to be hotter immediately above the gum line, especially, than it should be. There was not the necessary protection against accidental fire and destruction of the still. The flues were too small, and, as a consequence, the draft was not adequate to insure prompt, rapid distillation, and the final results were low-grade rosin and slow and costly operation, interspersed with frequent fires which destroyed the still and all of the gum, rosin, and turpentine within reach.

Serious experimental study during the past two or three years has finally resulted in the introduction by the bureau of an improved setting for fire stills. This setting is found to give complete satisfaction in that it reduces the tendency to scorch the gum and lower the grade of rosin, reduces the fuel consumption, shortens the time of distillation, and simplifies the operation of the still.

Blue prints and instructions for the proper setting of the fire still were prepared for distribution to naval-stores operators. There have been many calls from producers and from those interested in distillation for these plans and specifications, and those producers who have rebuilt their stills in accordance with the bureau's plans and specifications have advised the bureau that they have profited directly thereby.

A representative of the bureau has personally supervised the setting of a number of fire stills according to these plans and instructions, in one instance supervising the construction and lay-out of the entire plant. Many reports have been received concerning the satisfactory results that have been obtained in the operations of the reset stills. Increased yields of turpentine and better grades of rosin have resulted.

### FIELD TECHNICAL SERVICE

Service of a technical nature has been given operators through the office of the naval-stores technologist, located at Savannah, Ga. During the year more than 50 visits were made to plants producing naval stores. The services rendered at these times have been extremely varied. Advice and help were given on the layout of the plants and the type of equipment necessary for securing maximum efficiency; the problem of minimizing fire danger was handled; instructions were given in improving the methods of still operation and rosin straining; proper methods of handling crude gum were emphasized, and the reasons pointed out for muddy turpentine and smoky, stained, and dirty rosin. Special attention was given in all instances to the problem of producing higher-grade products.

These visits, the suggestions, and the help are given at the request of the individual naval-stores producers. The demand for help along these lines has been greater than the bureau has been able to meet with its present facilities. That the work is beneficial to a large degree and is appreciated by the turpentine and rosin farmers is convincingly shown by the letters of commendation and requests for help received both by the Savannah office and by the bureau in Washington. It is estimated that the value of this technical service which the bureau is rendering the producers of turpentine and rosin is worth at least half a million dollars a year to the industry.

### CUPS AND APRONS

Galvanized-iron cups and aprons are largely used for collecting turpentine gum from the trees. Frequently operators continue to use them after they become rusty, not realizing to what extent their profits may be cut by degraded rosin caused by iron-stained gum. In order to demonstrate the harmful effect on the color or grade of rosin resulting from the use of rusted galvanized-iron cups for collecting crude gum and the comparative effect of different metals, 0.5 per cent of metallic resinate was mixed with uniform samples of light-colored rosin and the mixture fused under uniform conditions of time, temperature, and agitation, and then compared with the same rosin heated alone. It was found that heating with zinc or with aluminum resinate darkened the rosin only slightly more than if it were heated alone under the same conditions. Heating with 0.5 per cent of iron resinate darkened the rosin greatly—as much as three or four grades—while heating with copper resinate had the next greatest darkening effect on the rosin. Heating high-grade rosin with as little as 0.01 per cent of iron oxide was found to lower the grade of the rosin. This work, which so clearly showed the effect of iron resinate in decreasing the producer's profits, is being continued with a view to developing the best way of keeping iron rust out of the gum.

### SPECIFIC-GRAVITY TABLES

Since under the methods of production there can be no foreign oils in spirits of turpentine, especially in gum spirits of turpentine, few tests as to the purity of spirits of turpentine are made on the primary markets. However, for the purpose of calculating the weight or gallonage of tank cars

or to determine whether or not the turpentine has oxidized in storage, it is customary to determine the specific gravity or the Baumé gravity of turpentine on the primary markets or at the time a tank car of turpentine is shipped from the still. This determination is customarily made at the prevailing temperature of the turpentine, and the weight per gallon or per tank car and the correct gravity are obtained by reference to proper tables.

At the suggestion of the Pine Institute of America (Inc.), work was done to determine whether hydrometers calibrated for use at 60° F. can be used with turpentine at temperatures much above or below 60°, and the results corrected with reasonable accuracy. From experiments with 16 authentic samples of turpentine. tables of gravities have been prepared showing how to obtain the true specific or Baumé values at 60° from readings made at other temperatures, ranging from 32° to 95° in 1-degree intervals.

These tables will facilitate calculation of volume from the weight or weight from volume of turpentine when sampled and tanked where no convenient means of regulating temperature are available. The results of this work with tables for correcting specific gravity and giving weights per gallon of turpentine of different specific gravities will be published at an early date.

### STEAM STILL

During the year the bureau has kept in close touch with producers who have installed steam stills, including those built in accordance with the designs and specifications of the bureau and those in which departures were made by the builders of the stills. Careful study of the installations so far made show that stills not constructed in accordance with the bureaus' specifications have given considerable trouble and usually have to be reconstructed. Those which were built in strict accordance with the bureau's specifications have continued to prove satisfactory and economical, although several minor changes have been made which have resulted in easier and more uniform handling of the stills.

### GUM CLEANING

Work on gum straining has continued with promising results. For the first time, so far as it is known, crude gum was strained entirely free from fine bark, sand, clay, chips, and other material usually present in the gum, without diluting it with a solvent, and the rosin produced was clear and brilliant. This work has reached the stage where it is felt that with proper facilities the necessary practical equipment can be constructed and operated with every promise of success. It is felt, however, that further work along this line must await the facilities furnished by a naval-stores experiment station before it can be completed in a satisfactory manner.

### TURPENTINE STORAGE

In the work on improved methods for storing turpentine, several substances have been tested as to their value in preventing or retarding oxidation. It has been found that metallic copper, zinc, magnesia, and sodium all react with the terpene acids, forming flocculent precipitates, and are therefore not suitable for the purpose. Stannous chloride also reacts with the turpentine and can not be used. Sodium nitrate, calcium sulphate, and calcium chloride appear to be of little or no value. Hydraquinone, pyrogallol, pyrocatechin, and beta naphthol, while of value in retarding oxidation, caused darkening of the turpentine. The work is being continued with those substances which so far have indicated that they may be of value in retarding oxidation.

In the meantime, however, it appears that keeping containers, whether they be barrels, drums, or storage tanks, completely filled with the turpentine and free from separated water is the best insurance against oxidation and thickening of turpentine in storage.

### GLUING TURPENTINE BARRELS

While a large percentage of the turpentine made is shipped and stored in tank cars, drums, or other metal containers, the greater percentage of turpentine is still shipped and stored in wooden barrels. Especially is this true with regard to the turpentine shipped or stored by the smaller operators. Leakage from the barrels has long been a serious and costly problem in the industry. During the year the bureau has initiated laboratory experiments with a view to so improving the gluing of barrels that these losses and expenses may be reduced. The work has resulted in the development of a gluing process which promises to be quite effective for the purpose, and which will be submitted to actual trial during the coming year.

### STATISTICS

At the urgent request of representatives of the industry, statistics to show the total quantities of rosin and turpentine used in 1927 and stocks on hand in each of the using industries, at the primary ports and the chief distributing centers on March 31, 1928, and also a report on the number of new cups sold for use during the year, have been made public. These figures, which are the bureau's compilation of those voluntarily supplied to it by individual users and manufacturers, are the only source of this information and serve to keep the naval-stores trade informed as to conditions. They are estimated to be between 90 and 95 per cent accurate.

### EXHIBITS

Both alone and in cooperation with the Office of Exhibits of the department, the bureau has continued to build up its exhibits to show better naval-stores practices and uses of the products. These are found helpful in the bureau's technological work in the field and also in informing users of naval stores as to methods and difficulties of production.

### SPECIFICATIONS

The bureau has continued to cooperate with the Federal Specifications Board, with the American Society for Testing Materials, and with the Association of Official Agricultural Chemists in the preparation of specifications and standards of quality for naval-stores products.

### NAVAL-STORES HANDBOOK

Further progress has been made on the handbook designed to contain technical, industrial, agricultural, and general information useful to producers. This handbook is being prepared in cooperation with other interested bureaus of the department, and the indications now are that it will be ready for printing within the next fiscal year.

### PAPER RESEARCH

The Bureau of Chemistry and Soils has long recognized the need for research work to determine the factors which control the suitability of paper and fiber board for the various uses to which they are put and especially for research on the factors that control the durability of paper used for permanent and legal records, such as historical documents, scientific articles, and particularly Federal, State, county, and city records, including deeds, wills, and other papers dealing with property.

The bureau has attacked these problems from the point of view of the paper maker and of the user of paper. It has studied means for elimination of waste in raw material during transportation, storage, and handling. It has realized that there is wide opportunity for saving in making and using the billion dollars' worth of paper now being produced annually in this country. In the past, the bureau has published a number of articles dealing with the general subject of paper and paper utilization and preservation. During the past year, in cooperation with the Government Printing Office, it has entered into a more extensive and vigorous investigation especially of the deterioration and discoloration of paper, with special reference to paper intended for purposes where great durability is required.

The work so far done has developed very definitely the fact that the presence in considerable quantity of sulphuric acid, which may come from the use of excessive quantities of alum to precipitate rosin size, is one of the outstanding causes of the deterioration of paper, and that for durable paper a minimum quantity of alum should always be used, since the free sulphuric acid which results from the reaction between the alum and the paper itself is never, under the present conditions of paper making, entirely removed from the paper, but remains in it to work its destruction throughout the life of the paper. It has been shown, too, that exposure to light of paper containing considerable quantities of free sulphuric acid hastens its deterioration.

A number of other interesting and important indications have already been developed in this work, which is being vigorously continued in cooperation with the Government Printing Office.

### PAPER AND BOARD FROM FARM BY-PRODUCTS

Careful investigation of the utilization of cornstalks for paper making and several other uses has been made by the bureau during the past year. A representative of the bureau has conferred with manufacturers of pulp, paper, and board, and others interested in the utilization of cornstalks and collected samples of products pre-

pared from cornstalks and other crop by-products.

Samples of paper made from approximately 65 per cent cornstalk pulp and 35 per cent chemical wood pulp and used for special editions of newspapers and farm journals were examined in the laboratory in comparison with regular standard print newspaper. It was found that the paper containing cornstalk pulp had a greater bursting strength and folding endurance than standard newsprint paper, but that the latter was more opaque and had better printing qualities.

One commercial plant using cornstalks is turning out a good fiber board, and prospects for financial success in making board from cornstalks appear bright where conditions are favorable. Good building, insulation, and other special types of board continue to be produced from wheat straw, flax straw, sugarcane bagasse, waste wood, and old paper, apparently with financial success.

To meet the demand for information on the subject, an 18-page mimeographed circular, Farm Wastes for Paper and Board Making, has been issued. This circular summarizes the experiments of the Department of Agriculture and of others on this subject.

#### UTILIZATION OF CORNSTALKS

Studies have been made relative to the utilization of cornstalks along various lines, with particular reference to corn-borer control. Special consideration has been given the possibility of using them when properly prepared as fuel, as an absorbent for various purposes, as a constituent of linoleum, of plastics, and for those purposes for which wood flour or sawdust is now largely employed. Progress in the development of small-scale plants for the production of gas and other products from crop wastes by means of destructive distillation has been followed closely, and one manufacturer of such equipment has agreed to supply the bureau with an outfit for experimental work on cornstalks and other crop wastes.

The bureau has kept in close touch during the year with the plants making paper pulp from cornstalks, with paper mills experimenting in the use of cornstalk pulp in newsprint and book papers, with plants making fiber board from cornstalks, with plants making fiber board from wheat straw, and with plants producing gas, carbon, and other products from crop waste. These investigations have confirmed the Department of Agriculture's previous findings that farm by-products can be used for making many different products, and the indications are that some products can be made economically and profitably.

### FARM FABRICS

#### PRESERVATIVE TREATMENTS

Work on the preservative treatment of canvas has been limited to keeping informed with regard to the commercial treatments offered to make canvas water and mildew resistant. A number of samples of canvas treated by commercial processes have been tested for mildew resistance in comparison with mineral-dyed khaki and gray duck. Some of these were found to be about as resistant as mineral-dyed khaki; others were found to be of little value or no better than the treatments devised and made public by the bureau.

#### FERTILIZER BAGS

The rapidity with which bags containing fertilizer deteriorate has long been a serious problem to the manufacturers of fertilizer and to the farmer. The bureau has started research work the object of which is to devise treatments to increase the resistance or to prevent the rapid deterioration of such bags. Preliminary results so far obtained indicate that bags made either of burlap (jute) or of cotton are rapidly attacked under favorable conditions either by dilute sulphuric acid or by freshly made superphosphate (acid phosphate); that if the temperature is kept low the deterioration is retarded; that the fluorine contained in superphosphate is an active agent in hastening deterioration; and that there is little difference in the rate of deterioration of cotton and jute bags.

#### TOBACCO SHADE CLOTH

Weather-exposure tests on tobacco shade cloth treated with lead chromate commercially and on samples of shade cloth, canvas, and sheeting treated in the laboratory were completed this year. It was found that the treated cloths had stood up well, confirming the findings of previous small-scale experiments that the chromate-treated shade cloth will be serviceable for two or possibly three years, thus decreasing materially the

cost to the tobacco growers of shade cloth.

Through consultation with the director of the tobacco substation of the Connecticut Agricultural Experiment Station, in cooperation with which this work on tobacco shade cloth is being done, it was found that the tobacco growers feel that there is need for further experimental work by the bureau with the view of developing a less expensive method for treating tobacco shade cloth. Work on such methods has begun and will be continued during the coming year.

### MISCELLANEOUS

Tbe bureau has continued to cooperate with the Federal Specifications Board in the preparation of specifications for the purchase of paper, paints, varnishes, linseed oil, leather and leather goods; with the Government Printing Office in the preparation of standards and specifications for the purchase of paper for Government use and for the purchase of leather and leather goods for the public printing and binding; with the Association of Official Agricultural Chemists in the study of methods for the examination of tanning materials, leather and leather goods, turpentine, and rosin; with the American Leather Chemists Association in the study of methods for the analysis of tanning materials, leather, and tannery raw materials; with the American Society for Testing Materials in the study of methods of examination and standards and specifications for paints, paint materials, turpentine, and rosin; with the American Chemical Society in the preparation of specifications for the paper used in its publications; and with the departments of the Federal Government and of States on subjects that come within the province of the bureau.

### INSECTICIDE INVESTIGATIONS

The loss caused by injurious insects in the United States is estimated to be fully $2,000,000,000 annually, and their control is a matter of vital economic significance, as evidenced by the recent depredations of the Mediterranean fruit fly and yearly losses from other better-known species of insect pests.

### INSECTICIDAL PLANTS

Work has been continued during the year on various insecticidal plants. The chemical constitution of rotenone, which is the insecticidal principle of *Derris elliptica*, has been closely investigated. It is now believed that its structure can be determined.

Following an invitation from a commercial firm, the bureau has agreed to assist a committee representing insecticide manufacturers interested in pyrethrum flowers in testing chemical methods for the evaluation of pyrethrum. Over 11,000,000 pounds of pyrethrum flowers, with an approximate value of $2,500,000, are imported annually into the United States, and there is great need for a chemical method of assaying them.

Through the aid of the consuls of the State Department, the division has been placed in touch with botanists and collectors of crude drugs in South America and Central America. Through these connections it is hoped to secure samples of certain rare plants which have been found to possess very great insecticidal value. As soon as they are received, an effort will be made to isolate and determine the nature of the insecticidal principles present in these plants.

### SPRAY RESIDUES INVESTIGATIONS

The problem of removing arsenical residue from sprayed fruit is a matter of great importance to the fruit growers and the public, as the metallic residues caused by overspraying or late spraying of fruit constitute a definite health hazard. The bureau has been successful in finding an improved washing solution for the removal of spray residue from apples. It has been found that the addition of certain salts, such as sodium chloride and sodium sulphate, greatly enhances the solvent action of hydrochloric acid for lead arsenate. It is believed that this improved washing solution will soon come into commercial use and result in the saving of many thousands of dollars to the fruit industry.

At Wenatchee and Yakima, Wash., the field work of this bureau in cooperation with the Bureaus of Entomology and Plant Industry has been so heavy that it was necessary to send two additional workers into the field for several months. Over 5,000 samples of apples were analyzed at Yakima and Wenatchee by chemists of the bureau in assisting the Bureau of Plant Industry.

### PREPARATION OF FLUORINE INSECTICIDES

Certain of the fluorine compounds have recently been proved more effective than lead arsenate in controlling

the European corn borer. The work of the bureau in preparing these compounds has been successfully continued. It was also ascertained by experiments at Yakima, Wash., that certain fluorine compounds appear promising as substitutes for lead arsenate for the control of the codling moth. It is believed that the compounds of fluorine upon which the bureau is experimenting now offer the best chance of an inorganic substitute for lead arsenate.

### TESTS WITH NEW FUMIGANTS

Particularly interesting are the results that have been obtained on mixing carbon dioxide with certain fumigants. The addition of about 10 per cent by volume of carbon-dioxide gas in a fumigating chamber not only enhances the insecticidal efficacy of the fumigant—such as, for example, ethylene dichloride—but also greatly shortens the necessary period of exposure. This new discovery has great commercial possibilities. Widespread interest has been attracted to the work of the bureau on ethylene dichloride as a clothes-moth fumigant. Recent work with ethylene oxide indicates that when used in vacuum fumigating apparatus it is even more toxic than hydrocyanic acid against certain insects.

### ANALYTICAL WORK

Much analytical work is performed for the Bureau of Entomology. During the past year samples of the following materials have been submitted for examination: Lead arsenate, calcium arsenate, tobacco powder, Derris root, Derrisol, pyrethrum powder, pyrethrum extract, various fluorides and fluosilicates, oils to be used in making oil emulsions, soaps, etc. Many determinations of arsenic upon samples of apples, blueberries, beans, and other products which have been sprayed or dusted by entomologists at various field stations have been made.

### OTHER INVESTIGATIONS

Investigations on pyridine derivatives have continued during the past year, and the special work on neonicotine is nearing completion. Four articles on this project have been published by scientists of this bureau in the journal of the American Chemical Society during the past year. Early in the year certain derivatives of formic and chloroacetic acids were prepared, also compounds containing the ethylene oxide linkage. These compounds were tested by a representative of the Bureau of Entomology upon *Aphis rumicis*, but none was found to be sufficiently toxic to justify further work with them.

In connection with arsenical studies a report will soon appear on the work of sampling cleaned apples for the determination of arsenical-spray residue. An investigation is also being made on the arsenic in manufactured forms of tobacco. A preliminary examination of cigars shows that arsenic may be present to the extent of 0.3 grain $As_2O_3$ per pound; this is thirty times the British tolerance for arsenic for apples.

## OIL, FAT, AND WAX INVESTIGATIONS

Fats and oils from new sources are being studied by the oil, fat, and wax laboratory to discover the purpose they may serve and to determine whether or not it is feasible to produce them commercially. Much attention is also being paid to the investigation of the composition of commercial fats and oils. In addition to these studies, attention is given to new research methods and to those for testing the purity of fats and oils.

### REINDEER FAT

Five samples of Alaskan reindeer fat were examined in collaboration with the Bureaus of Animal Industry, Home Economics, and Biological Survey. The composition as well as the characteristics of the reindeer fat have been determined. Unlike the fat from ordinary farm animals, reindeer fat was found to contain a small but noteworthy quantity of arachidic acid as glyceride. In some respects it resembles beef tallow and can be used for the same purposes—namely, edible and technical uses.

### NEW SOURCES OF OILS

In California walnut oil is now being pressed from the broken or otherwise unsalable "meats" obtained from the shelling plants. After the investigation of this oil it was pointed out that on account of its high iodine number it was particularly suitable for use as a paint oil. Previously most of it, if not all, was sold to the soap factories.

Experiments were made which indicated that avocado oil would, if of good quality, be suitable for local use in California or Florida as a cooking oil. Its smoking temperature was found to be slightly above that for olive oil.

The investigation of grapefruit-seed oil has begun. The air-dried seed contain somewhat more than 30 per cent of an oil which has been found to belong to the semidrying class of oils.

### WALNUT OIL

A thorough examination was made on an authentic sample of commercial walnut oil expressed in California. The characteristics and composition were determined. This is the first extensive study made of this oil which for a great many years has been used in Europe and Asia for edible purposes, as well as for making paint, particularly artists' colors. It was found that the California walnut oil was outstanding in its high iodine number, much higher than that usually found in Europe.

### SAFFLOWER-SEED OIL

Through the efforts of the Bureau of Plant Industry an increasing acreage is being planted to safflower in various States of the Northwest, and before long a new American industry will have been established.

The oil, which was expressed from seed grown in Montana, has been examined and its composition determined. It is a good drying oil and is suitable for use in the manufacture of paints, varnish, and linoleum; it is also edible. When the oil is heated for several hours from 300° to 310° C. it polymerizes and solidifies to a very stiff elastic mass, for which some practical use may be found.

### CHIA-SEED OIL

The characteristics and the composition of chia seed have been determined. The seed yields a strong drying oil, which is well suited for use in the manufacture of paints and varnishes, as well as oilcloth and linoleums.

### PALM OIL

Enormous quantities of palm oil are used in the United States by the soap makers and the tin-plate industry. With the improvement in the quality of the product, particularly that from Sumatra, increasing quantities of palm oil are being used in the manufacture of margarin, for which it is well adapted.

The laboratory was especially fortunate in receiving a sizable sample of palm oil of good quality from the Belgian Congo. The characteristics and composition of this oil have been determined. In view of the fact that commercial palm oil is produced in various countries, and often from different varieties of the African palm, *Elois guineensis*, and because some varieties differ greatly from each other in many respects, it is important that this study should be extended to include the palm oils from the important producing countries. These results will be of particular value to the soap makers and margarin manufacturers, as well as to those engaged in the cultivation of the palms, if the results indicate that the oil from certain varieties is superior in any marked respect to that from others.

## NUTRITIONAL INVESTIGATIONS

### PROTEIN INVESTIGATIONS

The general importance of a knowledge of the chemical composition and properties of protein in judging the value of animal feeds and food for man is so generally recognized as to need no emphasis. Statistics show that the value of protein concentrates, or meal, used in the United States for stock feed amounted in 1927 to $3,500,000,000. Nearly all the agricultural products that are used for food and feedstuffs are valued to a greater or less extent for their protein content. Recently, in the feed industry, the practice of buying and selling certain feeds on the basis of their protein content has become prevalent. Protein is one of the most important of the different food factors; yet not all proteins have the same nutritive value. Some are lacking in their content of certain nutritionally essential amino acids, without which young animals will not grow and adult animals fail to maintain a nutritively normal condition. On the other hand, there are proteins that contain relatively excessive amounts of these same amino acids. A knowledge, therefore, of the composition of different proteins is essential in the mixing of different feeds to give a mixture that will be the more efficient for animal production and provide the best and most economical utilization both of feedstuffs containing proteins of poor quality and those of unusually high food value.

Many unsolved problems of great importance depend for their solution upon a more complete knowledge of protein chemistry. In the baking industry these involve such subjects as strong and weak flours and the cause

of bread growing stale. Other problems which are linked up with protein chemistry are the keeping quality of fruit juices; the proper place in the diet of vegetables, tubers, and fruits; the effect of storage upon different food commodities, as well as studies of the cause and treatment of certain diseases involving questions in serology, immunity, and the action of antitoxins.

Practically no knowledge is available concerning the proteins of sweetpotatoes. Their extensive cultivation and use as food in the United States emphasize the need of undertaking work to secure information concerning their proteins. Accordingly, work is in progress to this end, and many preparations of purified proteins from different varieties of sweetpotatoes have been obtained for the first time. These proteins are being studied with reference to their properties, elementary composition, and amino-acid content. Evidences have been obtained of important changes that occur in the proteins during the storage of the sweetpotatoes, which may also be of great importance in connection with the storage of white potatoes and other roots and tubers that are used for food. Although the amount of protein in roots and tubers is low compared with that in seeds and some other foods, their extensive use as a food and the possibility that their protein may possess unusually high food value or have certain peculiar properties might make them rank high as a source of food protein.

Work formerly done on the proteins of peanuts, the results of which are described in 13 publications, has demonstrated the high nutritive value of these proteins. Some particulars regarding the properties of arachin and conarachin, the two chief proteins of peanuts, and the proportions in which they are present in the peanut, were not ascertained in the former studies. In view of the importance of peanuts as a crop furnishing feed for animals and having a wonderful potential value as a food for man, both from the standpoint of the oil and as a source of protein, work on peanuts has been resumed by this bureau.

The avocado, also known as the alligator pear, is steadily growing in favor and importance as an article of food. A native, tropical fruit of Latin-American origin, its cultivation in the United States, which has steadily increased, has been made possible by the introduction into this country of the most suitable varieties by the United States Department of Agriculture. The proteins of this group have been isolated and their composition determined in this bureau. This is the first time that the protein from any fruit has been isolated and its elementary composition and amino-acid content determined. Feeding experiments have been made to get further data on the nutritive value of these proteins and to determine the vitamins in the fruit.

Prerequisite to the development of further information along certain lines of protein chemistry is the obtaining of more data regarding the action of dilute alkalis on proteins. One of the two most important proteins of wheat—namely, glutenin—is isolated by first extracting gluten with dilute alkali. There is some evidence that the alkali used in this process produces fundamental changes in the protein. Consequently, the isolated glutenin as usually prepared probably does not represent the native protein as it existed in the seed. Determinations of the properties and composition of the isolated protein may therefore be misleading when taken to represent those of the glutenin as it exists in the wheat kernel.

Conflicting statements regarding the percentages of some of the nutritionally essential amino acids in casein, the chief protein of milk, have been reported by different investigators, due probably to the fact that the casein used by different analysts had undergone various changes produced by the alkali used in its preparation. In view of the importance of this question, studies have been undertaken and are in progress to investigate the action upon proteins of dilute alkalis under different conditions, a problem in protein chemistry concerning which our knowledge is at present very meager.

Investigations have continued on the glutelins of cereals. The glutelins in corn and rye have been isolated and their properties and content of amino acids determined. Work is in progress on the glutelins of buckwheat and certain varieties of sorghum.

Experiments with cows and dogs have shown that lignin, a substance entering largely into the composition of plants and which therefore constitutes a large part of the diet of herbivorous animals, is metabolized

and that the lignin in the diet contributes to the hippuric acid that is eliminated in the urine.

### GOSSYPOL

During the past year additional data have been gathered on the retardation of growth of rats when differing amounts of gossypol were added to a satisfactory diet. Rats show a marked difference in response depending upon whether 0.125, 0.150, or 0.175 per cent of gossypol is added to the diet. Of three cottonseed meals prepared by three different methods, tested biologically for toxic effect of gossypol, two showed practically no toxicity and one showed appreciable toxicity. This work indicates that properly conducted feeding experiments with rats may be as accurate in determining small amounts of gossypol in cottonseed meal as the chemical methods now available.

### VITAMINS

Work has been continued on a variety of foodstuffs to estimate the quantity of vitamins which they contain and to extend our knowledge concerning the properties of vitamins and develop more satisfactory methods for their assay.

A preliminary communication describing a technic whereby the storage of vitamin A in young rats may be controlled and maintained at a comparatively uniform level has been published. By means of this technic the time and labor required for the determination of vitamin A in foods and commercial preparations can be materially decreased.

Other studies have shown certain defects of the United States Pharmacopœia vitamin A assay of cod-liver oil. The United States Pharmacopœia X method does not eliminate vitamin D as a growth-promoting factor. When this factor is provided ophthalmia usually develops before growth ceases, so that the curative test can not be carried out on an animal free from disease.

In curative tests for vitamin A, although observations on the presence and change of severity of ophthalmia are essential, the growth response seems to offer a more tangible means of judging vitamin A potency. The vitamin A potency of a sample of butterfat was found to be approximately one-fifteenth of that of a good grade of cod-liver oil.

### VITAMINS IN THE AVOCADO

Work on the avocado which was completed during the year failed to reveal demonstrable amounts of vitamin A or D in the oil obtained from avocados. A dry, fat-free meal prepared from the pulp was tested for vitamins B and G. The meal was prepared by drying the pulp of the fruit in a current of air, and the oil was then expressed by pressure. The press cake was extracted with petroleum ether and again dried. This material is an excellent source of both vitamins B and G, being about half as potent as an excellent quality of dried yeast.

### VITAMINS IN SUGARCANE JUICE

Investigations on the vitamins in sugarcane juice which have been in progress intermittently during a period of years were completed during the year. Although containing vitamins A, B, and C, sugarcane juice can not be considered as a rich source of these vitamins. It contains no significant amount of vitamin D. Juice obtained from the upper portions of cane stalks was found to contain more vitamin B than that obtained from the lower portions of the same stalks. This vitamin was also found in larger quantity in juice expressed under the high pressure of a hydraulic press than in juice expressed at lower pressure in an experimental sugar roller mill. Tests made on cane sirup, cane cream, and samples of Louisiana and Porto Rico blackstrap molasses showed that these products contained little or no vitamin B.

### VITAMINS IN FISH OILS

Three samples of burbot-liver oil, and one each of shark-liver and pufferfish-liver oil, have been examined for both vitamins A and D during the past two years. The work has been completed, and it is planned to publish these results jointly with the oil, fat, and wax laboratory and to include their data on the chemical and physical properties of burbot-liver oil.

### VITAMIN STUDIES ON HYBRID CITRUS FRUITS

Evidence has been obtained showing that the tangelo, a hybrid resulting from a tangerine and grapefruit cross, inherits the characteristics of the latter parent with respect to vita-

min B. This would indicate that vitamin-B production is controlled by a single or limited number of genetic factors in the plant. If so, it should be possible to breed plants for a high vitamin-B content. For the continuation of these studies, there have been received from the Bureau of Plant Industry kumquats, limes, and a hybrid called limequat, produced by crossing the kumquat and the lime. The juices of these fruits will be tested for vitamin B as soon as other experiments now under way are terminated.

#### TECHNIC OF VITAMIN ASSAY

During the past year data have been obtained showing that vitamin A can be determined quantitatively by a preventative technic in which only one dose of the substance is fed. In many cases such a determination offers many advantages over the well established curative method commonly used. Studies are being continued which may establish further limitations as to commonly accepted methods.

#### VITAMIN ASSAY OF COMMERCIAL PRODUCTS

The results of the investigation of the vitamin content of 29 samples were reported to the drug-control laboratory during the past year. Twenty-five of the products were tested for vitamin D and 14 for vitamin A. Considerable attention has been devoted to liquid preparations containing 15 to 20 per cent of alcohol, which are claimed to contain extracts or concentrates of cod-liver oil.

#### EFFECT OF ETHYLENE GAS ON VITAMINS OF TOMATOES

In connection with work being done by the Food Research Division of this bureau on the effect of ethylene gas on tomatoes as used commercially in bringing about a forced coloring, feeding experiments have been conducted to determine what effect, if any, the gas treatment may have on vitamins A, B, and C. For this purpose four different lots of tomatoes gathered at definite stages of development were divided each into two portions. One portion was subjected to the ethylene treatment and canned according to usual cannery practices. The other portion, untreated with ethylene, was similarly canned. The vitamins were also determined in untreated mature tomatoes allowed to ripen naturally on the vines.

The results of the feeding experiments showed but little difference, if any, in the vitamin content of the treated and untreated immature tomatoes. A superiority, however, was found in the vitamin content of the naturally vine-ripened tomatoes over that of the immature tomatoes either treated or untreated.

## SOIL INVESTIGATIONS

A. G. McCall, *Chief*

#### THE SOIL SURVEY

Studies of soils in the field have been pursued much more extensively in the United States than in any other country in the world. It has long been accepted as a fundamental principle in the soil survey that the bureau is under obligation to obtain as broad a knowledge of the soils of the world as possible. This position has been assumed partly because of our interest in soil science as a whole and partly because of the tremendous practical importance of the agricultural industry.

Since the inauguration of the Soil Survey a little more than a quarter of a century ago, soil areas have been surveyed and mapped in every State and Territory in continental United States, in Porto Rico, Panama Canal Zone, Cuba, Central America, and South America.

During the past fiscal year soil-survey work was carried out in 72 separate areas distributed over 28 States. By this policy of wide distribution of projects each year there is presented an opportunity for studying soils under a wide variety of conditions and thereby extending our knowledge of the more important soil regions of the country.

The work of the Soil Survey for the past year is summarized in Tables 1 and 2. Table 2 also presents a recapitulation of the areas surveyed since the inception of the work 30 years ago. Detailed surveys aggregating 20,650 square miles and reconnaissance to the extent of 2,010 square miles were covered during the year, bringing the total acreage for the detailed survey to almost 500,000,000 and the reconnaissance survey to slightly more than 383,000,000 [redacted].

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1929*

| State | Area | Area surveyed | | State | Area | Area surveyed | |
|---|---|---|---|---|---|---|---|
| | | Square miles | Acres | | | Square miles | Acres |
| Ala. | Coosa County | 655 | 419,200 | Minn. | Hennepin County | [1] 348 | 222,720 |
| | Mobile County | [1] 367 | 234,880 | | Houston County | 391 | 250,240 |
| Ariz. | Yuma-Wellton area | 648 | 414,720 | Miss. | Hancock County | [1] 76 | 48,640 |
| Calif. | Capistrano area | 74 | 47,360 | Mont. | Lake County (part of) | 100 | 64,000 |
| | Oceanside area | 560 | 358,400 | | Milk River area | [1] 263 | 168,320 |
| | San Luis Obispo area | 587 | 375,680 | Nebr. | Cedar County | 735 | 470,400 |
| Colo. | Greeley area | 540 | 345,600 | | Dixon County | 225 | 144,000 |
| Ga. | Hart County | 164 | 104,960 | | Knox County | 189 | 120,960 |
| | Jefferson County | 220 | 140,800 | | Pierce County | [1] 345 | 220,800 |
| | McIntosh County | [1] 299 | 191,360 | | Saline County | [1] 111 | 71,040 |
| | Worth County | [1] 104 | 66,560 | | Stanton County | 106 | 67,840 |
| Idaho | Gooding area | 279 | 178,560 | N. Mex. | Socorro and Rio Puerco area | 76 | 48,640 |
| Ind. | Blackford County | 168 | 107,520 | N. Y. | Delaware County | 180 | 115,200 |
| | Pike County | 65 | 41,600 | | Nassau and Suffolk Counties | [1] 32 | 20,480 |
| | Rush County | 409 | 261,760 | N. C. | Craven County | [1] 401 | 256,640 |
| Iowa. | Butler County | [1] 443 | 283,520 | | Gates County | [1] 289 | 184,960 |
| | Calhoun County | 82 | 52,480 | | Macon County | 165 | 105,600 |
| | Guthrie County | 595 | 380,800 | | Person County | [1] 292 | 186,880 |
| | Pocahontas County | [1] 94 | 60,160 | | Watauga County | [1] 107 | 68,480 |
| | Poweshiek County | 443 | 283,520 | Ohio. | Brown County | 290 | 185,600 |
| | Sac County | [1] 283 | 181,120 | | Licking County | [1] 243 | 155,520 |
| Kans. | Crawford County | [1] 491 | 314,240 | | Ottawa County | [1] 44 | 28,160 |
| | Johnson County | [1] 220 | 140,800 | Oreg. | Columbia County | [1] 192 | 122,880 |
| | Marion County | 95 | 60,800 | Pa. | Tioga County | [1] 650 | 416,000 |
| | Neosho County | 51 | 32,640 | | Wyoming County | 92 | 58,880 |
| Md. | Anne Arundel County | [1] 375 | 240,000 | P. R. | San Juan area | 110 | 70,400 |
| | Calvert County | [1] 124 | 79,360 | S. C. | Greenwood County | 473 | 302,720 |
| | Caroline, Queen Annes, and Talbot Counties | 164 | 104,960 | Tex. | Frio County | [1] 514 | 328,960 |
| Mass. | Franklin County | 70 | 44,800 | | Galveston County | 213 | 136,320 |
| | Hampshire and Hampden Counties | [1] 510 | 326,400 | | Polk County | [1] 359 | 229,760 |
| Mich. | Alger County | [1] 735 | 470,400 | | Potter County | [1] 814 | 520,960 |
| | Branch County | [1] 102 | 65,280 | W. Va. | Hardy County | [1] 514 | 328,960 |
| | Eaton County | 95 | 60,800 | Wis. | Brown County | 252 | 161,280 |
| | Iron County | 241 | 154,240 | | Vernon County | [1] 275 | 176,000 |
| | Luce County | 115 | 73,600 | Wyo. | Basin area | [1] 384 | 245,760 |
| | St. Clair County | [1] 333 | 213,120 | | Total | 20,650 | 13,216,000 |

[1] These figures do not include portions of these areas surveyed in preceding years.

TABLE 2.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1929, and areas previously reported*

DETAILED

| State or Territory | Work during 1929 | Work previously reported | Total | | State or Territory | Work during 1929 | Work previously reported | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | *Square miles* | *Square miles* | *Square miles* | *Acres* | | *Square miles* | *Square miles* | *Square miles* | *Acres* |
| Ala | 1,022 | 52,011 | 53,033 | 33,941,120 | N. H | ------- | 1,411 | 1,411 | 903,040 |
| Ariz | 648 | 2,791 | 3,439 | 2,200,960 | N. J | ------- | 9,895 | 9,895 | 6,332,800 |
| Ark | ------- | 15,547 | 15,547 | 9,950,080 | N. Mex | 76 | 815 | 891 | 570,240 |
| Calif | 1,221 | 29,330 | 30,551 | 19,552,640 | N. Y | 212 | 26,071 | 26,283 | 16,821,120 |
| Colo | 540 | 3,904 | 4,444 | 2,844,160 | N. C | 1,254 | 40,932 | 42,186 | 26,999,040 |
| Conn | ------- | 1,704 | 1,704 | 1,090,560 | N. Dak | ------- | 16,878 | 16,878 | 10,801,920 |
| Del | ------- | 2,276 | 2,276 | 1,456,640 | Ohio | 577 | 15,144 | 15,721 | 10,061,440 |
| Fla | ------- | 15,160 | 15,160 | 9,702,400 | Okla | ------- | 6,540 | 6,540 | 4,185,600 |
| Ga | 787 | 33,315 | 34,102 | 21,825,280 | Oreg | 192 | 13,938 | 14,130 | 9,043,200 |
| Idaho | 279 | 10,319 | 10,598 | 6,782,720 | Pa | 742 | 16,903 | 17,645 | 11,292,800 |
| Ill | ------- | 6,770 | 6,770 | 4,332,800 | P. R | 110 | 330 | 440 | 281,600 |
| Ind | 642 | 16,848 | 17,490 | 11,193,600 | R. I | ------- | 1,085 | 1,085 | 694,400 |
| Iowa | 1,940 | 42,356 | 44,296 | 28,349,440 | S. C | 473 | 23,989 | 24,462 | 15,655,680 |
| Kans | 857 | 12,076 | 12,933 | 8,277,120 | S. Dak | ------- | 8,286 | 8,286 | 5,303,040 |
| Ky | ------- | 5,020 | 5,020 | 3,212,800 | Tenn | ------- | 11,198 | 11,198 | 7,166,720 |
| La | ------- | 16,769 | 16,769 | 10,732,160 | Tex | 1,900 | 50,058 | 51,958 | 33,253,120 |
| Me | ------- | 2,197 | 2,197 | 1,406,080 | Utah | ------- | 2,419 | 2,419 | 1,548,160 |
| Md | 663 | 12,226 | 12,889 | 8,248,960 | Vt | ------- | 1,175 | 1,175 | 752,000 |
| Mass | 580 | 7,604 | 8,184 | 5,237,760 | Va | ------- | 10,072 | 10,072 | 6,446,080 |
| Mich | 1,621 | 22,558 | 24,179 | 15,474,560 | Wash | ------- | 10,752 | 10,752 | 6,881,280 |
| Minn | 739 | 8,963 | 9,702 | 6,209,280 | W. Va | 514 | 20,530 | 21,044 | 13,468,160 |
| Miss | 76 | 29,139 | 29,215 | 18,697,600 | Wis | 527 | 24,742 | 25,269 | 16,172,160 |
| Mo | ------- | 37,177 | 37,177 | 23,793,280 | Wyo | 384 | 1,956 | 2,340 | 1,497,600 |
| Mont | 363 | 1,338 | 1,701 | 1,088,640 | | | | | |
| Nebr | 1,711 | 50,258 | 51,969 | 33,260,160 | Total | 20,650 | 753,427 | 774,077 | 495,409,280 |
| Nev | ------- | 652 | 652 | 417,280 | | | | | |

RECONNAISSANCE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Alaska | ------- | 31,915 | 31,915 | 20,425,600 | Ohio | ------- | 41,420 | 41,420 | 26,508,800 |
| Ark.-Mo | ------- | 58,000 | 58,000 | 37,120,000 | Pa | ------- | 41,405 | 41,405 | 26,499,200 |
| Calif | ------- | 32,135 | 32,135 | 20,566,400 | S. Dak | ------- | 41,400 | 41,400 | 26,496,000 |
| Kans | ------- | 39,960 | 39,960 | 25,574,400 | Tex | ------- | 152,855 | 152,855 | 97,827,200 |
| Mich | ------- | 1,322 | 1,322 | 846,080 | Vt | 105 | --------- | 105 | 67,200 |
| Minn | ------- | 1,923 | 1,923 | 1,230,720 | Wash | ------- | 16,540 | 16,540 | 10,585,600 |
| Mont | 1,905 | 31,919 | 33,824 | 21,647,360 | Wis | ------- | 14,425 | 14,425 | 9,232,000 |
| Nebr | ------- | 53,064 | 53,064 | 33,960,960 | | | | | |
| N. Dak | ------- | 39,240 | 39,240 | 25,113,600 | Total | 2,010 | 597,523 | 599,533 | 383,701,120 |

In addition to the extension of soil mapping, there are many ways in which the soil survey has been of inestimable value. The use of it has saved large sums of money and furnished information for the location of substations, the extension and development of certain crops, and the study of soil erosion.

In Alabama, when the State officials desired to purchase land upon which to locate the penitentiary farm in the southwestern section of the State, they called upon the State soil-survey man, who by the use of a soil map of that region, was able to select certain types of soil which would represent some of the best land in the coastal plain of Alabama. By his knowledge and by the use of the soil-survey map he saved the State from $30,000 to $50,000 on this purchase.

During the past year the director of the Alabama Experiment Station at Auburn has made valuable use of the soil survey, and particularly of the State soil expert, in locating and establishing several substations. It was the desire of the director that these stations be located in various parts of the State and upon definite and large soil areas so that the results obtained from their experiments would be applicable to the greater part of the State.

After the advent of the boll weevil throughout the northern portion of the coastal plain and southern part of the piedmont of Georgia, the farmers and extension people began to look around for other crops that could be profitably produced. The soil-survey maps of various counties in Georgia showed extensive areas of soils in the State

similar to the soils in North Carolina and South Carolina where tobacco and, to a less extent alfalfa, have been successfully grown. The development of the tobacco interest in the last few years in the State of Georgia is due largely to knowledge obtained by the soil survey.

The soil-survey maps reveal the boundaries of the sand-hill region in North Carolina and the northern part of South Carolina and to a less extent in Georgia. When the director of the Clemson College Experiment Station was apprised of the large acreage of this sandy land in South Carolina, and when it was considered that only a very small percentage of it was used for the production of crops, it was deemed wise to establish an experiment station somewhere in the sand-hill region. Consultation with the soil-survey men and a study of the soil maps made it possible to locate a substation on a soil that is typical of the great sand-hill region, thereby insuring a wide application of the results obtained.

The North Carolina Experiment Station has in the last few years, in addition to the work at its six substations, extended its plot work to include the large and important soil types in the State as revealed by the soil survey. It has been found that the greater part of the clovers and alfalfa produced in North Carolina are confined to certain well-defined and recognized soil types which are better adapted to their production than the general run of soils in the State.

The Reclamation Service has made use of the soil survey during the past year in its investigations of certain tracts of land in the South with a view to the establishment of colonization projects. The location and character of the soil, as indicated on the map, would in many instances be sufficient to determine whether or not the land in question was worthy of consideration.

In the soil-survey reports are described those soils which are subject to severe washing and erosion. It has been found that in the same region some soils erode much more severely than others, the difference being due to the physical character of the soil throughout its profile.

Progress has been made in the classification of organic soils, commonly known as muck and peat. This classification is based upon physical characteristics such as may be readily recognized by the soil experts, and so far as possible is correlated with native vegetation in order to facilitate mapping. While the organic soils are difficult to map, because of the swampy nature of the terrain in most areas, it is felt that the classification meets a need for detailed information regarding these deposits, valuable not only to agricultural interests, but for industrial purposes as well. The system of classification as now worked out has been used in 18 counties in Michigan, 3 counties in Wisconsin, and 1 county in Minnesota.

The work in cooperation with the Michigan Land Economic Survey continues satisfactorily. This survey is considered one of the most valuable of its kind in the country. Interesting correlations between soils and native vegetation are being brought out in this study, since not only the soils but the land cover is being mapped in detail. The economic survey produces three sets of maps, one of soils, one of cover (or vegetation, whether native or farm crops), and one of ownership. These maps also bring out correlation between soils and land utilization in an accurate and detailed way.

An interesting side light on the survey as a training course for soils workers is the plan of one of the midwestern experiment stations whereby all men chosen to engage in any sort of soils work for the station are required to have had some field experience on the soil survey. Men with soil-survey training are also engaged by the State highway department for subgrade investigations.

Engineering concerns engaged in laying pipe lines in the vicinity of Chicago are using the soil maps in connection with laying out their work and preparing estimates.

In the North Central and Northeastern States there is increased interest in soil-survey work. Cooperation has been established in Vermont and Kentucky and soil-survey work resumed after a lapse of many years.

A new interest in soil classification and mapping has developed in connection with reforestation. It is recognized that soil survey is the basis of land classification, which should precede all systematic plans for reforestation and the establishment of State and Federal forest areas.

### SOIL EROSION AND MOISTURE CONSERVATION RESEARCH

Soil impairment by erosion is one of the most important problems confronting American agriculture. The

losses resulting from unrestrained erosion amount to many millions of dollars annually. The value of the plant-food materials removed from the cultivated and pasture lands of the United States every year has been conservatively estimated to be in excess of $2,000,000,000. Of this amount there is evidence to indicate that many millions of dollars can be charged up as a direct tangible loss to the farmers of the Nation. In this connection it must be remembered that it is not the plant food alone that is removed by rain wash, but that the solid soil material itself is also washed away. The plant-food elements removed from the soil by growing crops can be restored in the form of fertilizers and manures, but the soil that is washed from the fields can not be restored except by those exceedingly slow natural processes of soil formation that require in many instances many centuries for the building up of a comparatively thin layer of soil from the underlying parent material. A very considerable part of erosional wastage in addition to being an immediate loss to the farmer is at the same time a loss to posterity. When the mellow topsoil, with its valuable humus and nitrogen, is gone, there is exposed in its place the subsoil, which is less productive, less permeable, and less absorptive of rainfall. Usually this exposed material is heavier than the original soil, stiffer and more difficult to plow, less permeable to plant roots, and less absoptive of rainfall. Soil erosion and water conservation are closely interrelated since methods designed to prevent destructive erosion, will in a large measure, function to conserve soil moisture.

The work of the Soil Survey of the Bureau of Chemistry and Soils, the investigations conducted by the Bureau of Public Roads, and the forestry and range-management studies carried out by the Forest Service have all served to indicate the wide extent to which the lands of the United States have been subjected to destructive erosion. A single county in the piedmont region of South Carolina was found by actual survey to contain 90,000 acres of land formerly cultivated which has now been permanently ruined by erosion. In another county in the Atlantic coastal plain of Georgia 60,000 acres of formerly rich soil is found to have been gullied beyond repair. In the brown-loam belt along the Mississippi River, county after county has been found to contain 10,000, 20,000, or 30,000 acres of land from which agriculture has been driven by reason of destructive and unrestrained erosion. Not only have the uplands been widely and disastrously dissected, but large areas of good alluvial land have in many cases been buried beneath infertile sands washed out of the upland gullies. Stream channels have been choked with erosional débris to such an extent that overflows have become exceedingly common and large tracts of formerly productive soil are now mapped as swamp land. These are only a few examples of the eroded areas that are to be found in practically all sections of the country.

During the past year a reconnaissance survey has been in progress for the purpose of locating and outlining the boundaries of the severely eroded areas in the United States. As a result of this survey, 18 districts have been recognized in which soil impairment by erosion has become a serious menace, and plans have been made to establish in each of these areas a field station at which erosion and moisture-conservation problems can be studied. This field work was inaugurated by the establishment of a station in cooperation with the Bureau of Public Roads, on a tract of 160 acres located about 4 miles south of Guthrie, Okla. By taking advantage of the immediately available provision of the appropriation act for 1930 it has been possible to establish stations and inaugurate work at similar stations located at Temple, Tex., on the black land and at Hays, Kans., on typical soil of that region of limited rainfall. At Guthrie and at Temple major emphasis is being placed on studies of erosional losses of the soil material, while at Hays emphasis will be given to moisture conservation as well as to sheet erosion.

### SOIL-FERTILITY INVESTIGATIONS

The division of Soil Fertility conducts field, greenhouse, and laboratory studies pertaining to prominent soil types in relation to soil-fertility problems. The investigational work concerns itself with a study of the nature and constitution of organic constituents of the soil and their biochemical relationships; the hydrogen-ion concentration of different soil types; the composition of the soil solution in its relation to plant growth; the influence of fertilizers on crop production and on the quality of the products, involv-

ing protein, fat, starch, and other determinations; the composition of fertilizers; the influence of chemical salts of synthetic origin on plant growth; a study of toxic and beneficial compounds on plant development; and general field investigations with fertilizers on crop growth and production and other soil problems of an important character.

An increased demand for soil-fertility and fertilizer studies on prominent soil types has resulted in the establishment of field laboratories by means of which closer contact with soil-fertility problems can be maintained. These activities are reflected in the work on cotton root rot in Texas; on pecan soils in Louisiana and elsewhere in the pecan-growing belt; on sugar-cane soils in Louisiana; on sugar-beet soil types in a number of sugar-beet-growing States; and the cooperative studies at the sand-hill station near Columbia, S. C., dealing with soil improvement. In connection with these activities, field and laboratory work are in progress, and definite cooperation with the various industries involved has been established.

The field work to determine the fertilizer requirements of prominent soil types and the crops grown thereon is being enlarged in scope. This includes field studies with new nitrogen materials and concentrated fertilizers. As a result of these field investigations more definite recommendations as to the kind and quantity of fertilizer material to use on different soil types will be made possible. Of special importance has been the work with concentrated fertilizers, whose use is increasing because of a number of economic advantages they possess, among them lower hauling and freight charges as well as the fact that fewer bags are needed than for the same quantity of ordinary-strength fertilizers. In sections where long freight hauls are involved and the growing season is relatively short the use of concentrated fertilizers is increasing. The field work referred to has been very helpful in guiding farmers and their organizations in the selection and use of these more highly concentrated fertilizer materials. These newer materials and their mixtures present other problems including studies of methods of placement and distribution. Such problems are of particular importance on the light soils of the Atlantic and Gulf coastal plains regions, where large quantities of commercial fertilizers are used.

In addition to helpful findings on highly important nutritional problems on such soil types, the field studies have developed the desirability of determining the influence of certain chemical elements not heretofore associated with the feeding of plants in the ordinary sense. Over a considerable area of the United States, more particularly along the Atlantic and Gulf coastal plains, it appears evident that growing crops require more than the addition of fertilizers containing nitrogen, phosphoric acid, and potash salts. Under certain soil conditions it has been found that small applications of manganese salts have given striking effects; on other soil types salts of copper, zinc, boron, and iodine and of similar uncommon soil elements have given crop responses indicative of unusual functions in connection with crop growth and development.

While the fundamental facts connected with the physiological functions of these and other uncommon soil elements remain to be worked out, sufficient progress has been made to indicate the importance of such studies. Associated with such problems is that relating to synthetic fertilizer salts in which very little, if any, so-called impurities occur.

Whether the absence of such material will tend to interfere with plant growth and development, especially on light sandy soils, is being given consideration.

The present year marked the inauguration of cotton root rot investigations in Texas, to study soil-fertility factors as related to the root-rot disease. Field and laboratory studies are now in progress for the purpose of correlating soil characteristics with the prevalence of this disease. A laboratory has been established on the campus of the University of Texas, at Austin, and field experiments are now in progress at 12 locations in the black belt of Texas, extending from San Antonio to Greenville. A large number of fertilizers and chemicals are being studied to determine their influence on cotton root rot. Some of the physiological acid fertilizers and some nitrogen materials lessened the ravages of the root rot on some of the less alkaline soil types last season, but additional work is necessary before definite conclusions can be reached.

Fertilizer investigations on prominent soil types of the Southeastern States were inaugurated in 1918. This project embraces the conducting of fertilizer experiments on prominent

soil types with leading farmers and on State experiment station farms in North Carolina, South Carolina, and Georgia.

Work is in progress on machinery and methods of applying concentrated and ordinary commercial fertilizers at two locations in South Carolina, in cooperation with the South Carolina Experiment Station and the National Fertilizer Association. A large number of fertilizer distributors of varying designs are used to apply the fertilizer, and records are made as to the effect of the fertilizer applied differently on the germination of cottonseed and on the yield of cotton. No results are available, since this work was not started until the spring of 1929.

### SOIL CHEMISTRY AND PHYSICS INVESTIGATIONS

This division is charged with a service duty which consists of the making of routine chemical and mechanical examination of soils for the Soil Survey and other units of the Government and of assisting in making adequate reply to private inquiries. This type of work has required the full time of five men and has resulted in approximately 500 chemical and 700 physical examinations of soils the results of which have been utilized by the Soil Survey, and in the development of the soil-erosion program. Information has also been furnished to the Bureau of Public Roads, the Bureau of Plant Industry, the Forest Service, and the Bureau of Entomology and to the Divisions of Soil Fertility and Fertilizer and Fixed Nitrogen Research.

In addition to this routine service the division has in progress researches on the following topics: The mineral and colloidal constituents of soil horizons in different soil types; the constancy of composition of the colloids within a soil series; the differences in composition of the colloids of different soil categories; the causes of toxicity of submerged soils; the absorption of acid dyes by soil colloids; the effect of colloid material on phosphorus assimilation by plants; the optical properties of soil colloids; the properties of soils which influence soil erosion; the use of the supersonic oscillator in the dispersion of soil particles; and the comparison of the physical and chemical characteristics of peat of widely different origin.

The investigations on improved methods of mechanical analysis of soils, which have been in progress for some years in connection with the routine work, will be published in a bulletin in the near future. The work has been completed and the manuscript is in preparation. There is very great need of increasing the scope of the work in the division, especially that on peat and organic soil colloids and investigations designed to utilize our present knowledge of soil colloids for soil amendment.

The work on certain of these projects is nearing completion; and when men are available work will be undertaken on a field method for determining the rates of percolation of water through soils, methods for diagnosing soil ills and prescribing remedies, the synthesis of soil components, and a study of the organic colloids of soils. During the year a number of subprojects have been terminated, and the results are now published or are in manuscript form awaiting publication. In the study of the occurrence of manganese dioxide in the soil there has been developed a method for the detection and estimation of this substance in soils. It has been shown that the dioxide of manganese does not exist in the colloidal fraction, but is formed through the agency of calcium carbonate, and that the presence of manganese dioxide is characteristic of certain soil series.

A chemical and mineralogical investigation of the alteration of mica in the soil has shown that mica may assume kaolinitic composition without visible alteration of its physical characteristics. This fact represents a very distinct contribution to our knowledge of soil genesis and evolution. A research completed during the year on the subject of the influence of different exchange bases on the properties of soil colloids has thrown important light upon behavior of colloids and has served to emphasize the relation between the properties of the finer soil constituents and the silica-sesquioxide ratio. A study of soil consistence has been undertaken by one of the field men of the Soil Survey, with a view to developing methods for estimating and terms for describing this important soil characteristic, for use in the field. This latter research, together with a number of other subprojects, is approaching completion, but the stage has not yet been reached which would justify prediction as to the probable date of termination.

### SOIL MICROBIOLOGICAL INVESTIGATIONS

The inclusion of soil microbiological investigations in the Bureau of Chemistry and Soils has made possible the undertaking of a comprehensive study of the soil population, including the larger organisms such as fungi and molds as well as such microscopic forms as bacteria.

Specific studies of soil fungi in the laboratory have been undertaken in cooperation with the bacteriologists of the division in the studies of various soils under controlled conditions in which the isolation and identification of fungi are merely one part of a combined study of the population. In this way hundreds of plates have been reviewed and the influence of various treatments upon the soil observed. The results thus far harmonize with our previous opinion, that while very great numbers of species are found in culture, comparatively few of them have contributory significance. In green-manuring experiments carried at the 5-inch level under very nearly optimum moisture conditions practically no mold activity is reported. An increased mold activity is anticipated in subsequent experiments which are planned to be carried out at less than optimum moisture content.

Another line of work under this project has consisted of the study of collections of soil fungi submitted for identification or verification by others. In July, 1928, the Zaleski collection of 35 new species of Penicillium isolated from forest soils in Poland was received. These had already been studied and their descriptions published by Zaleski, who did not have, however, a sufficiently wide acquaintance with either Penicillia or with soil fungi to express an adequate critical judgment upon either the organisms or their significance. Each of those species has been repeatedly cultivated and fitted as nearly as possible into the scheme of classification which was being developed here. Another series of fungi from the soil was received from workers at Northwestern University, in Illinois. These have likewise been identified and fitted into the culture collection. Isaac N. Lewis, of the University of Texas, submitted another series of 22 species isolated from soils in different parts of the State of Texas, for identification in connection with his own studies of soil flora.

The constant occurrence in the soil of all kinds of saprophytic molds and some parasites makes significant the study of miscellaneous collections submitted by workers in different parts of the world for general identification purposes. The most complete collection which has been submitted to us this year is a group of Penicillia used by Harold Raistrick and J. H. Birkinshaw for biochemical studies at Nobel's Explosives Co. (Ltd.), Stevenston, Ayrshire, Scotland. Since these organisms have been made the basis of extensive biochemical investigations over a period of years, we have been asked to complete the identification to give definite value to these biochemical findings. That identification work is still in progress. In addition to a number of groups of cultures of minor importance which have been submitted for identification, we have been asked to identify a number of molds isolated from cases of human disease. There has appeared to be no place in the service to which these could be sent for identification except here. As cooperative work with the Public Health Service and the Bureau of Mines, a number of such cultures have been handled. The most important of them consisted of a series of Aspergilli found in lung cases by the Bureau of Mines. The identification and experimental work in that connection is still in progress.

The monograph of the genus Penicillium which was begun by Charles Thom in the cheese investigations of the Bureau of Animal Industry in 1905 and has been written intermittently in connection with the various other projects was completed and delivered to the publisher on July 2. It is understood that it will be published as a book and that its publication will be accomplished within the next three months.

Crop rotations on the miniature farm on Walker Hill, Arlington farm, which were started in 1914 by F. Löhnis, have been continued without change during the past year. Two rotations are used—one a continuous-cultivation 4-year rotation, the other an 8-year rotation with two years grass. Treatment of the various plots includes rotted stable manure, sodium nitrate, ammonium sulphate, green manuring with rye or rye and vetch, returning of plant residues with and without addition of artificial nitrogen following. Lime is added to keep soils neutral.

The object of these rotations is (1) to furnish various conditions of soil and of crop growth to serve as a basis for bacteriological studies, (2) to test the efficiency of green manures, artificial nitrogen, and rotted manure, with and without crop residues, in maintaining the nitrogen of the soil, and (3) to compare a continuous-cultivation rotation with one having two years of grass.

On account of the pressure of other work, no bacteriological work was done on these rotations. However, the weights of all crops were obtained and nitrogen analyses made in order to have a complete record of the crops and the nitrogen removed from the soil. Likewise account was taken of the nitrogen added. Studies on the decomposition of green manures in soils of various reactions were continued along the same lines as last year. Rye and vetch growing on Collington fine sandy loam and on Leonardtown clay loam were cut, weighed, and turned under 5 inches below the surface. Examination of samples from these plots taken at frequent intervals confirms the findings of previously reported work to the effect that the addition of the green manures had no effect upon the fungi and actinomyces. After the addition of the green manure there was a rapid decrease in nitrates, reaching a low level in from four to seven days, after which an increase in nitrates took place which reached the high level of the original soil at the last sampling at the end of a 63-day period. No change in the hydrogen-ion concentration was detected.

With the foregoing results obtained, it seemed advisable to make further study of additional factors involved in the decomposition of the green material, such as the determination of the evolution of carbon dioxide, the production of ammonia, the effect on the numbers of *Bacillus radiobacter* and on the numbers of protozoa.

Rye was grown on plots 9 and 10 and vetch on plots 11 and 12. Equivalent weights of rye and vetch grown on separate benches were added to plots 3 and 4 and plots 7 and 8, respectively. In addition, plots 3 to 12, inclusive, were treated with superphosphate and muriate of potash.

The total plate counts confirmed earlier findings, and the numbers of fungi in the soil treated with rye and vetch green manure grown elsewhere remained quite constant. However, on those plots where the rye and vetch were grown and turned under, the numbers were and remained double those on the other plots receiving the same amount of material which had been grown in the other greenhouse. There were some indications that the numbers of protozoa increased in the decomposing green material.

Although the number of *B. radiobacter* was high at the first sampling in the soils where rye and vetch were grown and turned under, the numbers increased approximately ten times after the turning under of the green manure. Where the rye and vetch were grown on separate plots and turned under, the numbers increased somewhat but not in proportion as they did when the rye and vetch were grown and turned under on the same soil.

Ammonia increased in the soil of the green-manured plots immediately after treatment. This indicates a rapid decomposition of the nitrogenous materials in the green manure and accounts for the subsequent rapid nitrification which took place under these conditions.

The hydrogen-ion concentration of the soils where rye and vetch were grown and turned under averaged about 0.3 to 0.4 pH higher than where the soils were manured with plants grown elsewhere. This was true of both the limed and unlimed soils.

The evolution of carbon dioxide increased within a few hours after the green material was turned under. The peak was reached in four days, after which there was a gradual decrease to the fourteenth day after treatment. Thereafter the evolution was quite constant although appreciably higher than in the control. Under these conditions it appears that there is a close correlation between numbers of microorganisms and the evolution of carbon dioxide.

From previous experiments it seemed advisable that an effort should be made to gain some insight into the localization of the activities taking place when the green manure was turned under. Accordingly two plots of Leonardtown clay loam, one limed and the other not limed, were treated with green vetch as in the other experiments. Samples were taken at the usual intervals. Each 6-inch core was divided into 2-inch layers representing 0 to 2 inch, 2 to 4 inch, and 4 to 6 inch depths. In addition, the green material itself was separated from the 4 to 6 inch layer as completely as possible. The corresponding segments of some 20 cores were composited and analyzed for total plate counts, *B. ra-*

*diobacter*, protozoa, ammonia, nitrates. and pH. Carbon dioxide evolution from the soil was also determined.

No noticeable increase in the plate counts occurred in the different layers of the soil itself. That is, the numbers in the 0 to 2 inch layer remained fairly constant as did those in the 2 to 4 inch and 4 to 6 inch layers. However, in the decomposing green material there was a tremendous increase in numbers. At the time of turning under the material the numbers were 400,000,000 per gram of green material and increased to approximately 10,000,000,000 per gram for the unlimed plot at the 4-day samplings.

On the plates made up to and including the seventh-day sampling there appeared many colonies resembling *B. radiobacter*. Isolations have been made and are being compared. Later samplings showed typical *B. radiobacter* in high numbers in the samples of decomposed material but practically none in the soil samples.

The numbers of protozoa remained low and constant in the soil. However, in the decomposing green manure the numbers increased, reaching the high point in four days. They decreased rapidly after the disappearance of the green manure. Nematodes were observed in considerable numbers in the early stages of the decomposition.

In the first 4 inches of soil no ammonia was present at any time. In the 4 to 6 inch layer no ammonia was present until the seventh day sampling, when 60 parts per million were observed. In the samples of decomposing green manure the highest amount, over 1,000 parts per million, occurred in two days. This dropped to 150 parts per million at four days.

There was an accumulation of nitrates in the 0 to 2 inch layer in both plots. In the other layers, 2 to 4, and 4 to 6 inches, the nitrates remained quite constant. In the green manure the original nitrate content was over 600 parts per million, which dropped to 30 parts per million in seven days.

The production of ammonia in the decomposing green manure noted above is reflected in a higher pH of this material. This change in pH occurred only in the green material and not in the surrounding soil.

Carbon dioxide evolution increased as in other experiments. In four days the maximum evolution occurred, decreasing thereafter until the fourteenth day, after which the amount remained fairly constant and considerably higher than in the control.

The results of the foregoing researches may be summarized as follows:

Under conditions of optimum moisture and temperature in the greenhouse the decomposition of green rye and green vetch is brought about largely by bacterial action. This activity seems to be localized in the decomposing material in both the limed and unlimed soils, since the numbers in the soil did not increase. In addition to the bacteria, the protozoa and nematodes increased in the decomposing material. The part they play has not been determined.

Rapid ammonification of the green manure was observed, which was followed by a rapid nitrification and an accumulation of nitrates in the surface 2 inches.

The pH of the decomposing green material was considerably higher than that of the surrounding soil, undoubtedly because of the formation of ammonia.

Active carbon dioxide evolution takes place during the first two weeks, which indicates that the carbohydrate material is converted into carbon dioxide.

In the studies upon the decomposition of green manures a new method of determining the evolution of carbon dioxide from soil was invented to overcome certain objections inherent in other methods, such as the passage of air through the soil, or the accumulation of excessive amounts of carbon dioxide over the soil, or the alteration of natural conditions by the use of vacuum or pressure. The method has the advantage of being simple, inexpensive, and efficient. This apparatus will be described in an article to be submitted later.

In cooperation with M. Phillips, studies on the decomposition of lignin by soil microorganisms have been undertaken.

Crude cultures of soil organisms were inoculated into nutrient media containing natural lignin substances. Also media containing purified lignin were prepared with and without certain substances, as sugar and cellulose. The results indicate that soil organisms decompose the lignin along with the cellulose when these are in natural combination; however, purified lignin seems to be very resistant even when accompanied by pure cellulose.

A joint paper giving the results of this work has been prepared and submitted for publication.

### DISTRIBUTION OF LEGUME BACTERIA

By a continuance of a curtailment policy the free distribution of legume bacteria cultures has been limited to 10,000 bottles during the year. This is a decrease of 7,000 bottles, as compared with the number distributed during the similar preceding period. Much of the inoculating material distributed during the past fiscal year has been placed in the hands of county agents located in territories where the farm population needs encouragement in the growing of legumes. Some material has been distributed at the request of Senators and Representatives of various States and the remainder to those who in their applications to the department indicated a desire to do experimental work. A great many applicants have been furnished with information concerning sources from which cultures may be purchased.

### EXAMINATION OF COMMERCIAL INOCULATING MATERIALS FOR PLANTS

From an examination of inoculating materials sold under 47 different names it is apparent that all but a few of those firms or institutions who handle the larger part of this business produce material of good quality. In the list of sources which is prepared annually for distribution to farmers and others, 31 of the brands of nodule bacteria cultures are represented. Information has been furnished to regulatory agencies and cooperative organizations with reference to the quality and merits of specific inoculating materials. It is apparent that some of this information has had a part at least in stopping the flow of certain questionable products either promoted in fact or as stock-selling propositions.

### NODULE FORMATION IN RELATION TO CARBOHYDRATES

Samples of material collected in connection with the shading of soybean plants by cloth or corn have been partially analyzed; and while the figures obtained indicate some correlation, it is too early to draw definite conclusions. This experiment is being continued with more shading than was previously used, and results so far obtained give evidence that shading reduces the number of nodules. The results of experiments with inoculation on soybeans in the presence of sugars show that directly or indirectly certain of these carbohydrates, notably glucose, produce significant effects on nodulation and growth but apparently do not nearly take the place of sugars naturally found in the plant.

Work on the breeding of soybeans for susceptibility to nodule formation, which, by its nature will be of long duration but, on the other hand, requires but a small amount of time and labor, is being continued.

## FERTILIZER AND FIXED-NITROGEN INVESTIGATIONS

F. G. COTTRELL, *Chief*

No problem of greater importance confronts American farmers than the maintenance of the fertility of their soils. With the increasing depletion of the fertility of North American soils by cropping and erosion, the problem of supplying better and more economical fertilizers becomes more vital to our national well-being. The chief aim of this unit is to assist the fertilizer industry and American farmers in devising methods for the most economical production and use of the raw materials—nitrogen, phosphoric acid, and potash..

This year, for the first time, nitrogen fixed within the United States is an important part of the total supply, and for the first time domestic production is going directly into fertilizer. Previously other markets were more attractive to the new industry. It is predicted that the air nitrogen output of United States plants for the current year will be three or four times as great as last year and will be equivalent to some 600,000 tons of Chilean nitrate of soda. For many years those interested in this matter have worked toward a common objective, or an industry comparable to the needs of the country. It seems now that the objective is within reach. In this remarkable advance the fertilizer and fixed-nitrogen unit has played an important part. Its work on phosphates and potash also has a direct and important bearing upon the farming and fertilizer industries.

This unit, by the very nature of its objective, is primarily a technical-research organization, with much activity that may be said to lie within the realm of pure science. Owing to this fact and to the strictly scientific nature of much of the present research of the unit, this report contains considerable material and phraseology that is somewhat technical.

### CATALYTIC INVESTIGATIONS

Chemical industries of the present era and those looming largest on the horizon of the future will be dependent for their very existence upon effective and scientific use of catalytic materials. Accordingly, in the present program of work involving a study of catalytic materials and processes pertaining to the production and utilization of synthetic ammonia, every effort is being made to enable the contributions to be of use in leading to a better understanding of the phenomena of contact catalysis.

In studies of catalytic methods for purifying commercial hydrogen sufficiently to permit its being used in the production of synthetic ammonia, progress during the past year has been marked. It has been found possible to utilize hopcalite catalysts—such as were employed during the World War in gas masks—for the preferential combustion of the 1.5 to 2 per cent CO that remains in hydrogen obtained and purified in the water-gas process. An alternative method of effecting the nearly complete removal of the CO poison from hydrogen has been developed. It involves the use of fused cobalt catalysts promoted in such a way as to eliminate the formation of methane but catalyze the combination of steam and carbon monoxide. Equilibrium determinations in the system cobalt - cobalt oxide - steam - hydrogen have been completed.

The results will be of interest and use to all those utilizing the commercial water-gas process for production of hydrogen. An apparatus for continuous and automatic analysis of the effluent gases from catalyst test bombs for CO, $NH_3$, $SO_2$, etc., has been developed. A study of the two forms of $Fe_2O_3$, the cubic and rhombohedral modifications, has shown the incorrectness of the previously held view that the cubic modification was the more active catalytically. Some interesting characteristics of these materials have been discovered.

Continued effort is bringing to light valuable information relative to the commercial synthetic ammonia catalysts developed during the past 10 years at this laboratory. A quantitative study of the poisoning effects of these catalytic materials under high water-vapor pressure is in progress and is nearly completed. One more valuable link in the chain of experiments tending to show the reason for the difference in the behavior of good and poor synthetic ammonia catalysts will thereby be established. X-ray studies on the synthetic ammonia catalysts and the nitrides formed by interaction of the former with ammonia are being carried out. X rays have been shown to be without effect on the activity of a platinum catalyst used in the catalytic combination of hydrogen and oxygen. In all, eight papers relative to these catalytic processes and apparatus have been published or are in the hands of the publishers of scientific journals.

### PHYSICS INVESTIGATIONS

As the commercial feasibility of a process depends upon the rate of a given chemical reaction, it is of utmost importance to have as complete an understanding as possible of the fundamental principles underlying chemical reactions and catalysis. This information is necessary for a better understanding of present nitrogen-fixation and fertilizer practices in order to suggest further improvements in these methods as well as to evolve new methods. An intensive study of the chemically active properties of atoms and molecules is being made by physical and radiation methods. In many cases these methods are the only ones available for obtaining the necessary information.

The function of a hot surface in the activation of nitrogen and hydrogen in the decomposition of ammonia was investigated by means of the Arrhenius equation. The relative effect of electrons and ions on the activation of nitrogen and hydrogen in the synthesis of ammonia has been determined. A study of ammonia synthesis in a glow discharge has resulted in the discovery of an electrochemical equivalence law in a gaseous discharge similar to Faraday's law for electrolysis, and a theory of the mechanism of the reaction has been advanced.

An X-ray laboratory with five separate installations has been equipped which permits of working with X radiations from 0.2 to 10 angstroms and taking all the standard types of X-ray photographs. Preliminary examinations of soil colloids have been made in cooperation with the Division of Soil Investigations. Diffraction photographs have been made in order to identify solid phases in the ammonia catalyst.

The mathematical work has resulted in the preparation of an electromagnetic chart correlating frequencies, wave length, and energy for radiation. The mathematical analysis of solid

fertilizers and the application of equations of state to gases and gaseous mixtures have also been made. The radiation equipment which is now being assembled consists of an infrared recording spectrometer operating from the visible to 2½ $\mu$, a Steinheil spectrometer to be used in the visible, and specially designed quartz apparatus to be used in the ultra-violet. A cooperative program with the Smithsonian Institution has been inaugurated under which that institution will carry on the more theoretical aspects of the work and this laboratory will apply these principles and methods to nitrogen fixation and to agriculture.

### HIGH-PRESSURE STUDIES

Ammonia, methanol, and certain other compounds are synthesized from gases at high pressures. At the pressures employed the physical properties of these gases can not be even approximately estimated by the laws governing the behavior of gases at moderate and low pressures. Engineering design of high-pressure apparatus and a complete understanding of the chemical equilibria involved in these syntheses depend upon accurate experimental data concerning such properties as compressibility, density, specific heat, heat conductivity, viscosity, vapor content of the gases in contact with liquids, and solubility of the gases in various liquids. Most urgent has been the demand for data on the compressibility of real gases. Earlier measurements on the compressibilities and densities of hydrogen, nitrogen, and mixtures of these gases at pressures from 100 to 1,000 atmospheres and temperatures from 0° to 400° C. have been supplemented by similar measurements at —25° and —70°. Pure carbon monoxide has been investigated at 9 temperatures, from —70° to 200°, and at 13 pressures between 25 and 1,000 atmospheres. Some preliminary work has been done on mixtures of nitrogen, hydrogen, and ammonia. The investigations on nitrogen and carbon monoxide have made available data for more accurate calculation of the specific heat of these gases. With a second complete high-pressure system recently installed, data are now being compiled on the solubility of hydrogen in water. In addition, as a necessary part of the general problem, a method has been devised for accurately determining the amount of inert gas in gas mixtures and for analyzing mixtures of carbon monoxide and hydrogen.

The corrosion tests on steel for ammonia synthesis, which have been under way for some time, will be finished within the next year. Laboratory tests on phosphoric acid corrosion of various concentrations of both purified and crude acid on irons, steels, brasses, bronzes, and metal alloys are in progress. This work is directly applicable to industry, and actual factory conditions are duplicated wherever possible.

### TRANSFORMATION OF NITROGEN COMPOUNDS

In the study of the transformation of nitrogen compounds special emphasis has been placed on such compounds as may be obtained from the utilization of synthetic ammonia. Fundamental studies have been pursued involving the reactions occurring in the synthesis of urea, and a small-scale production plant has been operated. The conversion of urea into a compound of improved physical condition and of sufficient availability for fertilizer use has been investigated and additional progress made in the study of the oxidation of ammonia to nitric acid.

Urea as a compound very high in nitrogen has the advantage from the fertilizer standpoint of being readily soluble and available to the plant. Its value as a fertilizer material has been demonstrated both in this country and abroad, and extensive application probably would follow rapidly its commercial production in quantity. The synthesis of urea from ammonia and carbon dioxide has the commercial advantage of converting the ordinarily gaseous ammonia, produced by the synthetic ammonia process, into a readily soluble solid by combination with carbon dioxide, the principal by-product of the same process. Progress has been made in studying the phase relations of the melt obtained in converting ammonium carbamate to urea. Most of the analytical difficulties encountered have been overcome, and a method has been devised for measuring the vapor pressure of ammonia, carbon dioxide, and water in the gas phase. The data obtained from these studies will be of direct value in arriving at better operating conditions for the urea synthesis and for designing a proper still for the recovery of the unconverted portion of the gas. A redesigned small-scale urea plant has been operated successfully and has

demonstrated that the process can be carried out with little difficulty with a conversion of ammonia to urea so satisfactory as to encourage the prospect of the successful operation of the process commercially.

Efforts have been made to convert urea to a form less hygroscopic without impairing its usefulness as a fertilizer material. Urea readily forms addition products with various substances, one of which is formaldehyde. A study has been made of the properties of the urea-formaldehyde condensation products. The work has progressed sufficiently to show that some of the products obtained are considerably less hygroscopic than urea alone and have physical properties comparable with the more desirable fertilizer materials. The availability of the products has been tested by treatment with nitrifying bacteria and by determining the rate of nitrification. The results obtained give promise of varying the availability of the urea nitrogen as desired. This may be of considerable importance agronomically, as it is often desirable to have slowly available nitrogen in the soil, so that it may be gradually supplied to the crop during the growing season.

Investigation has been continued on the oxidation of ammonia as a source of nitric acid. A converter has been developed for the oxidation with pure oxygen, resulting in a high conversion of ammonia. By employing a converter so designed that there is a rapid removal of heat after the gas has passed the catalyst, high efficiency is obtained and safety of operation with the explosive mixture is successfully accomplished. The method provides for better economic operation through the more effective use of platinum and the recovery of the nitrogen oxides as strong acid. With the employment of cheap oxygen the process for producing strong acid would be considerably cheapened.

### PHOSPHATES

The complete chemical composition of the principal commercial types and grades of phosphate rock produced in the United States, the mechanical composition of ground phosphate rock and the chemical composition of the various fractions separated therefrom, together with the relative colloidal material in phosphate rock, were determined. It is expected that these investigations will clear up many of the questions regarding the composition, constitution, properties, and origin of phosphate rock and point the way to a more rational utilization of the various types of rock for specific purposes, particularly as regards the direct use of the finely ground rock as a fertilizer.

The properties of representative samples of Florida soft phosphate and of the claylike phosphate found in abandoned ponds used to receive the waste materials from Florida hard rock phosphate washing plants was determined with a view to utilizing as fertilizers these materials, which contain up to 60 per cent of colloidal material. The relation between fluorine and the phosphoric acid content of all the commercial types and grades of phosphate rock produced in the United States was determined and results published. A general recovery of the fluorine in the manufacture of superphosphates would result in the production of compounds having a direct value of $3,000,000 annually.

An experimental blast furnace was operated in order to obtain fundamental data on phosphate smelting. The thermal efficiency of this furnace was tested and found to be about 70 per cent. Preliminary data obtained on slag melting gave indications of the proper mixture of slag and coke for operation in the furnace. Tests on the reduction of phosphate rock in the blast furnace have shown that the reduction of the charge does not take place until a temperature close to 1,450° C. is reached. Theoretical consideration of the reactions taking place in the furnace has been made. The results to date indicate the entire feasibility of the process. Improvements in both fuel requirements and recovery should follow with further studies.

### POTASH

Although rapid progress is being made in establishing an American potash industry, the United States expends annually $18,000,000 for potash imported from Europe. The direct treatment of potash or phosphate-bearing raw materials with nitric oxide for the production of materials containing two or more essential plant foods is a problem of economic importance to producer and consumer. A large number of both potash and phosphate-bearing raw materials are suitable for this direct treatment, of which phosphate rock is the example chosen for experimentation. Results show that the phosphoric acid of phosphate

rock is easily rendered available by this method. Under properly controlled conditions a mixture of solid calcium nitrate and dicalcium phosphate is obtained which has many of the desirable physical and chemical characteristics of a good fertilizer. It was also found that by treating a concentrated solution obtained by passing water and nitric oxides in a countercurrent manner over phosphate rock with ground rock or other basic materials, a solid product is readily ob tained which is suitable for fertilizer purposes. This method of treating phosphate rock and other minerals containing fertilizer elements is apparently of real economic importance in that it offers a means of accomplishing simultaneously two essential operations—namely, the fixation of nitrogen oxides from ammonia oxidation as nitrates and the liberation of fertilizer elements present in an available form, which result in the direct formation in one operation of fertilizer compounds containing two or more plant-food elements.

Preliminary studies on the acid extraction of potash minerals for the recovery of various by-products to reduce the cost of the potash, as illustrated by past work with sulphuric acid on greensand, indicate the feasibility of this procedure. The principal acids are being applied to the principal potash minerals, emphasis in the recent past being placed on hydrofluoric acid in its action on Georgia shale and alunite. The success attending present endeavors to utilize blast-furnace design and technic in the volatilization of phosphorus from phosphate rock, combined with previous data established in the experimental volatilization of potash from its ores and economic analyses of proposed large-scale operations including by-product recoveries, strongly indicate the commercial feasibility of this procedure as another means of producing cheap potash, either alone or combined with phosphate. Enlarged equipment and greatly improved facilities have been installed for the more vigorous prosecution of this project now that increased funds have been made available for potash researches.

### CONCENTRATED FERTILIZERS

The present importation of concentrated fertilizers from Germany and the growing demands for fertilizer with higher plant-food content make the concentrated-fertilizer investigations of prime importance. Within a few years the percentage of plant food in fertilizers should be doubled. On the basis of present freight rates this would mean an annual saving to the American farmer of $10,000,000 in freight and about $6,000,000 on sacks on the 8,000,000 tons of fertilizer consumed. Valuable contributions to the design of apparatus and methods of fertilizer analysis have been made during the past year.

The influence of relative and absolute humidities, temperatures, hygroscopicity, size, shape, homogeneity, and specific gravity of the particles and friction in relation to the drillability and application of fertilizers has been investigated. The fertilizer interests were so impressed with the results of this work that added funds were secured for experimental plot work. Studies on the prevention of the caking of fertilizers have been carried out by means of granulation of fertilizer materials by two methods—a nozzle spray and by means of centrifugal action on both the solution and molten material. Industry has taken these results, and it is now considered that the dehydration of fertilizer materials by centrifugal spraying is more economical than any other procedure. The relative hygroscopicity of mixtures of salts containing common ions has been determined. The results are being compiled for publication. The fertilizer manufacturers are now making use of the hygroscopicity data obtained from the bureau in compounding their fertilizer mixtures and are continually relying on it for information relative to new materials as they appear on the market.

Measurements are being made on the solubility of ammonium phosphate in water at different temperatures and of the same salt in varying concentrations of phosphoric acid. These results are indispensable in the successful operation of an industrial plant for the production of ammonium phosphate by the saturation process. Potassium ammonium phosphate has been prepared for the Soil Fertility Division for use in field tests. It has been found that the ease of preparation of this product increases with the grade of the potassium chloride. A study of its physical properties, including drillability, is also being made.

### NITROGEN FIXATION BY LIVING ORGANISMS

The scope of the work dealing with the mechanism of nitrogen fixation by

lower organisms has been considerably broadened during the past year. Work has been conducted with legume nodule bacteria and their hosts, with Azotobacter, and with algae. Studies with chlorophyll have been included as a closely related subproject.

The research on legume nodule bacteria has furnished additional evidence to support the view that these bacteria can not fix nitrogen under ordinary laboratory conditions, when living apart from the host. Work is in progress now which it is hoped will furnish more definite information regarding the relations of these bacteria to the host plant. Morphological studies with the bacteria and the nodules have already suggested additional experiments of a chemical nature which will probably throw light on the mechanism of legume symbiosis.

A study of the gas metabolism of the free-living soil nitrogen-fixing bacterium, Azotobacter, has shown that this organism behaves uniquely toward oxygen gas concentrations, as compared with other living forms. At very low oxygen concentrations (0.1 per cent) they produce dry matter, i. e., grow at the expense of ten to fifteen times less food consumption as measured by total oxygen consumed than in air (21 per cent $O_2$), and at 80 per cent $O_2$ they do not make dry matter at all, although they still use relatively large quantities of food and oxygen. The most recent studies have shown that the various unique oxygen relations, of which one example has been given, are not the result of nitrogen fixation, however, since they obtain similarly when the organisms are fed fixed nitrogen, as ammonia. The actual experimental, as distinguished from the ideal thermodynamic, energy required for nitrogen fixation by Azotobacter has been determined with a fair degree of approximation. Work during the year has demonstrated that certain species of blue-green algae, living autotrophically, can fix atmospheric nitrogen. This type of alga is probably the first chlorophyll-containing organism which has ever been definitely proved to possess the ability to use free nitrogen gas. Certain investigators have claimed that a few higher plants can fix nitrogen, but their findings have not been generally accepted. Since the blue-green algae are widely distributed in soils, fresh water, and sea water, it is likely that they play an important part in adding to the fixed-nitrogen supply of the earth. These studies are being continued.

### ORGANIC INVESTIGATIONS

An understanding of the chemistry and mechanism of nitrogen fixation in nature is being sought by a study of the properties of organic compounds which are present in nature and by attempts to use these compounds as reagents to fix nitrogen. Attempts will also be made to use such other reactive organic compounds as may have the capacity for combining with nitrogen. Included in this study will be a careful consideration of the properties of widely occurring and important compounds such as chlorophyll and related substances. During the past year efforts were directed toward developing the necessary laboratory technic for the preparation of organic free radicals and azo compounds, which are to be used in experiments planned to try to fix nitrogen by means of free radicals.

### ENGINEERING DEVELOPMENT

The design of gas-tight apparatus in glass and metal for use at pressures from a very low vacuum to 15,000 pounds per inch is the basis of much of the work of this unit. The apparatus varied from sensitive radiation, ionization, and microapparatus to high-pressure relief valves, gauges, dead-weight gauges, and booster compressor.

### INFORMATION SERVICE

A continuing demand for information, both technical and economic, on all phases of the work has been satisfied by conferences or correspondence with interested parties, and thus the results of research have been promptly placed at the service of the public. Muscle Shoals has continued to be a pressing problem in Congress and with the executive branch of the Government, and has been the subject of many inquiries. Every effort has been made to cooperate with other Government agencies in order to realize the highest efficiency in the public work.

## PUBLICATIONS OF THE BUREAU OF CHEMISTRY AND SOILS ISSUED DURING THE YEAR JULY 1, 1928, TO JUNE 30, 1929

### TECHNICAL BULLETINS

No. 80. Tests of Blowfly Baits and Repellents During 1926.
No. 94. Soil Reconnaissance of the Panama Canal Zone and Contiguous Territory.

### CIRCULARS

No. 55. Soil Factors Influencing Crop Production in the Arkansas Valley, Colorado.
No. 56. Methods for Determining the Hydrogen-ion Concentration of Soils.
No. 61. A High-Pressure Gas-Compression System.
No. 64. Cyanamid, Its Uses as a Fertilizer Material.
No. 76. Fires in Cotton Gins and How to Prevent Them.

### JOURNAL OF AGRICULTURAL RESEARCH ARTICLES

The Influence of Substituted Cations on the Properties of Soil Colloids.

### SOIL SURVEYS

Harrison County, Iowa.
Jackson County, Minn.
Reconnaissance of West-Central Texas.
Moapa Valley Area, Nevada.
Ogemaw County, Mich.
Lycoming County, Pa.
Olmsted County, Minn.
Henderson County, Tex.
Auburn Area, Calif.
Chattahoochee County, Ga.
St. Marys County, Md.
Lake County, Ohio.
Cherokee County, Ala.
Green County, Wis.
Sheboygan County, Wis.
Fremont County, Iowa.
Harris County, Tex.
Harrison County, Miss.
Greene County, N. C.
Bishop Area, Calif.
Jones County, Iowa.
Macomb County, Mich.
Hillsdale County, Mich.
Minidoka Area, Idaho.
Worcester County, Md.
Rutherford County, N. C.
Lawrence County, Mo.
Cherokee County, Iowa.
Buffalo County, Nebr.
Walworth County, S. Dak.
Antrim County, Mich.
Isabella County, Mich.
Calhoun County, Ga.
Randolph County, Ga.
Lamar County, Ga.
Barry County, Mich.
Livingston County, Mich.
Berkshire County, Mass.
Garden County, Nebr.
Platte County, Nebr.

### FARMERS BULLETIN

No. 1590. Fire-Protective Construction on the Farm.

### MISCELLANEOUS

Analyses of Some English Bookbinding Leathers (joint publication of Government Printing Office and Department of Agriculture. Published and printed by the Government Printing Office.)

### YEARBOOK ARTICLES

Nitrogen Loss from Soil by Leaching Is Largely Preventable.
Organic Materials May Hurt Crops if Applied Undecayed.
Lawn Grass Aided, Weeds Checked by Ammonium Sulphate.
Avocado Culls May Prove Source of Oil and Livestock Feed.
Soil Bacteria Useful to Farmers May be Caused to Multiply.
Belt Failure Often Caused by Neglect or Faulty Installation.
Soil Deterioration by Sheet Erosion Lowers Fertility of Vast Area.
Fire Risk in Country Grain Elevators Not Recognized Enough.
Food Spoilage, Which Causes Heavy Losses, Due to Many Causes.
Cake of Different Kinds Needs Flour of Different Kinds.
Canning of Vegetables by New Steam Process Holds Flavors Better.
Coloring of Mature Fruit by Ethylene Gas Unobjectionable.
Cod-liver Oil in Feeds Requires Care to Preserve Vitamin.
Food Colors Certified by the Department are Both Harmless and Pure.
Dust-Explosion Hazard Exists in Nearly all Manufacturing Plants.
Dyes Important Both in Diagnosis of Disease and as Medicinal Agents.
Fertilizer Known as Double Superphosphate Has Useful Properties.
Fertilizer Concentration Need Not Increase the Risk of Burning Plants.
Iodine Survey Planned in Studies of Minor Constituents of Food.
Harness Life Can Be Doubled or Trebled by Cleaning and Repairing.
Soil Particles That Glitter Are Often Mistaken for Gold.
Molds Pressed Into Service in Utilizing Some Farm Products.
Nitrogen Supply of United States Much Dependent on Imports.
Sugar Cane Requires Nitrogen As Chief Plant-Food Element.
Insecticide Residues Removed from Fruit by Various Washes.
Light Rays a Factor in Helping to Solve Many Farm Problems.
Insect Poison Called Rotenone Highly Toxic But Costly at Present.
Soil Survey in 25 Years Maps More Than Half Our Arable Land.
Urea Demonstrated to Be Valuable As Nitrogen Fertilizer.
Sweet Potatoes As Possible Source of Starch Investigated.
Peat Deposits Under Some Conditions Are Serious Fire Hazard.
Pecans Respond to Commercial Fertilizer When Rightly Applied.
Potash Production in United States Increasing Though Still Far Below Needs.
Insecticide Research Develops a Promising Substitute for Nicotine.

U. S. GOVERNMENT PRINTING OFFICE: 1929

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 5 cents