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December 1, 1930

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U. S. Department of Agriculture

**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 6, 1930.

SIR: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1930.

Respectfully,

HENRY G. KNIGHT,
Chief of Bureau.

Hon. ARTHUR M. HYDE,
Secretary of Agriculture.

INTRODUCTION

The Bureau of Chemistry and Soils is primarily a research and fact-finding organization whose activities cover a wide range of subject matter pertaining to land utilization, soil fertility, fertilizer resource development, and the utilization of agricultural products of various kinds. The bureau has for its objective 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 and utilization of American soils and to crop-production and crop-utilization problems of regional and national importance.

The bureau is actively prosecuting investigations and research on 559 subprojects under 131 major lines of inquiry recognized as projects. These major lines of inquiry to all intents and purposes are continuous or at least cover a period of years, whereas the subprojects, which represent the detailed activities of the bureau at any given period, have time limits placed on them, and when completed they are succeeded by others usually in the same 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. Direct attack upon some of these problems, however, in the absence of essential fundamental knowledge would be wasteful of funds and energy. Search for the fundamental knowledge is therefore often necessary and it may lead 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 devel-

opment of skilled technic, intelligent and discriminating analysis of results, and ability of a high order to make the necessary practical applications.

It is the policy of the bureau to encourage the development of more research in the realm of pure science, always, however, with the definite objective of solving some practical problem. The results of such research may have a very wide application in fields far removed from agriculture or industries based on agriculture so that in such cases the bureau contributes materially to the advance of science in general. Research for research's sake without regard to practical applications in the fields assigned to the bureau has no place in this organization.

Much of the work of the bureau is carried on in cooperation with the States and in a few instances with industrial groups. For a period of more than 30 years the soil survey has been conducted on a national scale. This work has been in cooperation with the several States usually on a basis whereby the States have shared expenses equally with the bureau. Soil-erosion work is now carried on in cooperation with five States. Much of the soil-fertility work is in cooperation with the agricultural experiment stations of the several States, and wherever it seems practical and desirable other research is carried on cooperatively. Very close contacts are made with industrial groups utilizing agricultural materials or manufacturing finished products primarily for use on the farm.

The interest of the farmer should not terminate with the production of his crops, but he should be in 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, therefore, should function not only as a research agency to increase efficient unit production but it 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. Painstaking research and the application of the results to the problems of industry is the only way that this may be brought about. New industries have arisen during the past few years which use as their raw materials the products of agriculture. The utilization of waste and residue for industrial purposes is a subject which is receiving careful attention, and the possibilities in this field appear to be great. 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. If the history of the past is to be repeated the waste of to-day will become important raw material for the use of industry to-morrow.

More than one-half of the agricultural area of the United States has been surveyed by the bureau. Until we have a better knowledge of the soil resources of the United States, land classification on an

intelligent basis and effective land utilization based on sound principles are practically impossible. Furthermore, much of the soils work of the bureau and of the States is based on the soil survey. It is encouraging to note that 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.

Probably no industry depends more on research for its prosperity and its economy of operation than does the fertilizer industry. Research in this field aimed at economy of production reflects direct benefit to agriculture in the form of cheaper and more satisfactory sources of plant-food materials. Such researches are primarily functions of the Federal Government, since they are directed to the development of a more efficient national agricultural program.

The nitrogen-fixation industry in the United States seems to be making satisfactory progress. The phosphate industry has been very well stabilized, based on well-known practical methods, but new methods are being developed and put into use which will have a direct bearing on the concentrated-fertilizer industry. America has rather large sources of potash, but most of it is locked up in a form that can not readily be made available. The bureau is prosecuting special investigations in an attempt to perfect commercial methods for extracting potash from potash-bearing silicates, which are widely scattered over the country.

The use of fertilizers in agriculture is increasing, and 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 economical methods be developed for their preparation in satisfactory forms for use on the land. The increased use of mineral fertilizers, the large increase in the use of mechanical power replacing animal power, and the possibility of making larger use of agricultural residues in industry raise some very important questions in regard to the soil organic matter and its maintenance. These problems are being given careful attention by the bureau.

There has been a marked increase in the number of departmental publications from this bureau during the past fiscal year. A total of 60 departmental publications has been published from July 1, 1929, to June 30, 1930. This number includes 48 soil-survey reports, 8 technical bulletins, 3 circulars, and 1 miscellaneous publication, which represents a very marked increase over the number of technical bulletins published last year, and an increase from 40 to 48 soil-survey reports. Four articles by members of this bureau, published in the *Journal of Agricultural Research*, are not included in the 60 publications mentioned above.

The soil-survey reports published during the year contained descriptions and maps of soils in 20 States and cover a total of millions of acres of agricultural lands. The soil surveys are becoming increasingly helpful to farmers as practical handbooks for working out local agricultural problems.

The technical bulletins published in 1929-30 present valuable information on soils and chemical and technological research along agricultural lines.

In addition to the departmental bulletins, 109 articles by scientific workers of the bureau have been published in technical and scientific journals, magazines, and other publications, thus furnishing the public and other scientists the latest information on the progress of various lines of research carried on by the three units of the bureau.

The bureau has greatly increased its output of information to the press within the past two years and through its editorial office has prepared releases of timely interest on the varied work of its units. It is constantly cooperating with the press service and the radio service of the office of information of the department in supplying information to the public and to the special or regional groups to which it might prove of service.

In addition to the large number of departmental publications and the informational service supplied by the bureau, there have been sent 42,000 letters of information in reply to inquiries received in the various offices of the bureau's three units during the past fiscal year.

A number of leaflets and circulars are being prepared or printed with the purpose of supplying much of the information which the bureau has hitherto sent out in letters.

CHEMICAL AND TECHNOLOGICAL RESEARCH

The chemical and technological research of the bureau has as its main object the more complete and profitable utilization of products of the farm, ranch, and orchard. Such researches are at times abstruse and fundamental, but usually they have either directly or indirectly an economic outlook. The results have an important relation to the conservation of our national wealth and energy. Most people look upon conservation as the hoarding up, the storing away, or the holding in reserve of our forests, agricultural lands, and oil supplies, but a far more important conservation in the economic life of a nation is that which aids in the most complete utilization of its products. For instance, from a purely economic standpoint it is more important fully to utilize the hide of a farm animal in some form of leather than to produce an additional animal; it is more important fully to utilize the oil, the protein, and the coarser parts of wheat than to grow an additional bushel of wheat per acre; it is more important to utilize the cull fruit or vegetable, the undersized, the oversized, the odd-shaped product which is not acceptable in ordinary commerce, than to develop new orchards and produce additional yields of fruits and vegetables. For in such farm by-products, as they are sometimes called, a part of our national wealth is spent, represented by the fertility of the soil, which in a final analysis is an all-important factor in our national resources and in our national existence.

CARBOHYDRATE INVESTIGATIONS

CANE SIRUP

A more complete utilization of cane juice for sirup production and the adjustment of quality in relation to market requirements are of vital interest to the producers. Investigations of methods of manufacture of cane sirup from last mill juice have been continued,

and a procedure has been worked out whereby a blending sirup of satisfactory quality may be produced from last mill juice at reasonable cost. This information has been placed at the disposal of a number of sirup producers, and it is expected that it will be put to commercial use.

Investigation of the cause and remedy for "swells" in canned cane sirup was continued. This type of swells has caused severe losses to the cane-sirup industry. By preliminary "incubation" at elevated temperature it was possible to distinguish in advance sirups having a tendency to produce swells.

Research on the origin of the flavor of Barbados sirup has disclosed important information, and there has been isolated from this sirup an anaerobic bacterium which produces the typical Barbados flavor when introduced into domestic sirups. This flavor was in some cases much more pronounced than that of Barbados sirup, so that the next problem is to determine the conditions necessary for controlling and producing the exact degree of flavor desired.

Work on the standardization of cane sirup, which is produced on about 275,000 individual farms, is being continued.

CANE SUGAR

Investigation of the basic principles of clarification of cane juice and application of this information to the solution of problems of importance to the cane-sugar industry were actively continued. In work of this kind lies the greatest opportunity, aside from increase in the sugar content of the cane, to increase the net yield of sugar and thus offset to some extent low prices resulting from excessive production. Poor quality of raw sugar is exhibited in various ways, but one of the most tangible is the poor filterability of the raw-sugar melts in the refinery. Various methods of fractionating the extraneous material were used, and there were established maximum and minimum limits within which this material had adverse effect. Information regarding the composition of this material was also gained.

The work on methods of utilization of sugarcane in Louisiana concerned specific Louisiana problems pertaining especially to production of direct-consumption sugar on the plantation and production of molasses of improved quality. Here again clarification of the juice is the basic factor. Flavor and quality of molasses of table grade are also adversely affected by frost, with resulting financial loss. Consequently a special procedure which could be used for clarification of juice from frosted cane would be of very great value. Efforts were directed along this line, and important advances were made.

BET SUGAR

A satisfactory method for automatic control of pH in second carbonation of sugar-beet juice was devised and indications given whereby this information could be applied to third saturation of the juice.

The low price of sugar during the last few years has resulted in increased discrimination as to quality. Cooperative investigations

were conducted at several beet-sugar factories with respect to use of activated carbon for removing undesirable nonsugars. Some experiments were also made on use of other reagents for increasing elimination of nitrogenous compounds in the diffusion juice at the beginning of the beet-sugar process. Results to date have indicated modifications at several points in the present beet-sugar process, including also use of a small proportion of activated carbon, whereby the quality of beet sugar can be greatly improved at a reasonable cost.

MAPLE PRODUCTS

The principal work done on maple-sirup color standards during the year was the improvement and accurate definition of the standards, thereby correcting a rather demoralizing condition which has existed during the past few years as a result of variation in color standards from different sources. In many cases the variation has amounted to one and even two grades, which may be a serious matter to the producer in selling maple sirup.

The original color standards used in the industry were based on caramel made from refined sugar. It was found that, even with the most carefully controlled technic, the color varied considerably, due to slight variations in the quality and nature of the nonsugar contaminants which are always present to some extent even in the highest grades of refined sugar. The color standards were evaluated accurately on a spectrophotometric basis and a method devised whereby accurate and constantly reproducible caramel solutions can be made. Master color standards were furnished marketing organizations and State departments of agriculture and marketing bureaus in the various maple-products States. On the basis of the master standards these organizations prepared a large number of color-standard sets for distribution to individual producers throughout the States in question. This work is being continued in an effort to devise suitable and inexpensive permanent color standards.

HONEY

Improvements have been made in the method of determining the diastase value of honey. It was found that the diastase value varies considerably with the floral source, orange and alfalfa honeys being naturally deficient, whereas certain other types, such as buckwheat and sage, showed unusually high values. In general, the darker honeys showed a higher diastase value than the lighter samples. An endeavor is being made to classify domestic honeys more specifically, taking into account their variation in composition in relation to variations in properties. When such a survey and classification as is under way has been completed, the suitability of honeys for certain purposes will be much more apparent. As a part of this program an investigation of the colloidal constituents of honey has been started, representing an entirely new point of view in approaching this problem. It is believed that constituents of colloidal character not only are primarily responsible for the dark color of many honeys but are also concerned in the decomposition reactions and excessive discoloration apparent on heating honey.

MILK SUGAR

Investigation was made of the behavior of lactose in several kinds of candy and its possible suitability and advantage as one of the recognized ingredients thereof. This work was undertaken in the interest of the dairy-products industry, at the suggestion of, and in cooperation with, the Bureau of Dairy Industry. At present large quantities of sweet whey are wasted or inadequately utilized. The results so far obtained indicate that lactose, when used in certain proportions, is a valuable ingredient of hard candies, especially in that it tends to reduce hygroscopicity, which is one of the great problems in handling such candies.

SWEETPOTATOES

Experiments to ascertain the suitability of sweetpotato starch for commercial use were continued, and results so far indicate that commercially satisfactory conversion products can be made from it. Means were also devised whereby sweetpotato starch can be refined to a higher degree of purity. An investigation is now under way with reference to the possibility of more effectively utilizing cull sweetpotatoes so as to avoid the loss of any constituents. This study will be undertaken with the idea of using the culls for starch and starch-conversion products, for vinegar, and for cattle feed.

MISCELLANEOUS INVESTIGATIONS

About 50 wild domestic plants have been subjected to a preliminary chemical examination with a view to devising means for their utilization. One of the most interesting results obtained was with wild licorice. The glycyrrhizin content of this plant suggests the possibility of producing our own supply of licorice in this country. Investigations on corn sirup and corn sugar will be continued; also on the wider utilization and closer standardization of sorgo sirup.

CROP-CHEMISTRY INVESTIGATIONS

With the object of improving the quality of that part of the food supply of the United States which is derived from crops the bureau is engaged in scientific study of the factors affecting the quality of American crops, in order to discover such modification of present farming practices as will aid in effecting improvement.

During the past year experiments have been conducted on plots at the Arlington Experiment Farm, Rosslyn, Va., in which the effects of sodium nitrate fertilizer in increasing the protein content of wheat were compared with the effects of various modern synthetic nitrogen compounds. So far the results have been the same, although no final results can be reported, as the growing of wheat in the plots is being continued.

Experiments have also been continued to determine the extent to which the phosphorus content of wheat can be increased by special fertilizer applications. The influence of acidity and other factors on the absorption of phosphorus by wheat plants has been investi-

gated, and data obtained to guide the applications of fertilizers to the wheat plots on the Arlington farm.

Methods of determining the manganese content of cereals and the absorption of manganese by growing plants have been extensively studied, and several improvements have been made in existing methods. It has been found that ammonium persulphate can advantageously be used in determining manganese in plant materials. The absorption of manganese by young plants has been studied and some of the principles governing absorption worked out.

A number of culture experiments with wheat seedlings have been conducted, and certain principles governing absorption of nutrient elements have been formulated.

Much analytical work has been done in determining the inorganic constituents of the wheat in which lignin is also being determined. It has been found that relations can be traced between the amounts of several constituents and the nitrogenous fertilizers added, which also affect the lignin content.

As great interest is being shown in the soil-reaction preferences of plants of both horticultural and agricultural significance, most of the work under this project has consisted in furnishing information to the public. A manuscript has been prepared for a bulletin in which the questions most frequently asked have been answered, and the most elaborate list of soil-reaction preferences of plants yet compiled has been included.

FOOD RESEARCH INVESTIGATIONS

CITRUS BY-PRODUCTS

The possibilities of wider and more profitable utilization, in Florida, of citrus by-products, particularly those of grapefruit, were investigated. Visits were made to ascertain the possibilities of by-product utilization in connection with grapefruit canneries in California and Texas. Special problems of the canning industry were studied for the benefit of canners and orchardists in these States.

The production of pectin, grapefruit oil, and cattle food from the waste of grapefruit canneries was studied. The canned grapefruit industry of Florida has been developing rapidly. It is estimated that had it not been for the setback caused by the Mediterranean fruit fly, more than 25 per cent of the Florida crop would be canned. A very timely investigation of the possibility of utilizing the waste from grapefruit canneries has been undertaken. This project is of special significance owing to the fact that the waste from such canneries must undergo treatment in order to destroy the eggs and larvae of the fruit fly.

PRESERVATION BY FREEZING

With increased facilities for the storage and distribution of food products at greatly reduced temperatures, the question has arisen whether many of the fruit juices which undergo deleterious changes on sterilization can not be satisfactorily prepared by freezing. The greatly reduced cost of solid carbon dioxide (known commercially

as Dry Ice or Nu Ice) prompts the investigation of the possibility of preparing, shipping, and distributing fruits and fruit juices to the housewife in a frozen condition. This investigation is progressing, and there are now in storage several hundred packages of citrus and other products which have been frozen at temperatures ranging from 30° to 50° F. below zero. The possibilities of the different types of packages are being investigated and methods devised for packing the products in inert gas and under high vacuum. It is felt that the next few years will show a marked change in food distribution, with frozen foods playing a very important part in household economy.

The following frozen products have been prepared and are now in storage for observation and study: Orange juice, grapefruit juice, lemon juice, pomegranate, Logan blackberry, pineapple, and several blends of the foregoing. In addition, orange slices and grapefruit hearts in juice and sugar sirup, pineapple, banana, and avocado have been frozen and stored. These products have been packed in crown cap bottles, friction-top cans, and jars sealed under vacuum. In addition to these experiments, some of the products were treated with carbon dioxide prior to packaging.

DEHYDRATION AND SUN DRYING

Studies on the sulphuring of apricots and peaches have been successfully advanced. The fruit was prepared and in most cases picked by men in the field and after sulphuring was dried in the sun in the manner prescribed by commercial dry yard practice. When partly dried it was stacked and the drying completed. The moisture content was reduced to about half that usually found in growers' stock. This was done to keep the samples in as fine shape as possible for the work which was to be carried out later in the year.

It was found that while there are some exceptions, the general trend of grade is correlated with sulphur dioxide retention. The higher the content of sulphur dioxide the better the appearance of the sample, but there is no doubt that samples running around 80 grade are satisfactory in appearance and that it is unnecessary and undesirable to make the fruit translucent if doing so requires excessive sulphur dioxide.

It seems there is little difference between the 2, 3, and 5 hours of sulphuring, as far as the quality of the fruit is concerned.

As there is practically no difference shown in the 100°, 110°, and 120° F. temperatures, the best quality of fruit, taking sulphur content into consideration, was sulphured in 3 per cent concentration of sulphur dioxide, two to three hours at 110° to 120°.

The 100 samples of dried peaches obtained as a result of this work had been given about the same treatment as the apricots. The peaches, however, do not retain the sulphur dioxide to the extent that the apricots do. The most favorable concentration for peaches was 5 per cent. The most favorable time was 3 hours, the 5-hour samples being inferior to the 3-hour. Temperatures from 100° to 120° were most satisfactory.

A study is being made of the relation between the total contents of sulphur and of sulphur dioxide in dried apricots and peaches,

sulphured and unsulphured. Cooking experiments are under way, designed to ascertain whether there is a considerable loss in sulphur dioxide during cooking, and whether this loss, if any, is due to volatilization of the sulphur dioxide or to its oxidation.

EFFECT OF ETHYLENE ON FRUITS AND VEGETABLES

It has been demonstrated that in seasons when pears do not soften readily they can be treated economically with ethylene gas and are then ready for canning. The process usually eliminates sorting, except that which normally occurs on the preparation tables. It has also been demonstrated during the past year that pears may be treated under canvas with satisfactory results. Tests have shown that the varieties of apricots which tend to mature unevenly—one side softening while the other remains hard—can be harvested and softened by means of ethylene treatment so that the fruit will soften uniformly and its availability for canning be greatly increased. Actual cannery tests demonstrated that the proportion of soft fruit is increased and that of hard green fruit materially decreased by this treatment.

Work with tomatoes has shown that in all cases the treated fruit colors at a somewhat faster rate than the untreated fruit kept at the same temperature and not in direct sunlight, also that there is a slight but constant decrease in acidity of the juice of the treated sample.

A total of 18 samples of celery were treated with ethylene; they included Utah Chinese, a self-blanching Long Top, White Plume, and others. In all cases the treatment had but little effect. Where the type is self-blanching, an unimportant change occurs, but where the green celeries are treated, no effect is obtained, and these are the types that might be greatly benefited.

FOOD SPOILAGE AND DETERIORATION

The commercial preparation of mayonnaise is a rapidly growing industry, the value of the product in 1928 being estimated at \$16,500,000.

The effect of different grades of eggs and egg products on the quality of mayonnaise was studied. Bacterial counts on the samples of egg yolks showed that even those of fresh eggs contained fairly large numbers of microorganisms. While the original egg yolk contained large numbers of bacteria, the resultant mayonnaise gave fairly low bacterial counts. This study showed that in the manufacture of mayonnaise large numbers of the microorganisms causing the decomposition of the egg yolk were killed during the preparation of mayonnaise.

Samples of egg yolk were stored in such a way as to determine the effect of the following conditions: (1) Oxidation, (2) enzymic activity, and (3) bacterial decomposition. These experiments demonstrated that bacterial activity alone increased the time of the consistency test, whereas oxidation and possible enzymic activity also had a similar effect.

The pin-spot molding of shell eggs which causes an annual loss of thousands of dollars has been investigated. Experiments were made to determine the conditions which contribute to the development of the external pin-spot mold. The eggs were treated as follows: (1) Washing, (2) oil processing, (3) packing in moist flats and fillers, (4) sweating, (5) packing in green shook, and (6) no treatment of normal eggs. The eggs were examined from time to time and finally removed after six months storage. None of them showed the development of pin-spot mold except those packed in green wood cases.

A method has been devised for the oil coating of eggs under vacuum. This process results in a somewhat better seal of the shell by the oil than results in those dipped at room pressure. Determinations of the loss in weight of oiled and unoled eggs have shown that the oil coating of shell eggs markedly inhibits shrinkage under ordinary cold-storage conditions. Application of the oil by the vacuum method results in even less shrinkage than in eggs dipped under atmospheric pressure.

PRESERVATION OF FOOD PRODUCTS

Studies of the waterless canning of nonacid vegetables have been continued by the experimental canning of whole-grain sweet corn. Several cases of the product have been canned under different test conditions and examined for vacuum and flavor. Experiments have shown that in the preparation of corn by this method the most practical length of scalding is approximately 10 minutes and the best method for seasoning is the addition of salt in the form of a saturated brine.

The fermentation of turnips into sauerkraut was tested in the laboratory and found entirely practical. Sufficient sugar is present in the ordinary turnip to support fermentation to the desired acid content. The product is pleasing in flavor, and, aside from general appearance, is not unlike good cabbage sauerkraut.

FERMENTATION AND HEATING OF FARM PRODUCTS

Laboratory heating experiments were conducted with moistened salted and unsalted alfalfa hay. No heating was recorded under anaerobic conditions, but heating occurs in the presence of air. Thirty per cent moisture was found to be the optimum moisture content for microbial heat production. The addition of 5 per cent salt failed to prevent microbial heating. However, salting was found to induce considerable delay before heating started, depending on the relation of the amount of salt to the total moisture. The addition of 2 per cent salt prevented bacterial growth but failed to prevent mold development, although the growth of the mold was considerably delayed. Results would indicate that the prevention of molding and spontaneous heating of hay by the addition of salt would only be efficient under such conditions as would allow for drying below the critical point for mold development within the short period of delay caused by the salt.

MILLING AND BAKING INVESTIGATIONS

A billion dollars worth of cake is made annually in this country from 5,000,000 barrels of flour. Recent work has shown that as good, and often better, cake can be made in the laboratory by mixing all the ingredients together and at once than by following heretofore approved directions which call for creaming the fat and sugar first and then adding the other ingredients. This, if found practical in a commercial bakery, will simplify cake baking, save time and considerable labor, reduce the cost, and no doubt increase consumption.

The early stages of rancidity in rice and rice-mill products has been studied. This is preliminary to the work which is being carried on in the study of rice bran and rice polish, which readily turn rancid. One method of treating these products has been to incorporate with them some vehicle like molasses and to subject the mixture thus prepared to a high pressure (about 1,000 pounds). In this way it is believed that as a result of excluding the air these perishable products will not become rancid so soon. Furthermore, the bulk of these products is materially lessened.

Flour obtained from germinated grains (chiefly legumes) has been added to the extent of 2 per cent to wheat flour and a greatly improved loaf produced. The results indicate that the length of time of germination exerts a material influence on the quality of the loaf. Considerable work is still required to determine the optimum germination period needed to produce the best effect, as well as the optimum amount of material which should be added to the flour.

PHYTOCHEMICAL INVESTIGATIONS

A study of the progressive changes in the waxlike coating on the surface of the apple during growth and storage has been brought to a successful conclusion.

With the particular object of determining the progressive changes which occur in the composition of this waxlike coating, analyses were made of summer, fall, and late varieties of apples at several stages of growth and after storage at 32° F.

Results of these analyses, expressed in milligrams per 100,000 mm. of apple surface, indicate that there is an increase in ursolic acid, oily fraction, and total ether extract throughout the ripening period and during storage.

In general, larger quantities of ursolic acid and total ether extract are deposited on the shady than on the sunny side of the same apple, whereas there seems to be no appreciable difference in quantity of oily fraction. As a result, the percentage of oily fraction in the total ether extract is lower on the shady side.

The change in physical properties which the waxy coating of apples undergoes as the fruit ripens may be an important factor in the formation of certain odorous constituents. A decrease in permeability might readily restrict the exchange of carbon dioxide and oxygen to such an extent that an intercellular gas condition would be reached similar to that found by Thomas in which certain concentrations of these gases resulted in the formation of abnormal quantities of acetaldehyde.

A preliminary study of the permeability of apple membranes (cutin and epidermis) to water has indicated that considerable variations exist among varieties.

During 1930 supplies of raw cutin, oily fraction, and ursolic acid have been collected for future investigations.

CHEMISTRY OF PLANT PRODUCTS

A study of the acid of the blackberry, isocitric acid, was made with the object of establishing the identity or nonidentity of the blackberry acid with synthetic isocitric acid. It was found that the synthetic acid corresponds to the inactive form of the natural acid. The results of this investigation have added to our knowledge of fruit acids and will be of special interest to the food analyst.

Analyses were made of 15 samples of Indian foods for moisture, ash, crude fiber and fat, insoluble solids, pectin, etc. (This work was done in collaboration with the carbohydrate division which is making an investigation of the carbohydrates in Indian foods.) A complete analysis was made of the ash of *Camassia esculenta*, which gives promise of having commercial possibilities.

An investigation of the organic acids in 15 samples of honey of different floral varieties from different parts of the United States (including one from Hawaii) was completed. The volatile acids of honey are small in quantity and were found to consist mainly of formic and acetic acid. Many of the samples contained traces of succinic acid, and malic and citric acids were found in all. Only of tulip honey was it possible to isolate the acids as esters and to distill the ester fractionally. In the case of orange honey it was found possible to isolate and identify methyl anthranilate, an ester of delightful odor, to which the aroma of orange flowers is largely due.

A chemical investigation of green vegetables was undertaken primarily because a question arose as to the desirability of spinach as a food on account of its oxalic acid content. Therefore, the work began with an investigation of the acids of spinach. Only one sample of spinach thus far has been examined, and it was found to contain 0.32 per cent of oxalic acid (in the form of salts) in the fresh vegetable, in addition to citric acid and a small amount of a malic acid.

A similar investigation of broccoli, is in progress, and results have already shown that this vegetable contains much less oxalic acid than does spinach. A complete analysis of broccoli is in progress.

At the request of the Office of Cereal Crops and Diseases of the Bureau of Plant Industry, an investigation was started on the organic acids of wheat seedlings. The predominating nonvolatile acid in a water extract of wheat seedlings was found to be l-malic acid. Considerable quantities of aconitic and citric acids, a small amount of malonic acid, and a trace of oxalic acid were also isolated.

The effect of arsenical sprays on the composition of oranges is being studied. Heavily sprayed oranges were found to contain from one-seventh to one-fourth of the normal free acidity of the unsprayed fruit. Heavily sprayed fruit was also found to be lower in sucrose, although the total sugar was not appreciably affected.

Overspraying seriously lowers the market value of the fruit. A study is being made of the effect of processing oranges in compliance with the department's requirement for shipment from certain sections of Florida. It was thought that the treatment might cause some inversion of the sucrose present, but none has been detected. Some changes taking place in oranges in cold storage are also being studied in connection with the work on the effect of arsenical sprays and of processing.

INDUSTRIAL FARM-PRODUCTS INVESTIGATIONS

HIDES AND SKINS

Under present conditions it is necessary to buy from foreign sources about one-half the hides and skins used by our leather industry, yet each year in this country millions of dollars worth of hides and skins are lost because of wasteful practices in handling them before they reach the tannery. Conservation of these essential leather-making raw materials is the primary object of the work under this project.

SKINNING AND CURING HIDES

More than 500 personal calls on butchers and dealers have been made by the bureau's hide experts. Methods actually employed in skinning and curing have been noted, and ways to improve them and eliminate waste have been explained and demonstrated. The practical value of the work is demonstrated by the fact that requests are being received from hide dealers to have our hide specialists call on their customers from whom shipments decidedly off in quality are being received. Some butchers have almost entirely abandoned the use of old, bloody salt, and they are receiving more for hides and skins as a result of following the instructions and advice of the hide specialists. The indifference of many producers is caused by lack of standardized grades. Work is being done in cooperation with the Bureau of Agricultural Economics in acquiring data on which to base grade descriptions and specifications.

SALT STAINS

Investigations on salt stains, which cause especial damage to the grain of calfskins, have been continued. Another type of damage known as "reddening" is also being studied. Using nearly sterile, well-salted skin and a red, salt-tolerant organism isolated from a salted hide, a bright red discoloration strikingly like the pink or red color frequently occurring on frigorifico, or South American packer hides, has been reproduced. This reddening of hides and skins has been the subject of much controversy between sellers, buyers, and ocean carriers. The above experimental result is but preliminary, and much remains to be done to establish its identity, but there is evidence that the organism causing reddening occurs only in certain salts.

TANNING MATERIALS

Means to conserve the rapidly diminishing domestic supplies of tanning materials and the development of new sources of material and of more economic processes of tanning are being investigated. Samples of many trees obtained from different foreign localities by the office of forest pathology, Bureau of Plant Industry, have been examined for tanning content. Fifty-two samples of *Castanea crenata* and eight samples of *C. mollissima* have been obtained so far. Both the bark and wood of these specimens are being examined for tannin. The results indicate that the tannin content of the wood of these *Castanea* is as high, if not a little higher, than that of American chestnut wood. Other properties of these materials, including especially the quality and color of the leather made with them, remain to be determined.

Specimens of Chinese chestnut trees grown on the department's experiment farm at Bell, Md., have also been examined for comparison of their tannin content with that of the American chestnut tree and for the purpose of correlation of analyses of these trees with analyses of the upper branches of domestic-grown Chinese chestnut trees in order that the latter may be rated, according to tannin content, for seed propagation.

VEGETABLE-TANNED AND CHROME-RETANNED SOLE LEATHER

Experiments to obtain comparative data on tannage and wearing quality of vegetable-tanned and chrome-retanned sole leather showed that on an average the light to medium retanned chrome sole leather, even though thinner than the vegetable-tanned leather, wore from 60 to 80 per cent longer. The wear of chrome-tanned sole leather decreases as the amount of vegetable retanning is increased. In respects other than wear resistance, vegetable-tanned sole leather is superior. Chrome tanning is much faster than vegetable tanning. The natural supplies of vegetable tanning materials are gradually decreasing. These experiments point out the desirability of developing a leather combining the greater wear of chrome tannage with the good properties of vegetable tannage. The development of such a product is worthy of most serious and concerted efforts, since it would decrease our dependence on foreign sources of hides, conserve vegetable-tanning materials, give the people a product of lower production cost and greater serviceability, and reduce materially the slow turnover of the present process for vegetable-tanned, heavy leathers.

BOOKBINDING LEATHERS

Investigations on the deterioration of bookbinding and other leathers have been continued and show that a number of factors contribute to the decay of leather bindings, chief among which is the presence of harmful acids, either left in the leather from finishing processes or taken up from the atmosphere, which numerous investigations, abroad and in this country, have shown conclu-

sively is usually contaminated to a greater or lesser extent in the vicinity of large cities or manufacturing centers. Work is being done on the prevention of damage from contaminated atmosphere.

Formulas for making several preservative dressings and directions for applying them are contained in a leaflet entitled "Preservation of Leather Bookbindings" now in press.

During the year more than 80 bookbinding leathers have been examined and analyzed for the Government Printing Office. The results compared with those obtained several years ago on corresponding bid and award samples show a general improvement in quality, and it may reasonably be expected that bindings made with these leathers will prove to be more durable and economical.

PAPER AND FIBER BOARD

Plant fibers (including wood) are the principal raw material for the manufacture of paper and fiber board, the annual production of which in the United States amounts to about 12,000,000 tons, with a value of about \$1,000,000,000. With fibrous by-products amounting to millions of tons annually, agriculture is keenly interested in the paper and fiber-board industry as a possible purchaser of such by-products. The object of the work being done on paper and fiber-board investigations is to acquire and disseminate information on the possibility and practicability of utilizing agricultural by-products in making paper and board and on the chemical and physical properties needed in papers to be used for specific purposes.

BAGASSE AND CORNSTALKS

During recent years widespread interest has been shown in the utilization of cornstalks, bagasse, straw, and other agricultural by-products for making paper and fiber board. Economic considerations bearing on this subject have been given careful attention, and close contact has been maintained with experimental and industrial developments. There have been many calls for information on these subjects from officials in this department, from Members of Congress, and from the general public. A circular was prepared and distributed to correspondents seeking such information.

Paper and boards have long been made on a commercial scale from straws. Within recent years the production of insulating and building board from sugarcane bagasse and straw, as well as from wood, has become fully established, with the consequent development of a limited market for these by-products of the farm.

DETERIORATION OF PAPER

Some years ago the Secretary of Agriculture, anticipating the almost certain destruction within a comparatively short time of priceless legal and historical printed and written records, and realizing the necessity for having the most durable papers for keeping such records, directed the bureau to inaugurate work on the durability of paper and its suitability for various purposes, and to work out specifications that would insure more durable and more suitable papers for Government and commercial use. The paper used by the

Federal Government is purchased upon specifications prepared largely as a result of this research activity.

In the continuation of this work much has been done on the chemical, physical, and microscopical examination of papers of the more important kinds and of various ages, and special attention has been given to methods of analysis and examination and to the effect of sizing materials, inorganic acids, aluminum sulphate, and nature of stock on durability of paper. The bureau's work on the deterioration and suitability of paper is moving along lines originally outlined and will be expanded and vigorously pushed.

PAPER SPECIFICATIONS AND TESTS

The bureau continues to assist the Government and scientific societies in the preparation of specifications which will make possible the procurement of papers best suited for specific purposes. Samples of miscellaneous papers submitted by purchasing officers of this department have been tested and advice given regarding purchases.

Relative resistance to fading by light was determined on series of copies produced from originals made with three kinds of hectograph carbon paper and three kinds of hectograph typewriter ribbons.

Assistance was given to the postage stamp division of the Bureau of Engraving and Printing in determining the relative adhesive qualities of four experimental lots of gummed stamps.

FARM FABRICS

The purpose of this work is to devise and improve treatments for canvas, tobacco shade cloth, and other cotton fabrics used out-of-doors on farms and elsewhere, which will make them more serviceable and more durable through increased water repellency and resistance to destructive agents such as light, fire, acids, and mildew. The work has included collaboration with industrial firms in determining the cause of discoloration of blue awning stripes and the comparative mildew resistance of awning stripes produced with different dyes and pigments, in suggesting pigment compositions that would resist mildew, and in testing the mildew resistance of commercial preparations and treated fabrics; collaboration with the Post Office Department in determining the causes for rapid deterioration of mail bags; and collaboration with the War Department in an effort to determine the cause of corrosion of brass cartridge cases which come in contact with bandoleer fabric.

FIREPROOFING OF COTTON CANVAS

Active work on the permanent flame-proofing of cotton fabrics was inaugurated. The literature on the subject has been abstracted and previous work on the subject summarized in an accessible form as a foundation for the experimental work. Thus far the efforts to find a satisfactory flame-proofing agent have been confined to simple treatments except for the so-called permanent inorganic materials, involving insoluble salts which must be precipitated by suc-

cessive immersion in at least two different aqueous solutions. Mixtures of organic and inorganic treatments have not yet been tried. Certain of the treatments devised and tried have shown some promise since they render the canvas incombustible and have other desirable characteristics. One treatment, as a result of which cotton fabrics have shown good flame resistance in preliminary tests, gives exceptionally promising results. However, much more remains to be done.

NAVAL STORES

The annual production of turpentine and rosin, the principal materials in the class of pine-tree products known as naval stores, has a value of \$50,000,000 to \$60,000,000.

While naval stores are valuable and essential products of farm and forest, the practices and methods of production in many localities are such that operators frequently fail to make a profit. The purpose of the work under this project is to improve practices, processes, and equipment so as to prevent wastes, reduce costs of production, obtain products of better quality, and promote utilization. It is conservatively estimated that the work of the bureau in improving naval-stores practice is potentially worth a million dollars annually to producers.

TECHNOLOGICAL WORK

The naval-stores technologist visited 54 turpentine places and stills for the purpose of giving instructions in and demonstrations of improved stilling practices and information on various naval-stores problems, and has supervised the setting of eight fire stills in accordance with the improved design worked out by the bureau. The number of persons witnessing and profiting from this work was 392. Information on naval-stores problems was also given to 130 persons who called at the office in Savannah and to 124 persons at the State forestry fairs and at a general meeting of naval-stores men in Jacksonville, Fla. In addition, much information has been given through correspondence.

It has been found that fire stills erected under the bureau's supervision require less than the usual amount of fuel and that wherever still settings approximate the bureau's plans they work much better and more economically than the old-style construction and make better grades of rosin, as a rule. Stills erected under bureau supervision have become demonstration units for the surrounding country, numbers of operators calling to see the stills run during the operating season.

Steam stills previously erected in accordance with designs and specifications prepared by the bureau have continued to show satisfactory results in operation, with a saving of time and fuel.

GUM CLEANING

The large laboratory-scale work on gum cleaning has been completed with the production of gum containing but a trace of foreign matter and which yields rosin of great transparency and brilliancy, rosin that is as transparent as glass of the same color. The problem of filtering gum has apparently been solved, and steps have been

taken to prepare the plans and specifications, build full-size equipment, and conduct cooperative work therewith at one of the producers' plants in Florida before the close of the present season in order that this equipment, if found to work satisfactorily, may be available to producers during the season of 1931-32. It is estimated that if this equipment works as well commercially as it has worked on a large laboratory scale it will very materially increase the value of rosin to the producer, eliminate 75 per cent or more of the losses of rosin which now occur in dross, and that the rosin will be worth more to all the users because it is clean and uniform.

COMPOSITION OF TURPENTINE

Samples of gum spirits of turpentine and of steam-distilled wood turpentine have been fractionated and the relative proportions of alpha and beta pinene and tailings in gum turpentine have been determined on the fractions by the optical method of Darmois. Accumulation of such data on various American turpentines will be useful in evaluating turpentines for the manufacture of chemical products, as, for example, synthetic camphor.

TURPENTINE STORAGE

Laboratory experiments on the storage of turpentine in glass containers in contact with various materials having a reducing effect, a dehydrating effect, or a combined reducing and dehydrating effect have been continued.

After two and one-half years' storage the materials which have proved most effective in preventing deterioration of gum spirits of turpentine are lime (CaO) and magnesium in powdered form. The turpentine stored in contact with these materials was water white, had the sweet odor of fresh gum spirits, and showed no evidence of deterioration. Lime would be the most practical material to use from the standpoint of availability and cost. Bone char prevented the development of rancidity, but the turpentine acquired a yellowish color. A number of organic reducing compounds prevented rancidity but discolored the turpentine. This would not prevent their use in colored turpentine products like shoe polishes. An interesting observation made in connection with these experiments was that turpentine stored in contact with stannous chloride had a decided odor of limonene and terpineol. This matter is being investigated.

In collaboration with a commercial firm, physical and chemical constants were determined on four samples of turpentine to show the effects of storage. These were the last of a series of tests, at 6-month intervals, covering a period of three years. Only slight changes had taken place in these turpentines which had been stored under conditions recommended by the division and designed to prevent oxidation; that is, in full tanks kept free of water and separated from the outside air by liquid seals.

GLUING TURPENTINE BARRELS

The loss of turpentine through leakage has been estimated as more than \$60,000 annually. The bureau is at work to improve the present methods for coating the inside of turpentine barrels to

prevent leaking and absorption of turpentine by the wood or to devise practical new methods for the purpose.

It has been the custom to coat the inside of turpentine barrels with hot glue solution to prevent leaking and absorption. When proper care is exercised in the selection, preparation, and application of the glue, and when the turpentine is thoroughly cooled and free from water, the method is generally satisfactory. Observations in this field have shown that very often gluing is poorly done and that leakage results from the method of gluing and from the quantity used rather than from the quality of the glue or the way it is cooked. Efforts have been made to improve ordinary gluing practice and to devise methods which require less care in application. Laboratory experiments have indicated that exposure of freshly glued surfaces to formaldehyde vapor results in quicker setting, considerable water resistance, and flexibility. Following recommendations of the bureau, a number of producers are trying out the use of formalin in gluing barrels.

EFFECT OF CUPS ON GRADE OF ROSIN

Analyses of rosins made from gum collected in galvanized-iron cups, zinc cups, and aluminum cups showed that the rosin collected in galvanized-iron cups contained nearly three times as much iron as that collected in zinc or aluminum cups, and that the rosin was several grades darker.

COMPONENTS OF GUM

In collaboration with the United States Forest Service, 48 samples of crude turpentine gum or "dip" and 15 samples of "scrape" were analyzed for turpentine, rosin, and extraneous material, and the grade of rosin that could be made from each sample was determined. In these laboratory tests the lowest grade of rosin made from fourth-year gum was K from longleaf and WG from slash gum. From one exceptional slash gum (fourth year) M grade rosin was made. While it is not likely that the average producer will make these grades from similar gums, the results do indicate the possibility of making better grades of rosin when all precautions are taken.

USES OF NAVAL STORES

The quantity of turpentine and rosin used in this country amounts to about half of the total domestic production and has an annual value of \$25,000,000 to \$30,000,000 at primary markets. Rosin holds the important position of an essential raw material in the manufacture of many products, including paper size, soap, varnish, printing ink, and plastics. Turpentine, used in the manufacture of synthetic camphor and of ready-mixed paints and largely in the manufacture of varnishes, still finds its largest use as a safe and dependable thinner in the hands of the applying painters.

The bureau is working to promote the utilization of naval stores by studying their composition and properties, and determining how they may be used in new products and how they may be used to best advantage or improved for use in old products.

NAVAL-STORES HANDBOOK

Publication of the naval-stores handbook which is being prepared in cooperation with other interested bureaus of the department has been delayed by pressure of other work. Progress in its preparation is being made, and it is expected that it will be issued in 1931.

EXHIBITS

Additions have been made to the exhibit material on naval stores. These additions have been made to those exhibits made through the office of exhibits and also through the museum and to exhibits retained by the bureau itself. Such exhibits are found especially helpful in the bureau's technological work in the field and in informing producers and users about the methods and difficulties of production and the need for improving products.

STATISTICS

The compilation of statistics on the consumption of naval stores was undertaken in 1918 at the persistent request of producers and users of naval stores because the information can not be obtained as promptly or as reliably by any other agency. Comparison with statistics for former years allow estimates of future demands and thus are of service in planning production and use. Work has been started on statistics of industrial consumption during 1929 and stocks on hand at the close of the naval-stores season, March 31, 1930.

OIL, FAT, AND WAX INVESTIGATIONS

Fats and oils from new sources are being studied in the oil, fat, and wax laboratory, in order to discover their economic value. Much attention is also being paid to further investigations of the composition of commercial fats and oils. In addition to these studies, attention is being given to new research methods and to methods for testing the purity of fats and oils.

PALM OIL

Palm oil is used extensively in the United States by the soap makers and the tin-plate industry. With the improvement in the quality of the product from Sumatra, increasing quantities are becoming available for use, after refining, in the manufacture of oleomargarine, for which it is particularly well adapted.

In view of the fact that commercial palm oil is produced in various tropical countries from a number of different varieties of the African palm (*Elæis guineensis*) and because some varieties differ greatly from each other, it is important that this study should be extended to include the palm oils from the more important producing countries, especially as comparatively little is known regarding their composition. These results will be of value to the soap makers and oleomargarine manufacturers, as well as to those engaged in the cultivation of oil palms, if they indicate that the oil from certain varieties is noticeably superior to that from others.

During the last year the characteristics and composition of an authentic sample of Sumatra palm oil have been determined. The palm oil from the Belgian Congo, previously examined, contained considerably less linolic and more stearic acid than the sample from Sumatra.

CHIA-SEED OIL

Chia is a native of Mexico, where it is being cultivated in increasing quantities for its seed. There is the possibility of its future cultivation as an oil-seed crop in some of the Southern States. Chia-seed oil belongs to the drying class of oils and has been found suitable for use in the manufacture of various kinds of paints, enamels, and varnishes, as well as oilcloths and linoleums. The investigation of the expressed oil has been completed and the results have been published.

GRAPEFRUIT-SEED OIL

The characteristics and composition of the expressed oil have been determined, and, for the purposes of comparison, the characteristics of the oil obtained by solvent extraction also. The quantity of seed separated annually at the canning plants amounts to about 600 tons. It is expected that the quantity of seed obtained will be increased shortly, owing to the rapid expansion of this comparatively new industry. Experiments were made which showed that the oil could readily be converted into a light-colored medium-hard soap that possessed good lathering qualities. As a result of these studies it is believed that the crude oil could be sold to advantage to the soap makers.

PECAN OIL

The characteristics and composition of pecan oil have been determined. The oil studied was expressed from unsalable fine nut fragments. It had a very mild, agreeable taste and was found particularly suitable for use as a salad or a cooking oil. Upon saponification it gave a soap with excellent lathering qualities. The oil has good keeping qualities.

METHODS FOR THE ANALYSIS OF COTTONSEED

Throughout the year an extensive study has been made on known and suggested methods, as well as on the development of other methods in connection with the work of the interbureau committee on the sampling and analysis of cottonseed. It is of importance that cottonseed be graded by selected methods by which the actual quality of any lot of seed can be determined.

The work of the members of the committee in this bureau is confined to a study of the methods of analysis. Existing methods have been subjected to critical study, with the result that suitable procedures have been selected for the determination of moisture and nitrogen (protein). As no known method was entirely satisfactory for the determination of the oil, it became necessary to develop one adapted to this purpose. A modification of the present official method of the National Cottonseed Products Association was obtained that appears to give satisfactory results, but certain phases of the method require further study.

NUTRITIONAL INVESTIGATIONS

CHEMICAL INVESTIGATIONS ON PROTEINS

Cooperative work has been carried on with the Hygienic Laboratory of the United States Public Health Service in estimating the cystine content of a number of proteins by means of the Sullivan colorimetric method. Extensive investigations formerly conducted in this bureau on the nutritive value of the proteins of a number of beans and legumes, including the navy bean, Lima bean, adzuki bean, lentil, and cowpea, have shown that these proteins, in an otherwise adequate diet, will not support the growth of young animals unless the amino acid cystine is added to the diet. The percentages of cystine now found in the legume proteins by means of the more recent and distinctive colorimetric method are much lower than those formerly found and are entirely consistent with the results of the former feeding experiments. This is an interesting illustration of the fact that in some cases feeding experiments can be a more reliable way of detecting amino-acid deficiencies of proteins than chemical analyses.

Work has been continued on the proteins of sweetpotatoes, and the proteins of two varieties of sorghum—milo and feterita. Further work has been done on the study of glutelins.

Sweetpotatoes rank second in importance as a truck crop, and constitute one of the chief vegetable foods in the Southern States. The annual commercial production in the United States is approximately 85,000,000 bushels, with an approximate farm value of \$80,000,000. Compared with other root vegetables, sweetpotatoes rank high in protein, containing an average of about 2 per cent.

Some varieties contain more than 3.5 per cent. These proteins have been found to be good sources of some of the amino acids that are essential for the growth and satisfactory nutrition of animals and which are lacking or deficient in the proteins of certain seeds and cereals. For this reason sweetpotatoes should be a valuable supplement to correct the deficiencies of the proteins of corn, wheat, grains in general, and several of the legume seeds, such as the navy bean, Lima bean, cowpea, and lentil.

In 1925 approximately 4,500,000 acres of grain sorghum were planted in the southwestern part of the United States. In certain sections of the United States sorghum is preferred to corn by the farmers because it is better suited to local climatic conditions. The number of acres devoted to the production of sorghum is steadily increasing from year to year. Of the three horticultural varieties of sorghum, kafir and milo covered three-fourths of the total number of acres, whereas only one-fifteenth was used for feterita.

Investigations in this bureau have recently shown that the chief protein present in these sorghum varieties is an alcohol-soluble protein (prolamin). Kafir prolamin had been previously prepared and analyzed. From a nutritional standpoint, it was very important to determine whether or not these proteins lacked any of the nutritionally essential amino acids, particularly in view of the fact that it was known that unless grain sorghum was fortified by other feed proteins the animals showed nutritional disturbances. It was found that milo lacks tryptophane and that feterita contains only a small

amount. The distribution of the other amino acids was also determined.

Investigation on the effect of alkali on proteins has been continued. Considerable evidence is available showing that many proteins which have been isolated from natural food products do not represent the native proteins as they existed in the original material, but have undergone changes during the process of their isolation. This is particularly true in cases where the proteins have been exposed to the action of even dilute alkali.

It is a matter of great importance to know whether the proteins are changed in their chemical or physical properties by the use of alkali in processing some of our cereal foods. Since glutelins represent one of the chief proteins in cereals, efforts have been concentrated on determining the effect of alkali on this class of proteins. As a criterion for studying the changes, the optical behavior of the cleavage products has been used. It was found that the changes which take place are proportionate to the strength of the alkali used and to the temperature to which the alkaline protein solution is subjected; also to the length of time the alkali is in contact with the protein. As a result of this investigation, which is still of a preliminary nature, it has been found that alkali does not racemize proteins at body temperature, since optically inactive cleavage products can not be obtained except when the hydrolysis is carried to the amino-acid stage. It is intended to continue this work and to determine whether or not it is true that the so-called racemized proteins are digested by proteolytic enzymes.

BIOLOGICAL INVESTIGATIONS ON PROTEINS AND VITAMINS

Additional space and equipment have been made available during the year for the nutrition laboratory. This laboratory is now very well provided with space, facilities, and equipment for carrying on nutritional work with small animals, including automatic temperature control, the latest type of cage racks, a room and apparatus for microphotographic studies of bones and tissues, a specially devised apparatus for preparing large quantities of vitamin-free casein for feeding experiments, and equipment for work with ultra-violet light.

A cooperative arrangement between this bureau and the Bureau of Fisheries has made possible the undertaking of nutritional studies on fishery products and by-products. The extensive and rapidly increasing use of these products, in the feeding of farm animals, particularly the use of fish meals and fish oils for supplying vitamins A and D, gives them a place of great importance in the field of agriculture. As a result of this cooperation between the two bureaus results have already been accomplished, at a minimum expense to the Government, which, it is believed, will be of great benefit to both the agricultural and fishery industries of the United States. More than half the cod-liver oil used for domestic consumption is imported, most of which is used in animal feeding.

A study of vitamins A and D in several of the most important fish oils has been completed. The total production of fish oils, other than fish-liver oils, in this country is more than 10,000,000 gallons. The production of the most important oils ranges from approximately 4,000,000 gallons for pilchard to 25,000 gallons for tuna. The quan-

tity of fish-body oils can be greatly increased and the quality improved. At present these oils are used principally in the soap industry and as drying oils in the paint industry, and to some extent for sizing leather and tempering steel. The suprisingly high potency of vitamins A and D found in some of these oils, together with the enormous potential supply of the oils, gives them a marked significance as sources of these vitamins.

Fish oils representative of the quality of oils available in commerce have been tested for vitamins A and D. The oils used were menhaden, pilchard, Maine herring, Alaska herring, salmon, and tuna. Of these oils only salmon oil contained enough vitamin A to make its use practical in animal feeding. This oil was found to have nearly one-half as much vitamin A as an excellent grade of medicinal cod-liver oil and is within the range of the poorer cod-liver oils in vitamin A potency. Assigning to the vitamin D value of cod-liver oil the arbitrary figure of 100, the oils studied would have the following vitamin D values: Tuna, 100; pilchard, 100; menhaden, 75; salmon, 50; Alaska herring, 30; and Maine herring, 20. Since these oils sell for approximately one-third of the price of cod-liver oil, salmon oil is a cheaper source of vitamins A and D than cod-liver oil. Bearing in mind that none of the oils used were prepared with the idea of preserving the vitamins and that the potential supply of salmon oil alone is three times as great as our present supply of cod-liver oil, these findings take on added significance.

Work has been continued on the effect of commercial processes and practices on the nutritive value of foodstuffs. During recent years a large number of commercial processes used in the preparation of foods have been developed which may have a pronounced effect upon the food value of the original material. Definite information in many cases regarding the effect of these processes on vitamins, proteins, and other food factors is not available. During the year three problems in this connection have arisen which are of such immediate practical importance that it was deemed advisable to cooperate in their study at the expense of suspending certain fundamental researches already in operation. It was shown that the practice of treating unripe fruits and vegetables with ethylene gas, which induces a coloration of the treated products to simulate those naturally ripened, produces fruit of inferior vitamin value when applied to tomatoes. Orange juice and tomato juice are the principal sources of vitamin C for infants. The juice of tomatoes ripened on the vine is a better source of vitamins A, B, and C than the juice of ethylene-treated or green fruit. The vitamin A, B, and C content of ethylene-treated tomatoes was not different from that of similar untreated fruit in early or late stages of maturity. The vitamin C content of tomatoes increases as the fruit matures and reaches a maximum in the fully matured, naturally ripened fruit. There was no evidence of any deleterious effect on the vitamins present in tomatoes ripened by ethylene treatment.

Drastic methods have been instituted to eradicate the Mediterranean fruit fly from Florida. To combat the adult fly, trees are sprayed with arsenical sprays to which has been added a certain amount of molasses to serve as a bait. Although this procedure has been found to be very effective in reducing the number of flies, the

spraying produces marked changes in the character of oranges from sprayed trees. There is a marked decrease in organic acids and a change in the type of sugars of the mature fruit. To prevent the spread of the fly into noninfested areas through larvæ, oranges are subjected to a prolonged heat treatment. Since oranges are an important source of vitamin C, particularly for infants, the effect of methods instituted to combat the fruit fly on the vitamin content of the fruit is of importance. Studies carried on during the year have shown that the practice of spraying orange trees with arsenates decreases materially the vitamin C content of the oranges produced.

There is also under way a study of the effect of sulphur dioxide treatment on the vitamin C content of apricots. In the commercial drying of fruits the practice of sulphuring has been well established.

A publication which appeared during the past year demonstrated that although vitamin C is destroyed completely when apricots are dried without sulphur dioxide treatment, the vitamin can be preserved under certain conditions of drying in the presence of sulphur dioxide. Sulphuring has been carried on largely for the purpose of preserving the color of the fruit, and in the past attempts have been made to discourage the practice because of the possible injurious effects of sulphur to the human organism. If sulphuring improves the nutritive value of the fruit under commercial conditions, its disadvantages may be offset.

Apricots that were dried during the summer of 1929 at the Los Angeles fruit and vegetable chemistry laboratory of the food research division have been received for vitamin studies. Feeding tests have been started.

Cooperative work also has been carried on with the National Cottonseed Products Association through a fellowship established in this bureau for the study of problems associated with cottonseed cake meal feeding. These studies are largely a continuation of work done the previous year. Several important results of a fundamental nature have been accomplished which will form the foundations for a more thorough study of related problems. The importance of cottonseed cake meal as feed is realized when it is considered that during the years 1926-27 and 1927-28 the total consumption amounted to nearly 2,000,000 tons and 1,500,000 tons, respectively. A considerable quantity, in addition, is used as fertilizer. Furthermore, its high content of protein and of vitamins B and G, together with the fact that it is a good source of inorganic salts, make it very desirable to study further its nutritive properties and more satisfactory methods for its commercial production as a feed.

High-grade cottonseed meal has been shown to contain an abundance of vitamins B and G. The particular meal studied contains approximately one-half as much of these vitamins as dried yeast. In view of the fact that yeast is used as a specific for pellagra because of its vitamin G content it seems possible that properly prepared cottonseed cake meal may become an important article of human food.

A preliminary study of the nutritive value of the proteins of cottonseed meal has shown one meal to contain excellent proteins. There is reason to believe that the quality of the protein of different meals may vary.

Studies of the vitamin content of sugarcane juice and some commercial products made from it show that sugarcane juice contains a small amount of vitamin A and little, if any, vitamin D; that sugarcane juice is a poor source of the antineuritic vitamin, and the juice from the upper portions of cane stalks is richer in this vitamin than juice from the lower portions. Juice obtained from bagasse by using high pressure is richer in the antineuritic vitamin than ordinary cane juice. Cane sirup, Louisiana, and Porto Rico blackstrap molasses, and cane cream, products made from sugarcane juice, were found devoid of demonstrable quantities of vitamin B.

There were no demonstrable amounts of vitamins 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 meal is excellent material as a source of both vitamins B and G, being about half as potent as an excellent quality of dried yeast.

During the past year the bureau has reported the results of 32 vitamin assays to the drug control laboratory. Fourteen vitamin-A, 16 vitamin-D, and 2 vitamin-B determinations were made. This work is carried out under the cooperative arrangement whereby the division conducts the assays on commercial products alleged to contain vitamins, that come under the surveillance of the organization charged with the enforcement of the Federal food and drugs act.

During the past year the bureau has improved its technic in vitamin A assay. In most laboratories the period of depletion of stored vitamin A ranges from four to six weeks or even longer. Attempts to reduce the depletion period usually result in producing inferior test animals. By applying the method of controlling vitamin A storage described in a publication from this bureau, excellent animals have been grown which can be depleted of their vitamin A storage and are suitable for curative tests three weeks from the time they are weaned.

COLOR AND FARM-WASTE INVESTIGATIONS

DYE INTERMEDIATES

Vat dyes are chiefly used in dyeing cotton goods and artificial silks. The consumption of such dyes has increased to more than 9,000,000 pounds in 1929 as compared with 6,500,000 pounds in 1928. The work of this division deals with the production of new vat-dye intermediates. Such intermediates present a means of meeting the competition of foreign vat-dye specialties, which amounted to 2,500,000 pounds in 1929 in spite of the increase in domestic production. Several new intermediates have been synthesized during the past year and are now receiving the consideration of the dye industry.

Naphthanthraquinone is produced by the combination of phthalic anhydride and naphthalene in the presence of aluminum chloride. At the time that last year's report was filed this work was still under way. Since then the subproject has been completed, the results have been published, and the process is now before the indus-

tries for their consideration. The bureau has succeeded in solving the main difficulty which was under consideration at the time of the last report, namely, the closing of the naphthanthraquinone ring in the preparation of alpha-benzoyl-benzoic acid. Yields have been obtained on this part of the process in excess of 90 per cent, with an over-all yield of nearly 90 per cent on the phthalic anhydride used.

Work on the problem of preparing phenylanthraquinone and derivatives from 2-chloro and 4-chloro-diphenyl has resulted in the conclusion that they are so closely related that it is best to make a report on them as a unit. The reason for this is chiefly that there is little difficulty in preparing the phenyl-benzoyl-benzoic acids from either diphenyl or chloro-diphenyl, and it is practical to make the substituted phenylanthraquinones, whereas a great deal of trouble has been experienced in closing the ring to form the unsubstituted phenylanthraquinone. Twelve new compounds have been synthesized and their physical constants established. The chemistry of the keto acids has been investigated, and information of value has been obtained both as to the structure of these materials and as to the influence of substituents in the phenyl nucleus on the ring closure.

BIOLOGICAL APPLICATIONS OF DYES

During the past year several new stains, which will be of great value have been synthesized. There has been extensive cooperation with the Garvan Cancer Research under Doctor Bloodgood, of Johns Hopkins University.

This project is concerned with the biological application of dyes, both for the advancement of pure science and for the utilization of science in numerous matters of vital practical importance. In the past the work has been carried on in close collaboration with the Army medical authorities and with the Commission on Standardization of Biological Stains. At a meeting of the commission held on April 15, 1930, representatives of all three agencies expressed satisfaction with the progress of the year's work, and their appreciation of the bureau's assistance in the prosecution of their activities.

In the synthesis of biological stains and dyes of therapeutic or antiseptic value, the most extensive research of the year has been concerned with the synthesis and study of a comprehensive series of magentas. It is hoped that this investigation will eventually make possible the explanation of anomalies which are met with in various staining applications of these dyes, and that it may lead to practical improvement in staining in this field which will parallel the advancement of staining in other fields following other investigations of this division. A variety of aluminum salts and lakes of dyes and an extensive series of compound dyes were prepared for the Garvan Cancer Research, of which a number are proving of considerable practical interest and importance.

MISCELLANEOUS INVESTIGATIONS

The work of the year was of a very miscellaneous nature. The solubilities and light absorptions of a number of stains were determined for the Garvan Cancer Research. A spectrophotometric

study was made of a proposed colorimetric method for the differentiation of natural and artificial oil of sassafras for the Food and Drug Administration, and numerous samples of mercurochrome and substitutes were examined for the same organization. The spectrophotometric analysis of 60 solutions of plant pigments was carried out for the Bureau of Plant Industry in connection with their investigation of virus activities in mosaic diseases.

A novel and comprehensive scheme was developed for the identification of stains by means of convenient spectrophotometric technic. Satisfactory and convenient spectrophotometric methods were developed for the analysis of neutral red, pyronine G, and pyronine B, three important stains which can not be evaluated by reduction methods, and which can not be analyzed by other chemical methods owing to the nature of the impurities which market supplies of the dyes contain.

FARM-WASTE INVESTIGATIONS

The work on bagasse cellulose has resulted in the production of a cellulose with an alpha content of 90 per cent or more, and an alkali-soluble content of 8 to 11 per cent. The pulp is produced in yields of 32 per cent on the air-dried bagasse and is more than equivalent to the Brown Co.'s alpha cellulose or the Riordan sulphite pulp, both of which are used in rayon manufacture. It would seem that the use of this cellulose would be conditioned, very largely by the price at which bagasse could be purchased.

The work on lignin is of special importance because of the enormous annual production of this material, which has been estimated as 40,000,000 tons. There are two main sources of loss. One is the annual farm wastes, such as cornstalks, corncobs, straw, etc., and the other is the waste liquor from the various paper mills. The work during 1930 has been more predominantly chemical than that during 1929.

The work on destructive distillation of lignin has taken the form of a more careful examination of the fractions obtained in the destructive distillation. The greater active portion of the phenolic fraction is not volatile with steam, and a great deal of the work has been done to find out, if possible, the nature of these phenols. Up to the present time they have been divided into fractions by distillation under reduced pressure, and it has been found that by far the greatest portion of the material came over at or below 140° C. Further than this none of the materials has been identified.

Lignin has been found to give resinous condensation products with the following compounds: Furfural, o- and p-toluidine, p-nitroaniline, m-toluylene diamine, alpha and beta naphthylamine, tolidine, cyamidine, aniline, o-nitroaniline, and dimethylaniline. A table has been prepared summarizing the optimum temperature, time of heating, the ratio of lignin to the second component, and the properties of the rosin. Further investigation on this work will await the opinion of industry on its possibilities. Most of the rosins are of the fusible and soluble type, and may be used as varnish rosins.

Investigation of the formation of lignin in growing plants was undertaken in cooperation with the bureau's laboratory of crop chemistry to determine whether lignin is a factor in bringing about

lodging or the falling or bending over of plants during a wind or rain storm. It has been found that crops which have been heavily treated with sodium nitrate are apparently more susceptible to lodging than others of the same kind. Two plots of wheat were selected for this work; one was untreated and one heavily treated with sodium nitrate. Lodging finally resulted in the second plot. Periodical samples indicated that the lodged plants invariably and consistently contained a greater percentage of lignin. It appears, then, that the excess of sodium nitrate in some way stimulates the plant to produce a greater percentage of lignin which in turn increases the brittleness of the stalk.

Experiments on the modification and degradation of lignin have demonstrated that various oxidizing agents either have no effect on the lignin and methylated lignin or break it down so far that only the simpler organic acids, such as oxalic, acetic, and succinic, are produced. Such products give no information whatever about the basic structure of the lignin molecule, which is the chief objective of this subproject.

Certain sulphonation experiments have indicated the following: (1) Free lignin in contradistinction to lignin as it is found in the plant is comparatively resistant to the action of the mixture of SO_2 and bisulphite (the active delignifying agent in the so-called sulphite process). (2) The insoluble residue is not merely lignin which had resisted the action of SO_2 and bisulphite, but is a sulphur-containing compound (insoluble in lignin sulphonic acids). The last two facts are of special interest in connection with the sulphite process for paper pulp. Work on this is being continued, using lignin prepared by various methods.

Experiments were also conducted on the distillation of lignin with zinc dust in an atmosphere of CO_2 . A yield of oil amounting to 19 per cent of the weight of lignin used in the experiment was obtained. This oil was steam distilled and 28 per cent was volatile with steam. This fraction, as well as the steam-nonvolatile fraction, was separated into phenolic and into neutral portions. Both fractions were found to be predominantly phenolic in character. In the steam-volatile fraction the phenols amounted to about 60 per cent of the oil, and in the steam-nonvolatile fraction to 80 per cent. The only phenol definitely identified is guaiacol. The steam-nonvolatile phenols were fractionally distilled under reduced pressure, and judging by the boiling-point range it was apparently a very complex mixture.

A considerable quantity of phenol-furfural rosin was made for the purpose of testing the possibility of using cornstalk flour as a filler in place of the more commonly used wood flour. In cooperation with companies at North Tonawanda and Lockport, N. Y., a number of articles which were very satisfactory in quality and appearance were molded from this prepared material.

Since the work on phthalic anhydride was started a great deal of valuable information on the subject of the catalytic atmospheric oxidations and catalytic oxidations of other kinds has accumulated in this division. It is thought, therefore, that any project which will utilize this information is of great importance in the work here. After some consideration, p-cymene, a well-known paper-mill waste, was chosen as a suitable material for a study along these lines.

Catalytic vapor phase oxidation of p-cymene.—A large number of runs have been made on p-cymene, using a variety of catalysts and including changes in various other conditions of operation. The best results have produced about 9.5 per cent of formic and 17½ per cent of p-toluic acids.

INDUSTRIAL FERMENTATIONS

During the year the semiplant scale process for the production of gluconic acid has been completed and the results published. Very largely as a result of this bureau's activities, calcium gluconate is receiving a great deal of attention as a physiological source of calcium.

The development of fermentation processes for the production of chemical products has been a leading feature of chemical development during the last 10 years. During the past year new companies have been formed for the manufacture of industrial solvents, and a number of visits have been made to this bureau for the purpose of obtaining advice and suggestions on the installation of plants for the manufacture of citric acid by fermentation. Considerable interest has also been manifested in the development by the bureau of a method of production of gluconic acid on a semiplant scale.

Prior to the work of the bureau there was nothing obtainable in the literature on the subject of the application of fermentation to industrial problems of this type, and it is apparent that the work that has been done and reported by this bureau will serve as a model for future investigations, whether made in this bureau or elsewhere.

An industrial process for the manufacture of gluconic acid, using a different organism but similar in other respects to the work of this bureau, is now operating. Before this process was announced commercially this bureau had, however, distributed between 100 and 200 pounds of calcium gluconate for experimental purposes in the country at large. Research based on this material will undoubtedly be of great value in the future.

Up to the present time a survey of the action of about 50 molds on solutions of xylose has been studied without any marked results. Apparently many of these organisms possess the property of utilizing xylose for their growth but do not produce metabolic products on a sensible scale.

INSECTICIDE INVESTIGATIONS

INSECTICIDAL PLANTS

Through the cooperation of the State Department, samples of plants reputed to have insecticidal action have been obtained from tropical countries. These have been examined and new compounds of insecticidal value have been isolated. "Cube" root from Peru has been chemically examined and found to contain about 7 per cent rotenone, the chief insecticidal constituent of Derris root. Timbo from Brazil has also been found to yield rotenone. Interest in rotenone has greatly increased as the result of the bureau's activities, and it is believed that within the coming year many proprietary insecticides manufactured within the United States will contain rotenone as the essential insecticidal constituent. Much progress has been made

in the study of the structure of the rotenone molecule, nine papers on this subject having been submitted for publication.

SYNTHETIC INSECTICIDES

Work on the synthesis of neonicotine has been continued. One of the large coal-tar manufacturers is now marketing an insecticidal mixture which contains a small proportion of neonicotine.

SPRAY RESIDUES

It has been found that a portion of the hydrochloric acid in the usual acid wash may be advantageously substituted by sodium chloride. This improved wash, which is not only cheaper than the one formerly used but is less injurious to the fruit and to the washing machinery, is now being commercially used in the Northwest.

ANALYTICAL INVESTIGATIONS

Methods for the determination of arsenical spray residue have been studied and their limitations determined. Statistical studies have been made to determine the number of apples required to constitute an adequate sample. A new method that has been studied for the determination of small amounts of arsenic promises to be superior to the Gutzeit method.

FLUORINE INSECTICIDES

New fluorine insecticides have been prepared and distributed to entomologists for testing against the European corn borer, Mexican bean beetle, codling moth, and other pests. One of these, potassium hexafluoroaluminate, has been prepared on a large scale by a leading insecticide manufacturer and extensive tests with it have been made in the field. Six applications for United States Public Service patents covering methods of manufacturing these fluorine insecticides have been filed.

FUMIGANTS

Ethylene oxide, which was developed in cooperation with the Bureau of Entomology in 1927-28, has grown rapidly in public favor. More than 3,000,000 bushels of wheat have been successfully fumigated with a mixture of ethylene oxide with carbon dioxide. This mixture has also been used commercially for fumigating dried and other foodstuffs.

ARSENICAL INSECTICIDES

A survey has been made of all brands of calcium and lead arsenate on the market. These two compounds are the most important commercial insecticides, about 30,000,000 pounds of each being used annually. This study of calcium arsenate will lead to the formulation of specifications defining a calcium arsenate suitable for the control of the Mexican bean beetle. Many of the present brands of calcium arsenate severely burn bean foliage when used for the control of this insect.

DUST-EXPLOSION INVESTIGATIONS

INERT GAS

In small grinding plants where inert gas is used for fire and explosion prevention, the obtaining of a sufficient quantity of suitable gas is not ordinarily a serious problem. In large plants, however, where a number of high-speed grinders of large capacity are used, the source of inert gas becomes a question of importance. Attention has therefore been directed toward the development of methods of obtaining flue gas from near-by boiler plants. In one of these installations it has been found necessary to install gas-washing or conditioning equipment because of the high sulphur content of the coal and the consequent need for removing SO_2 from the gas.

A special study of gas washers and conditioning equipment was made during the year and a complete test made of the equipment installed at one of the large feed-grinding plants. The results of these tests are being coordinated with the results obtained in the small-scale experimental equipment at the Arlington farm.

Experiments are under way at another plant using a large quantity of flue gas to determine the practicability of maintaining a temperature above the dew point of the gas to prevent precipitation of the SO_2 and moisture. In this way it may be possible in certain instances to eliminate any washing equipment.

INDUSTRIAL-PLANT STUDIES

In addition to the investigation of dust explosions which have occurred during the past year, studies were made in a number of industrial plants to observe unusual operating conditions or to obtain information of value in planning further research work on dust-explosion prevention. Visits for the purpose of observation of new methods and installations, testing conditions for dust-explosion hazards, and for making recommendations as to prevention of explosions were made to a large flour mill, two sugar refineries, a plant producing powdered-food products, an oil plant, a sulphur-grinding plant, a woodworking plant, a corn-sirup refinery, and several other industrial establishments.

LABORATORY RESEARCH

During the past year considerable data relating to the mechanism of dust-cloud explosions have been obtained. Most of the work was done with aluminum dust. These data show that not only does the maximum pressure increase with concentration, but the rate-of-pressure increase also increases with concentration, giving a doubly dangerous explosion. This indicates that considerable experimental work will be necessary to determine the practical possibility of explosion-venting devices. Tests were made for the determination of flame speed in dust clouds of constant volume. A study was made of the efficiency of a gas scrubber for the removal of SO_2 from flue gas. Thirty-four samples of dust sent in by various firms were tested for explosibility, and reports were prepared giving information concerning methods for reducing the explosion hazard.

DUST-EXPLOSION HAZARDS COMMITTEE

The very close cooperation that the bureau enjoys in this dust-explosion-prevention work with the industries, insurance organizations, underwriting agencies, State commissions, and safety organizations makes possible very prompt application of the control and preventive methods developed by the bureau engineers. One of the most prominent contacts is through the work of the dust-explosion hazards committee of the National Fire Protection Association which includes representatives from the following organizations: Corn Products Refining Co., American Spice Trade Association, Allen & Billmyre Co., Mutual Fire Prevention Bureau, Grain Elevator Construction Engineers, International Machinists Organization, National Bureau of Casualty and Surety Indemnity, Terminal Elevator Grain Merchants' Association, Railway Fire Protection Association, Westinghouse Electric & Manufacturing Co., National Board of Fire Underwriters, Underwriters Laboratories, Spencer-Turbine Co., United States Bureau of Mines, National Electric Light Association, International Association of Industrial Accident Boards and Commissions, Association of Governmental Labor Officials of the United States and Canada, and Associated Factory Mutual Insurance Companies. 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 been experienced.

Meetings of the committee were held in New York October 14, 1929, and in Chicago March 11, 1930. At these meetings special consideration was given to the preparation of safety codes for wood-flour manufacturing plants, spice-grinding plants, and the use of inert gas for fire and explosion prevention. The bureau cooperated during the year with the national fire waste council of the Chamber of Commerce of the United States. Meetings were held in Washington in October, 1929, and in March, 1930. The cooperation with this council affords an additional opportunity of translating into actual practice the results of the bureau's research through the fire-prevention committees of the local chambers of commerce throughout the country.

FARM-FIRE INVESTIGATIONS

SPONTANEOUS IGNITION OF HAY

Fires caused by spontaneous ignition are responsible for enormous annual losses. It has been estimated that spontaneous ignition of hay and other agricultural products results in an annual fire loss on farms of at least \$20,000,000, or one-fifth of the total yearly farm fire loss of \$100,000,000. Closely related to fire losses is the damage to agricultural and industrial products when spontaneous heating occurs which is arrested short of the stage of ignition. There is no basis on which to make any estimate of the aggregate losses resulting from such spoilage, but it is obvious that the total is enormous. During the year experimental work was carried on in a specially constructed barn on the Animal Husbandry Experiment Farm at Beltsville, Md. In the first experiment about 10 tons of incompletely cured alfalfa with a moisture content averaging 36 per cent was tightly packed in

the mow. Provision was made for the taking of gas samples when desired and samples of heated hay at the conclusion of the experiment. Every precaution was taken to avoid interference with the natural course of heating. Rather rapid heating occurred at first and comparatively high temperatures prevailed for a considerable time (highest temperature reached was 72° C.) but the heating stopped far short of those temperatures which were to be expected for actual ignition.

In the second experiment about 12 tons of baled alfalfa was placed in the barn. The bales were broken and water was sprinkled over several layers of the hay. About a week later a maximum temperature of 77° C. was reached in one section of the mow, after which the hay cooled rapidly.

Analyses of the hay and gas samples collected for laboratory study yielded interesting information. The relation between the carbon-dioxide content and the oxygen content in some of the gas samples indicates not only bacterial but also chemical action, this observation being a confirmation of certain experimental work of Haldane and MacGill. No evidence of easily inflammable gases was found. Further experiments with a much larger quantity of hay are needed, as the smaller stack gave too much opportunity for loss of generated heat.

CONFERENCE ON SPONTANEOUS HEATING AND IGNITION

A complete report of the conference on spontaneous heating and ignition, which was held in Washington, November 14 and 15, 1929, incorporating the several papers presented with ensuing discussion, has been prepared for publication and will be a valuable contribution to the literature on this subject. The final action of the conference was the adoption of a motion authorizing the executive of the National Fire Protection Association to organize a committee on spontaneous heating and ignition to continue the work initiated by the conference, to correlate research activities on the subject, and to serve as a clearing house for future work in this field.

EXHIBITS AND PUBLIC INFORMATION

To display the results of research in the bureau, exhibits were prepared on fertilizers and farm-waste materials, and the booth exhibits on soil erosion, naval stores, and dust explosions were improved. A model steam-still setting was built. The bureau participated in exhibitions at the Chemical Industries Exposition at New York; the National Fire Protection Association at Memphis, Tenn.; the Cambria County Industrial Exposition at Ebensburg, Pa.; the Illinois State Fair; the Greater Peoria Exposition, at Peoria, Ill.; the Alabama State Fair; the North Carolina State Fair; the conference on spontaneous heating and ignition at Washington, D. C.; the International Livestock Show; and the naval stores meeting at Jacksonville, Fla.

ENGINEERING DESIGN AND DEVELOPMENT

Engineering assistance is rendered to various divisions in the bureau in the design, installation, and operation of mechanical equipment for the commercial application of scientific discoveries for the utilization of agricultural resources, and to conduct engineer-

ing research on production costs, market values, and industrial development of chemical engineering processes using agricultural products as raw material.

During the past year all of the work on engineering design and development service has been conducted in cooperation with the industrial farm products division. Plans were prepared on the design of fire-still turpentine plants of 1-still and 2-still sizes. Observations were continued on the operation of the improved steam still designed and recommended by the department. The superheater which was designed by the department in connection with the steam-still installation has continued to give excellent service wherever installed. The work on gum cleaning has progressed beyond the preliminary stage. The theoretical principles involved in the process developed by the bureau have been tested.

Considerable work was performed on the development from cornstalks of a flour that would meet the requirements of the manufacturers of linoleum, dynamite, and artificial resins. In experiments with plastics using cornstalk flour as a filler, products having the same physical properties as those using wood flour as a filler were obtained. Experiments were conducted in producing a hard panel board from cornstalk flour and in obtaining a satisfactory surface for this board. Studies both of a large-scale and laboratory nature were made on the grinding and milling separations of cornstalk flour.

SOIL INVESTIGATIONS

THE SOIL SURVEY

The practical aspect of the work of the soil survey is expressed mainly in the number of square miles covered by the field parties each year. During the fiscal year 1930, 24,561 square miles, or 15,719,040 acres, of land have been covered and the soils mapped in detail. These maps show the different kinds of soils as determined by definitions, the definitions of the soils being given in terms of those characteristics which determine their natural productivity and their natural adaptability to crops. The maps show with great accuracy the acreage of each kind of soil, and the reports accompanying the maps supply the information for arranging all the soils in the order of their natural productivity, and for determining to what crops the natural characteristics of the soils of all degrees of productivity are best suited.

This information is of very great value to the agricultural industry of the United States whatever may be the status of that industry at any particular time. At the present time and for the immediate future, it has peculiar value because of the readjustment which is taking place in agriculture, as this is the information upon which the future inevitable land classification must be based. No land classification based on the natural productive capacity and the natural adaptability to crops of the soils is possible without the facts supplied by the soil survey. If this information were not supplied by the Federal survey, it would have to be supplied by each locality. The possible measure of its value, therefore, would consist of an estimate of what it would cost each community to determine the character of

its soils on its own initiative. We have no accurate information on the basis of which this cost can be determined.

An additional value of the soil survey which is probably as great, although it can not be expressed in dollars as can the practical value, consists in its scientific results. The soil survey is an institution for engaging in research in the field. The soil is studied in its natural habitat, not only on the basis of the characteristics of the soil itself but in relation to the environment in which it has developed.

In addition to the work of soil mapping and the research work that is carried on in the field, the results of which are expressed in the soil map and the report, investigations are being carried out on a number of collateral lines by the soil survey staff. These research projects consist of the work on soil erosion, peat and muck investigations, routine work in the determination of the reaction of soil types established by the soil survey, the preparation of a series of typical soil samples for educational purposes, investigations in the field for the Bureau of Reclamation, the Indian Service, the War Department in its flood-control work in the lower Mississippi Valley, the Treasury Department in the location of desirable sites for farms in connection with the establishment of institutions for the treatment of narcotic addicts, the Bureau of Public Roads in determining the influence of the character of the subgrade on the permanence of highway pavements, the Bureau of Standards in determining the influence of soil characteristics on the corrosion of iron pipes, the Bureau of Plant Industry in studying the causes of alfalfa failure in the Mississippi alluvial lands, and for the Department of State in the study of the influence of smelter fumes on crop plants in the northeastern part of the State of Washington. Most of these lines of work, in addition to their fundamental aspects, also include studies in the fundamental characteristics of soils. The results of these studies furnish scientific information determined for the first time, and therefore new to the field of soil science.

Tables 1 and 2 summarize the field work of the soil survey for the past year, to which is added a recapitulation of the areas surveyed since the inauguration of the work.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1930*

State	Area	Area surveyed	
		Square miles	Acres
Alabama	Dallas County	203	129,920
	Mobile County	¹ 530	339,200
	Perry County	¹ 270	172,800
Arizona	Nogales area	98	62,720
California	Capistrano area	¹ 342	218,880
	El Cajon area	437	279,680
Colorado	Suisun area	336	215,040
	Greeley area	¹ 215	137,600
	Longmont area	246	157,440
Georgia	Hart County	¹ 97	62,080
	Jefferson County	¹ 426	272,640
	McDuffie County	241	154,240
Idaho	Benewah County	361	231,040
	Gooding area	¹ 116	74,240

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

TABLE 1.—Individual areas surveyed and mapped during the fiscal year ended June 30, 1930—Continued

State	Area	Area surveyed	
		Square miles	Acres
Indiana.....	Jennings County.....	350	224, 000
	Pike County.....	¹ 273	174, 720
	Washington County.....	61	39, 040
Iowa.....	Calhoun County.....	¹ 486	311, 040
	Hancock County.....	406	259, 840
	Poweshiek County.....	¹ 137	87, 680
Kansas.....	Washington County.....	490	313, 600
	Marion County.....	¹ 440	281, 600
	Neosho County.....	¹ 529	338, 560
Kentucky.....	Mercer County.....	126	80, 640
Louisiana.....	Livingston Parish.....	188	120, 320
Maryland.....	Caroline County.....	¹ 155	99, 200
	Kent County.....	55	35, 200
Massachusetts.....	Talbot County.....	268	171, 520
	Franklin County.....	¹ 627	401, 280
Michigan.....	Alger County.....	¹ 185	118, 400
	Eaton County.....	¹ 274	175, 360
Minnesota.....	Iron County.....	¹ 280	179, 200
	Luce County.....	¹ 805	515, 200
	Montmorency County.....	175	112, 000
	St. Clair County.....	¹ 132	84, 450
	Hennepin County.....	¹ 81	51, 840
Mississippi.....	Houston County.....	¹ 179	114, 560
	Hubbard County.....	379	242, 560
	Kittson County.....	349	223, 360
Montana.....	Norman County.....	860	550, 400
	Wilkin County.....	745	476, 800
Nebraska.....	Hancock County.....	¹ 280	179, 200
	Lower Flathead Valley area.....	¹ 312	199, 680
New Mexico.....	Colfax County.....	405	259, 200
	Dixon County.....	¹ 247	158, 080
	Furnas County.....	92	58, 880
	Harlan County.....	61	39, 040
	Knox County.....	¹ 750	480, 000
	Staunton County.....	¹ 325	208, 000
	Fort Sumner area.....	118 ¹	75, 520
Rincon area.....	75	48, 000	
New York.....	Delaware County.....	¹ 185	118, 400
	Steuben County.....	104	66, 560
North Carolina.....	Brunswick County.....	297	190, 080
	Franklin County.....	50	32, 000
	Macon County.....	¹ 348	222, 720
Ohio.....	Montgomery County.....	498	318, 720
	Brown County.....	¹ 191	122, 240
Oklahoma.....	Licking County.....	¹ 158	101, 120
	Putnam County.....	¹ 119	76, 160
	Craig County.....	76	48, 640
Oregon.....	Grant County.....	175	112, 000
	Pittsburg County.....	415	265, 600
	Tillman County.....	552	353, 280
	Columbia County.....	¹ 271	173, 440
Pennsylvania.....	Umatilla County.....	178	113, 920
	Tioga County.....	¹ 310	198, 400
Porto Rico.....	Wyoming County.....	¹ 305	195, 200
South Carolina.....	Soil Survey of.....	¹ 420	268, 800
Texas.....	Dillon County.....	302	193, 280
	Collin County.....	584	373, 760
	Frio County.....	¹ 296	189, 440
	Galveston County.....	¹ 182	116, 480
	Polk County.....	¹ 515	329, 600
	Randall County.....	937	599, 680
	Scurry County.....	55	35, 200
Virginia.....	Rockbridge County.....	53	33, 920
West Virginia.....	Pendleton County.....	291	186, 240
Wisconsin.....	Barron County.....	62	39, 680
	Brown County.....	¹ 277	177, 280
Wyoming.....	Crawford County.....	259	165, 760
	Johnson County.....	63	43, 520
	Sheridan County.....	410	262, 400
Total.....		24, 561	15, 719, 040

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, 1930, and areas previously reported

DETAILED

State or territory	Work during 1930	Work previously reported	Total	
	Square miles	Square miles	Square miles	Acres
Alabama.....	1,003	53,033	54,036	34,583,040
Arizona.....	98	3,439	3,537	2,263,680
Arkansas.....		15,547	15,547	9,950,080
California.....	1,115	30,551	31,666	20,266,240
Colorado.....	461	4,444	4,905	3,139,200
Connecticut.....		1,704	1,704	1,090,560
Delaware.....		2,276	2,276	1,456,640
Florida.....		15,160	15,160	9,702,400
Georgia.....	764	34,102	34,866	22,314,240
Idaho.....	477	10,598	11,075	7,088,000
Illinois.....		6,770	6,770	4,332,800
Indiana.....	684	17,490	18,174	11,631,360
Iowa.....	1,519	44,296	45,815	29,321,600
Kansas.....	969	12,933	13,902	8,897,280
Kentucky.....	126	5,020	5,146	3,293,440
Louisiana.....	188	16,769	16,957	10,852,480
Maine.....		2,197	2,197	1,406,080
Maryland.....	478	12,889	13,367	8,554,880
Massachusetts.....	627	8,184	8,811	5,639,040
Michigan.....	1,851	24,179	26,030	16,659,200
Minnesota.....	2,593	9,702	12,295	7,868,800
Mississippi.....	280	29,215	29,495	18,876,800
Missouri.....		37,177	37,177	23,793,280
Montana.....	312	1,701	2,013	1,288,320
Nebraska.....	1,880	51,969	53,849	34,463,360
Nevada.....		652	652	417,280
New Hampshire.....		1,411	1,411	903,040
New Jersey.....		9,895	9,895	6,332,800
New Mexico.....	193	891	1,084	693,760
New York.....	289	26,283	26,572	17,006,080
North Carolina.....	1,193	42,186	43,379	27,762,560
North Dakota.....		16,878	16,878	10,801,920
Ohio.....	468	15,721	16,189	10,360,960
Oklahoma.....	1,218	6,540	7,758	4,965,120
Oregon.....	449	14,130	14,579	9,330,560
Pennsylvania.....	615	17,645	18,260	11,686,400
Porto Rico.....	420	440	860	550,400
Rhode Island.....		1,085	1,085	694,400
South Carolina.....	302	24,462	24,764	15,848,960
South Dakota.....		8,286	8,286	5,303,040
Tennessee.....		11,198	11,198	7,166,720
Texas.....	2,569	51,958	54,527	34,897,280
Utah.....		2,419	2,419	1,548,160
Vermont.....		1,175	1,175	752,000
Virginia.....	53	10,072	10,125	6,480,000
Washington.....		10,752	10,752	6,881,280
West Virginia.....	291	21,044	21,335	13,654,400
Wisconsin.....	598	25,269	25,867	16,554,880
Wyoming.....	478	2,340	2,818	1,803,520
Total.....	24,561	774,077	798,638	511,128,320

RECONNAISSANCE

Alaska.....		31,915	31,915	20,425,600
Arkansas-Missouri.....		58,000	58,000	37,120,000
California.....		32,135	32,135	20,566,400
Kansas.....		39,960	39,960	25,574,400
Michigan.....		1,322	1,322	846,080
Minnesota.....		1,923	1,923	1,230,720
Montana.....	4,703	33,824	38,527	24,657,280
Nebraska.....		53,064	53,064	33,960,960
North Dakota.....		39,240	39,240	25,113,600
Ohio.....		41,420	41,420	26,508,800
Oklahoma.....	1,164		1,164	744,960
Pennsylvania.....		41,405	41,405	26,499,200
South Dakota.....		41,400	41,400	26,496,000
Texas.....		152,855	152,855	97,827,200
Vermont.....	3,210	105	3,315	2,121,600
Washington.....		16,540	16,540	10,585,600
Wisconsin.....		14,425	14,425	9,232,000
Total.....	9,077	599,533	608,610	389,510,400

Considerable progress has been made among the several State organizations cooperating with the bureau in the proper correlation and classification of soils. Many of the States are establishing projects looking to the proper classification of soils, with special emphasis on soil profiles. Many of the States, as well as other branches of the departmental service, are recognizing the value of the present-day classification of the soil survey, and are insisting that their work be correlated with the nomenclature of this bureau.

Work on soil-profile studies has continued throughout the year and hydrogen-ion determinations have been made on more than 200 soil profiles. These profile samples were gathered throughout the United States, and most of them represent recognized soil types that were collected for correlation purposes. Altogether 835 samples from different horizons have been studied and their reaction values determined.

On 45 soil profiles special work was done on samples in both the moist-field condition and in the air-dry state to show the effect of air-drying on the hydrogen-ion concentration of the soils. It is expected that the results of this work will show the correlation between hydrogen-ion concentration and soil type, and throw some light on the question of how these are related to different climatic conditions.

During the summer of 1929, in cooperation with the Wisconsin Geological and Natural History Survey, studies were made of profiles of a number of Wisconsin soils, which will prove of great assistance to the bureau in the correlation of soils of that region. A total of 23 soil types was examined, and a complete record of the results is on file in the office of the soil survey.

The flood-control plan adopted by the War Department for the lower Mississippi Valley contemplates the building of levees along the river and the provision of a certain number of spillways to take care of excess water when the pressure on the levees becomes dangerously heavy. The tentative plan, so far as it concerns the Bureau of Chemistry and Soils, contemplates the preliminary survey by the soil survey of five or six strips, 2 miles wide, across these spillways, for the purpose of obtaining a basis for the classification and evaluation of the land. A special appropriation from the War Department was transferred to this bureau for the work which is now in progress. The soil survey is also cooperating with the Indian Service.

SOIL INVESTIGATIONS FOR LAND-CLASSIFICATION PURPOSES

Early in 1930 preliminary investigations were started in cooperation with the Bureau of Reclamation, Department of the Interior, looking to the preparation of plans for the proposed soil survey and land classification to determine the economic feasibility of the all-American canal through southern California. This preliminary work has been completed and additional investigations are being undertaken for the Bureau of Reclamation on soil questions which involve the transfer of water from the Sacramento to the San Joaquin Valley. One of the important conditions to be determined is the area of soil suitable for irrigation in both valleys. This study is still in progress.

During the summer field season 1929 an examination was made of the soils in the Flathead project in Montana for the Bureau of Indian Affairs in order to classify the land with respect to requirements for the development of an agricultural program. Similar work is in progress on the Wapato project of the Yakima Indian Reservation in the Pacific Northwest.

PEAT AND MUCK INVESTIGATIONS

The activities in peat investigations during 1929-30 continued the main lines of field and laboratory work indicated in the subproject. The outstanding results of the fiscal year may be summarized briefly as follows:

In its visualization of regional peat investigations the bureau has outlined the following nine regions as being of major importance, each of which should be considered as a whole:

1. The New England peat areas.
2. The Atlantic coastal peat areas.
3. The Florida and Gulf States peat areas.
4. The Great Lakes peat areas.
5. The Mississippi River peat areas.
6. The Columbia River and northern Pacific coastal peat areas.
7. The California and southern Pacific coastal peat areas.
8. The mountain Alaskan and alpine-boreal peat areas.
9. The tropical peat areas.

Actual examination has been made this year of the distinctive characteristics of important peat soils in Florida, North Carolina, Maine, California, and Washington. Their inherent structural differences and the conditions which tend to determine productive power have been reported in a series of papers which have appeared in several scientific journals.

Various specific laboratory activities dealing with peat materials and profile sections have been thrust on this bureau by practical necessity owing to the increasing requests of scientific, agricultural, and other agencies for the botanical identification of different peat samples. The nature of the problems calls for painstaking professional skill, the development of uniform tests and methods of microscopic analysis, and the standardization and illustration of plant remains as types of peat.

SOIL-EROSION AND MOISTURE-CONSERVATION INVESTIGATIONS

During the fiscal year the principal phase of the work of the Bureau of Chemistry and Soils in connection with soil-erosion and moisture-conservation investigations was centered about the selection of suitable experimental station sites in the defined major soil regions, where erosion and water losses are very serious agricultural problems; the installation of necessary experimental equipment for measuring these losses from varying slopes on definite soil types existing under natural, undisturbed conditions; and the operation of these experimental installations by highly trained specialists. The main purposes of these investigations are twofold: (1) It is necessary to have accurate quantitative measurements of the effects of soil washing and the run-off of rainfall for definite, extensive, and

important soil types existing under varying conditions of slope, crop use, and crop treatment, in connection with the needs of the engineering problems of erecting erosion-prevention and control structures, and for devices intended to increase the storage of water within the soil for subsequent crop use; and (2) it is necessary to save the measured erosional débris in order that it can be stored and properly exhibited in an educational way on the spot where the processes involved have been in action and the measurements of the effects made.

In connection with the operation of these undisturbed soil plots similar comparative measurements are being made on (1) virgin soil and (2) on soil from which the A horizon, or topsoil, is removed down to the subsoil. This will give a measure of the rate of erosion and amount of water storage under opposite conditions of eroded soil (or the equivalent of eroded soil) and uneroded soil, and also comparative crop values for these extremes.

A second phase of the station work is the measurement, on 1-acre plots, of the soil-erosion and moisture-conservation effects of various tillage operations, under field conditions such as subsoiling, leaving the ground in a condition of rough fallow, and the practice of planting row crops up and down the slopes and along the contours of slopes. For accurate measurements of the effects of erosion and run-off from the smaller plots it is necessary to install a system of substantial tanks of sufficient capacity to take care of the maximum 48-hour rainfall for the region, as based on available weather records and the estimated run-off, which latter is a variable dependent on slope, soil type, length of plot, and character of usage. These tanks and plots must be erected and protected with such scrupulous care and exactness that elements of leakage, overflow from abnormal precipitation, and undue soil transportation are minimized to the utmost limits; and the tanks must be carefully calibrated for the purpose of precise and expeditious measurements.

Measurements of run-off and wash-off on the various other experimental plots, such as the 1-acre plots, will be handled with Ventura flumes and accurate sampling made of spill water to determine silt losses.

Another important phase of the station work centers about measurements of water losses from and storage within the soil, as affected by soil type, with particular emphasis on the relation of the soil horizons, separately and collectively, to water losses, and storage within the soil, as affected by soil type. In order to work out this phase of the investigation studies will be made under a large variety of surface conditions and crop treatments on definite types, with and without erosion-prevention and moisture-conservation structures, in small plots and large fields. It is expected that these studies will throw light on various problems of rainfall penetration, evaporation, and circulation under conditions of varying rainfall intensity, time between rains, soil aridity and humidity, exposure, slope, soil treatment, depth to water table, soil horizontal characteristics, and depth of the soil profile. A number of problems relating to this highly important agricultural feature of rainfall disposition and the effect of artificial devices in modifying its disposition have never been satisfactorily worked out, and probably never could be except by studying the factors concerned, in the field. It is known that the

soil type, with its differing component horizons, markedly influences the run-off, penetration, absorption, and circulation of moisture, and it is therefore necessary that highly trained soil specialists, familiar by experience with soil types and soil morphology, should study the problem in the field. Such men are being put on this work.

The greatest possible care is being exercised in locating sites for the stations. Sufficiently large tracts of land of uniform soil conditions must be found, and these must have a variety of slopes. Other necessary features are a not too severely washed condition to begin with, absence of noxious weeds, location on a good highway, and nearness to towns with housing facilities for the personnel.

The regions are being thoroughly examined in order to find suitable locations that can be easily reached by farmers, extension people, bankers, merchants, teachers, and others at any time of the year. It is expected that soil-saving and water-conservation schools will be held at these stations when the work has sufficiently advanced. Already visitors are daily coming to see the work at the stations in Oklahoma and Texas, and this desirable feature is certain to grow.

Searching out the proper soil and topographic conditions requires the services of our most widely trained soil scientists. In one region the search extended in considerable detail to 15 counties and in a reconnaissance way to other counties.

Additional station work will require the keeping of accurate rainfall, sunshine, wind, and temperature records, and the measurement of atmospheric and ground dust accumulations, the taking of numerous soil samples, and the making of moisture determinations from the various soil layers.

The reconnaissance erosion survey of the Nation is being continued, although the time required by the other phases of the investigation has not allowed the desired progress on this important project, the principal purpose of which is to determine the geographical distribution of eroded lands, the types of erosion, and the extent of the damage. Detailed erosion surveys are being made of all the experimental stations before actual operations begin.

In the Washington laboratory chemical and physical analyses are being made and research work carried on in connection with measurable properties of soils of relatively low and high erosivity. In connection with our recent soil surveys and explorations in the Tropics, various soil types have been found which possess markedly different properties of structure, resistance to erosion, swelling, shrinking, etc. Studies of tropical soils of lateritic character, such as those of Costa Rica and eastern Cuba, have shown that these soils resist washing in a remarkable degree, absorb most of the heavy regional rainfall, do not scour well over the moldboard of plows, show but slight stickiness, and crack but little on drying. Somewhat similar characteristics apply also to certain important soil types of the United States, as the Davidson, Nacogdoches, and Aiken types. The plastic clays, such as the Iredell, exhibit, to a marked degree, properties opposite to those of the lateritic group or the clays of low silica. Laboratory investigations of samples of these indicate the possibility of measuring the erosivity of these clay types by determining the relative dispersability of their colloids.

The work for the fiscal year 1931 will continue along the line of that carried on during 1930. With the funds requested it is expected to get under way experimental stations for an additional number of major erosion regions in which stations could not be equipped and operated with the funds available in 1930. This work of establishing these key stations and getting them into operation will be pushed as rapidly as funds allow. The erosion survey and other phases of the work will go forward, but the greatest emphasis will be placed on the completion of the regional erosion stations.

SOIL-FERTILITY INVESTIGATIONS

POTATO-SOIL AND FERTILIZER INVESTIGATIONS

Field work during the fiscal year was conducted on prominent soil types in the leading potato-producing sections of Maine, New Jersey, New York, Pennsylvania, and Virginia. These investigations are being carried on in cooperation with the agricultural experiment stations of the first four mentioned States, and with the Virginia Truck Experiment Station.

In the various commercial potato-growing regions in which the fertilizer work is being conducted, close contact has been maintained with potato growers and their organizations. In a majority of cases the fertilizer experiments have been made on land assigned by leading farmers. Through these contacts the purpose of the work and the results obtained are more definitely realized and appreciated by the people of the potato-growing sections.

The results obtained during the fiscal year continue to furnish practical evidence with respect to (1) the proper proportion of nitrogen, phosphoric acid, and potash to employ for potatoes on different soil types, (2) the kind and amount of nitrogen materials to use, (3) the kind and amount of potash materials to use, (4) the amount of phosphoric acid to use in potato-fertilizer mixtures, and (5) the most economical rate of application of fertilizer for potatoes on specific soil types and under different farm-management systems. These are results of immediate importance to potato growers and represent important accomplishments.

The 1930 results are giving further indications concerning the influence of fertilizer compositions and ratio on culinary quality and shape of potatoes.

The influence of fertilizers on fresh-cut and suberized seed stock showed clearly the advantage of suberization. Fresh-cut potato seed pieces were much more easily injured than the suberized stock. This is of importance to potato growers on light soils or where the fertilizer fails to become properly mixed with the soil.

SUGAR BEETS

The soil-fertility investigations with sugar beets during the past year have included a study of the various soil types as to their adaptability for growing sugar beets, together with the fertilizer requirements of those soils. Ten fertilizer experiments located in 7 of the 18 States in which sugar beets are grown were the basis for study of these problems. In addition to these experiments, five other fer-

tilizer experiments were conducted cooperatively with the office of western irrigation agriculture and the office of sugar plants, Bureau of Plant Industry.

The value of these experiments is accentuated by the low cost of the plant-food element most needed and the results to be obtained from as small applications of fertilizer as 125 to 200 pounds per acre of a 16 to 20 per cent phosphate. Where the treble superphosphate is applied not more than 100 pounds per acre are generally necessary. The cost of the fertilizer to the grower ranges from \$2 to \$2.50 an acre. With increased yield of 3 tons per acre, at \$7 a ton, the gross profit is about \$18 an acre—equivalent in value to a good wheat crop. In 1922, when the soil-fertility work with sugar beets was started, no fertilizer was used on sugar beets in Colorado, the largest and most profitable sugar-beet territory in the country. The American Beet Sugar Co. was the first to adopt a fertilizer program based on results furnished them from experiments conducted by the bureau in the Arkansas Valley. The practice more than doubled with each succeeding year's results and recommendations. During the past year the Great Western Sugar Co. put on a program of "phosphate for sugar beets" with recommendations to all of its growers to use it. Such recommendations are far-reaching and will no doubt lead to complications, as no two types of soil behave alike, where the same kind and amount of fertilizer is applied to each.

In order to safeguard the growers there is need to extend the fertilizer work to include all the important soil types on which sugar beets are grown. No definite information is available at this time to show the acreage of sugar beets that will be fertilized this season, but it has been estimated at 200,000 to 250,000 acres, which, with an increased yield of 3 tons per acre, would raise the value of this year's crop by \$5,000,000 less the \$500,000 expended for fertilizer.

SUGARCANE

The accomplishments for the fiscal year include soil and fertilizer studies in the field and chemical studies with soils and fertilizers in the laboratory at Houma, La. Before the fertilizer experiments were started in 1930 a reconnaissance survey of the entire sugar belt of Louisiana was made to determine the probable extent and location of the various soil types on which sugarcane is grown. A large number of samples of soil were collected and sent to the laboratory at Houma where a study of the hydrogen-ion reaction and other properties was made to determine, if possible, the limiting factor for growth of sugarcane on the various soil types. During the course of the reconnaissance survey a tentative soil map was prepared showing the probable extent of the different types of soils of the sugarcane belt. After making the reconnaissance of the soils of the sugarcane belt, fields were selected typical of each of the main soil types which were used for fertilizer test plots.

Seven test fields, picked for uniformity of soil type, were established at strategic points on the dominant soils of each area. Five mixtures containing different proportions of nitrogen, phosphoric acid, and potash were replicated from two to four times. Plant cane gave very little response to fertilization, owing to the residual effect

of green-manure crops. The results from first and second stubble, however, indicate that nitrogen is the most essential element, though mixtures of nitrogen and phosphoric acid and nitrogen and potash gave very satisfactory returns on certain soil types. Applications of 40 pounds of nitrogen per acre on first stubble grown on Yazoo silt loam showed an increase of 11.8 tons per acre over check, while second stubble on Yazoo loam gave an 11.1-ton increase. The phosphoric acid and potash mixture gave practically no increase over check.

CONCENTRATED-FERTILIZER INVESTIGATIONS ON PROMINENT SOIL TYPES

In a majority of cases the field work outside of Washington is conducted in direct cooperation with leading farmers. The crops employed as indicator crops are cotton, potatoes, sweetpotatoes, citrus fruits, corn, tomatoes, peas, beans, and sweet corn.

During the fiscal year results of importance were obtained demonstrating still more conclusively the crop-producing and economic value of concentrated fertilizers. Actual experimental field work in close contact with farmers and their organizations in some sections has enabled them to appreciate the fact that plant-food concentration does not mean less yield. It has been feasible, as a result of the field studies, to bring to the attention of many farmers in a number of crop regions the economies to be effected by the use of high-analysis fertilizers, such as savings on mixing materials, bags, freight, hauling, and handling.

At the same time the field work during 1930 has given positive evidence of the necessity for exercising the utmost precaution in using concentrated fertilizers on soil types of a sandy nature. It is on such soils that the importance of placement and distribution of concentrated fertilizers is clearly evident. The results which are being obtained have enabled the bureau to make more definite recommendations with reference to the use of high-analysis materials and their mixtures than it was heretofore possible to do. It has been found in Aroostook County, Me., for example, that the use of concentrated fertilizers for potatoes has increased considerably during the past year owing largely to the bureau's cooperative work on concentrated fertilizers with the Maine Agricultural Experiment Station, a report of which was issued by the Maine station. This is true of other sections, primarily owing to the work conducted by this bureau.

COTTON ROOT-ROT INVESTIGATIONS

The following soil investigations with the cotton root rot of Texas are in progress: The influence of fertilizer, rare elements, and soil amendments; influence of deep, shallow, and thorough tillage; and the influence of the physical and chemical characteristics of the soil on the root rot of cotton. A laboratory and offices are located in the University of Texas building at Austin, but field activities cover the entire black-land belt. Fertilizer and soil-amendment experiments were made at the United States Cotton Breeding Station, Greenville; United States field station at San Antonio; Texas Cotton Root Rot Experiment Station, Temple; and with 12 farmers in the black-land belt.

During the past season a series of 14 major field experiments were conducted in the black-land region of central Texas to test the effect of a variety of fertilizer ratios on cotton grown under conditions of root-rot infestation. The experiments were so distributed as to cover the range of variations in soil type and climatic conditions prevailing in the region and were carried out in conformity with the farm practice prevailing in the several localities.

In general, significant increases in yield resulted from the application of mixtures containing the higher proportions of phosphate, together with some nitrogen, although in some instances the greatest response was to the higher proportions of nitrogen in the presence of phosphate. In a number of cases the increases in yield were in excess of 75 per cent. The returns from such increased yields counterbalance or even measurably exceed the losses due to root-rot infestation. In several experiments phosphatic fertilizers appreciably accelerated maturity of the crop, offering promise of evasion of losses from root rot by maturing the cotton before killing of plants takes place. The prospects of indirect control of cotton root rot by use of suitable chemical fertilizers appear hopeful.

In most of the experiments considerable increase in yield of cotton has resulted from the use of fertilizers. A noticeable influence of certain fertilizer materials was effective in hastening the growth, fruiting, and maturing of cotton, and in delaying the appearance of cotton root rot. On many of the soils worked with, the cotton which was fertilized produced mature bolls, equivalent to from one-third to one-half bale of cotton, before any root rot started, whereas on the unfertilized areas no mature bolls had formed when root rot became established.

The tillage experiments under way are showing some promising results. When the heavy, stiff land is subsoiled to a depth of 16 or 18 inches and the intermediate area between the surface and this depth is chiseled to break up the hard compact mass and allow thorough aeration, considerably less root rot has appeared. Subsoiling to a depth of 18 inches, carried out in October, 1928, on a cotton field highly and uniformly infested with root rot, resulted in a reduction of infestation in 1929 to one-third of that occurring on adjoining nonsubsoiled land.

There is a marked correlation of root rot with the character of the soil in the black-land belt. Eroded fields where the subsoil is exposed and where tillage is poor are much more subject to loss of cotton from cotton root rot than fields which are well terraced and well cultivated. Surveys of definite areas which are spotted with root rot show that the root rot has caused most loss where the soil is shallow and the subsoil near the surface.

SOIL-FERTILITY AND FERTILIZER INVESTIGATIONS WITH PECANS

A field laboratory and office is located at Shreveport, La., and is maintained in conjunction with offices of the Bureaus of Plant Industry and Entomology. A chemical study and field studies of pecan soils of the region are under way to determine the soil's chemical and physical characteristics as correlated with pecan tree growth, nut yield, and quality. An experiment is in progress at Albany, Ga., using varying amounts of nitrogen in a complete

fertilizer, and one in cooperation with the Bureaus of Plant Industry and Entomology with fertilizers, cover crops, and tillage methods to study these factors on tree conditions and nut yield. Two experiments are in progress in Florida, one on Norfolk sand at Jacksonville, and one on Bladen sandy loam at Baldwin, to determine the best fertilizer formula for pecans on these soils. Results to date indicate that these Florida soils require more potash for pecans than the Georgia soils of the Albany section.

The work in the southeastern belt of Georgia, Florida, and Alabama has been in progress since 1918 and has led to the formulation of a fertilizer practice which is being generally followed by growers in these regions with increased yields.

FERTILIZER INVESTIGATIONS ON PROMINENT SOIL TYPES

Investigations were started in 1930 to study the fertilizer requirements of various soil types in North Carolina for sweetpotatoes and potatoes, in cooperation with the North Carolina Agricultural Experiment Station and potato growers organizations in the State. Experiments have been completed with potatoes on Norfolk sandy loam and Dunbar sandy loam at New Bern, N. C. The investigations showed that potatoes could be produced more economically with much less potash than was being used in the locality on these soil types, and resulted in a great saving to the potato growers. A fertilizer mixture composed of 5 to 6 per cent nitrogen, 7 per cent phosphoric acid, and 4 to 5 per cent potash has given best results.

Sweetpotato experiments have been completed on Portsmouth sandy loam at New Bern, N. C., Norfolk sandy loam at Beaufort, N. C., and Cecil clay loam at Newton, N. C. In these investigations a fertilizer mixture consisting of 4 per cent nitrogen, 7 to 8 per cent phosphoric acid, and 8 to 10 per cent potash gave best results. A 4-8-10 formula is used generally in these communities, as a result of the work, with largely increased yields.

Experiments have been in progress for five years with sweetpotatoes on Norfolk loamy fine sand in Currituck County, N. C. This county produces the largest quantity of early sweetpotatoes of any section of the United States. A fertilizer mixture containing 4 per cent nitrogen, 8 per cent phosphoric acid, and 8 per cent potash has given best results and its use has been adopted by growers, resulting in largely increased yields. The results of the concentrated-fertilizer studies to date are published in North Carolina Experiment Station Bulletin No. 252.

Fertilizer experiments with peaches were begun in 1922 in cooperation with the Georgia Agricultural Experiment Station. The results show that the maturing of peaches can be varied from 10 to 20 days by the use of varying amounts of nitrogen and potash. High phosphate fertilizer hastens and high nitrogen fertilizer delays the maturing of peaches.

THE OXIDATION OF SOME ORGANIC COMPOUNDS IN SOIL

The work on forms of nitrogen in soils has developed along two lines: (1) A further study of hydrolysis products, and (2) a continuation of the study of compounds by actual isolation and identification.

The fact that soils suspended in dilute alkali absorb oxygen when air or oxygen is passed through such suspensions, with the formation of an alkali carbonate, has been recorded and discussed in a bulletin in press. The continuation of work along this line has indicated a possible connection between this behavior and the presence of uronic acids, and it is believed that further consideration of this possible connection may throw light on the mechanics of the process just referred to.

Oxidation of soil organic matter by hydrogen peroxide has produced some interesting results. It has been shown that when soils are treated with hydrogen peroxide until no further action takes place there is left an insoluble residue which still contains carbon and nitrogen. Investigation of the nature of the nitrogenous material in such residue from one soil, Chester loam, has shown that it contains a compound or compounds similar to those classified in the indol group.

SOIL REACTION AND OXIDATION STUDIES

In general, this work has comprised the testing of all new methods or modifications of old ones proposed in the literature for the determination of hydrogen-ion concentration. One of the results of this work is the conclusion that the quinhydrone electrode can not be recommended for general use on soils. It is not applicable to soils that are alkaline and it is not accurate on soils containing much manganese. Inasmuch as nearly all soils contain some manganese and it is not definitely known how much manganese is necessary to make the method inaccurate, the only safe plan is not to use it on soils.

A method for determining chlorides electrometrically has been developed, and it is believed this will be just as accurate and very much more rapid than the method of extraction and titration.

GREENHOUSE INVESTIGATIONS

Considerable greenhouse work has been carried on during the year in conjunction with field problems. Some large-scale pot experiments to study the comparative effectiveness of phosphate materials on different crops were conducted and suggest that, in the main, the more readily available phosphate materials are superior to the less readily available phosphate carriers. Final conclusions are reserved until more data are obtained.

Studies with alunite and polyhalite as potash sources for oats and wheat indicate from results obtained during the fiscal year that polyhalite, in particular, compares favorably with potassium sulphate as a source of potash in mixed fertilizers.

MANGANESE STUDIES

Manganese studies are being carried on as a sequel to the greenhouse trials in which five different commercial manganese-carrying materials were tested as to their value for supplying that element to tomato plants grown in the manganese-deficient calcareous glade soils of Florida.

In all, 25 plant samples and 5 of the ripe fruit were analyzed for their content of moisture, ash, and manganese. The fresh and dry weights also were recorded. These plant samples analyzed represent check plants, control plants receiving known quantities of manganese, and plants grown in pots containing varied quantities of the several manganese carriers; also one set receiving magnesium sulphate but no manganese. The series represents plants grown for different lengths of time subject to the several soil treatments.

The general fertilizer used and the Dade County soil were also examined for their manganese content and the fertilizer, soil, and each of the manganese carriers have been examined for water-soluble manganese.

STRAWBERRY SOIL FERTILITY AND FERTILIZER INVESTIGATIONS

A field laboratory and office is located at Chadbourn, N. C., in conjunction with the Bureaus of Entomology and Plant Industry. A chemical study has been made of various types of soils on which strawberries are growing and plant conditions correlated with the soil's chemical and physical factors. The soils of the Chadbourn section vary widely in range of acidity. Field experiments are being made to study the influence of various nitrogen sources, the ratio of nitrogen, phosphate, and potash, and amounts of fertilizers. Investigations in pots and field are also being made of the effects of rare, essential chemicals, as manganese, iron, zinc, copper, etc. Manganese has had an appreciable effect on the plant, and there has been noted a correlation between the phosphate content of fertilizers and the amount of dead caps of strawberries. Especially good results have been secured with concentrated fertilizers composed of synthetic materials. So far as taste and flavor of the berries are concerned, these seem to be most favorably influenced by nitrogen.

SOIL MICROBIOLOGICAL INVESTIGATIONS

As a result of work in soil bacteriology done by the bureau and in the State colleges, inoculation of leguminous crops with nitrogen-fixing organisms is now widely accepted. The annual commercial distribution of cultures for this purpose is valued at about \$1,000,000 and probably affects crops valued at \$50,000,000. As directed by Congress, the Bureau of Chemistry and Soils inspects all the products offered for this purpose. This distribution was found divided among 14 State institutions and 22 commercial organizations. A list of 24 distributors producing satisfactory products was prepared and distributed to the public. Fraudulent and unsatisfactory products are being eliminated by this inspection. The bureau continues to support the distribution of high-grade cultures by maintaining a tested collection of types available to all applicants.

The decomposition of crop residues, natural vegetation, and waste products of all kinds in the soil depends on the microorganisms present. With a thousand types of soil described in the United States, the task of utilizing the power of this microbiological soil population in producing conditions favorable to crop production is immensely complicated. Conspicuous types of depleted acid soil have been selected, and the possibility of regenerating their produc-

tivity by fertilizer and the proper stimulation of the soil population has been demonstrated. The rate and nature of the decomposition processes which restore tillable conditions in soils which have become nearly worthless are being worked out on an experimental scale. The response in terms of increased crop production is fully demonstrated.

Along with the study of the function of microorganisms in mass, study of the presence and significance of special groups of organisms has shown one group, the slime molds, or Myxomycetes, not hitherto recognized in general agricultural work, to be present and active in the decomposition of plant residues on and in the soil.

INSPECTION OF SOIL INOCULANTS

Commercial preparations of nodule and other soil bacteria presumably beneficial to plant growth have been collected under more than 50 trade designations to the extent of more than 500 samples. In addition to these, 65 samples of seed inoculated with material of several kinds have been obtained.

The practice of preinoculating seed is new and is not recognized as a satisfactory method by specialists in soil bacteriology, the chief objection being that the organisms are subjected to severe drying under the circumstances and that the greater part of the material added falls from the seed. Finely divided soil mixtures, charcoal, and pulverized humus are used as carriers for the inoculants to be applied dry. Soil, sheep manure, peat, sand, nutrient broth, and agar are the chief materials employed in preparing cultures for application with water. Field comparisons of wet and dry applied materials have given better results with the former.

The samples collected, whether seed or cultures of organisms in packages, have been examined or are in the process of examination to determine their flora of microorganisms, principally their content of legume-nodule organisms, and their ability to produce satisfactory nodulation and plant vigor on the legumes for which they are intended. Since the last report several of the questionable cultures have been removed from the market and their manufacture evidently discontinued. The quality of the samples of inoculating material for legumes of the major producers continues fairly good, but there are several small producers who manufacture practically worthless cultures, none of which possesses as much efficiency as a fairly rich soil. Information concerning the quality of inoculants has been disseminated by letter, published lists, through the extension service, and by personal contacts. Companies with which cooperation is possible have been notified of defects found in their material.

ROOT NODULE BACTERIA

Studies in cooperation with the University of Wisconsin have indicated the variability in efficiency of soybean nodule organisms in fixing nitrogen. A similar condition was found in connection with Austrian winter peas at a livestock farm at Jeanerette, La. Bacteria from vigorous and weak plants of this field, the latter predominating, were tested in the greenhouse on the same legume and on two different occasions reproduced a condition similar to that

noted in the field. This work has been published under the title "A Failure of Austrian Winter Peas Apparently Due to Nodule Bacteria," in the Journal of the American Society of Agronomy.

At present cooperation is in progress whereby the department is testing the materials which are used by different cooperative farmers' organizations.

COOPERATION WITH THE EXTENSION SERVICE

During the past year approximately 6,000 cultures of nodule bacteria for treating seed of alfalfa, red clover, cowpeas, soybeans, vetch, and other legumes have been distributed to farmers and experimenters, either directly in response to written requests or through agricultural agents. In some cases where particular problems have arisen and no satisfactory source of inoculation was available, county agents have been supplied liberally with material for demonstration purposes.

A list of firms distributing inoculating material was compiled on October 2, under the title "Sources of Legume Bacteria Cultures" and distributed to those inquiring for such information.

MICROBIOLOGICAL STUDIES OF SELECTED SOILS

Studies with Leonardtown and Collington soils has been continued. Additional data obtained showed that the decomposition of green manures in the soil was largely local in nature.

It was found that numbers of bacteria increased tremendously in the green manure itself. Fungi increased in numbers to some extent. Protozoa increased as numbers of bacteria increased. No increase in numbers of any of these microorganisms was observed in the soil proper. A decided increase in pH and in NH_3 nitrogen took place in the green manure; as the decomposition processes slowed down the pH and NH_3 nitrogen content decreased while a gradual accumulation of NO_3 nitrogen took place. This NO_3 nitrogen tended to concentrate in the upper half inch of soil.

Carbon dioxide evolution was determined, and an apparent correlation with rate of decomposition was found.

In addition to microbiological studies on Leonardtown clay loam and Collington fine sandy loam inaugurated two years ago, an experiment has been started for the purpose of obtaining data on the maintenance of nitrogen in a number of selected soils.

An apparatus has been devised which is suitable for the determination of amounts of CO_2 given off by the soil and which can be used both in the greenhouse and in the field. The apparatus and its application has been described in a paper published in Soil Science under the title "A Method for Measuring Carbon Dioxide Evolution from Soil."

THE FUNGI OF THE SOIL

In connection with survey work in the field, plasmodia of the Myxomycetes were found, and repetition and extension of this work developed the information that this great group of organisms is much more abundant and active than has hitherto been supposed.

The amoeboid and plasmodium phases of these organisms have been shown to be abundant during the months from December, 1929, to April, 1930, all the way from the tips of decaying vegetation several inches above the soil to the level of the roots several inches in the soil. Cultures have been isolated and experiments for the determination of the part they play in soil economy are already in progress. A paper on this subject will appear in an early number of the *Journal of the Washington Academy of Sciences*.

Collections of saprophytic fungi from the soil and other sources continue to be submitted for identification from different workers in North America and abroad. Such assistance is given wherever possible. The Public Health Service continues to refer their inquirers and to send their own cultures of molds charged with pathogenicity in human cases to the bureau for identification. Since no other laboratory in the service seems prepared to handle these cultures, the questions have been answered as far as facilities allow.

The Monograph of the *Penicillia* has been completed and was published in book form in January, 1930. Plans have been made to extend in every way possible the study of fungi as active agents in soil processes.

SOIL CHEMISTRY AND PHYSICS INVESTIGATIONS

The work of the bureau in soil chemistry and physics is of two types: Service duties carried out at the request of other governmental agencies and research on soil topics.

During the fiscal year the service duties required a very large amount of time and labor and involved making about 1,300 examinations for the soil survey, the Bureau of Plant Industry, the division of soil fertility, smelter-fumes investigations, Bureau of Public Roads, phosphate investigations, Forest Service, Veterans Bureau, War Department, Bureau of Animal Industry, Bureau of Fisheries, Michigan Agricultural College, Post Office Department, and various other miscellaneous purposes. Many of the routine examinations are utilized by the bureau in supplementing research or confirming conclusions arrived at by other methods. They have also assisted in giving accurate and adequate replies to inquiries from the general public.

PHYSICAL EXAMINATIONS

During the year work was completed upon a pipette method of mechanical analysis of soils, based on improved dispersion procedure. This method has not only resulted in a more accurate measure of the texture of soils but has lessened the cost of operation. The main investigation has resulted in the publication of Bulletin 170, and certain aspects have been published in the *Journal of the International Society of Soil Science*. As a corollary of this investigation, a method of mechanical analysis of ground phosphorus and marl, and a discussion of the method and its application, has been accepted for publication as a technical bulletin.

In connection with the work of the bureau on soil erosion, a very careful study of the properties of soils which influence erosion has been made and has appeared as Technical Bulletin 178. The inves-

tigation has shown that the properties of major importance in soil erosion are the dispersability of the colloid and the moisture equivalent of the soil. Further studies are being made upon means of alteration of these and other properties. In the same connection, a study has been made of a laboratory method of determining the percolation rate of water through soils in the field. This investigation has thrown considerable light upon the variations of the permeability of soils, both in respect to their composition and their previous treatment, and the results promise to be useful in the problems of erosion.

Studies have been carried out on the optical properties of soil colloids in collaboration with the fertilizer and fixed nitrogen unit, with the result that much light has been thrown upon the constitution of the soil colloids.

Research is in progress upon the use of a supersonic oscillator in the dispersion of soil particles and is approaching completion. A very careful investigation of the soils upon which are located the erosion experiment stations is being made, and the results will be available for the assistance of those carrying on the field experimentation.

A study is being made on the osmotic character of soil colloids, but has not yet reached a point where definite conclusions can be drawn.

CHEMICAL INVESTIGATIONS

An investigation of the chemical effect of soil submergence in water has been completed and the results published in *Soil Science*. It has been shown that not only are toxic quantities of iron and of manganese developed in the soil solution, and that the soil is depleted in its calcium content, but that large quantities of gases are also produced from the organic matter, and include such normally toxic materials as hydrogen sulphide and carbon monoxide.

Continued studies on colloids have resulted in the publication of two bulletins and two articles in the *Journal of Agricultural Research*.

It has been shown that acid anions are absorbed by soil colloids, to a very slight degree, indeed, but that such absorption does occur, and in general is more marked in soils of the lateritic type than in the less completely decomposed soil materials of other soil types. A study of the chemical composition of the colloid isolated from certain soil types points to the possibility of fractionation of the colloids in such a way as to reveal differences in composition and throw light upon the process of development of such material. This investigation is being actively prosecuted and has already shown important results. The work will not be completed for a year or more.

The two bulletins above referred to have to do with the constancy of composition of the colloid of a given soil series and with the wide differences shown by the colloids derived from different soil series. This work is important not only as an aid to, and a justification of, the results of soil classification, but as a basis of variation in treatment of soils of different origin.

An investigation is being made of the effect of colloid material on phosphorus assimilation by plants. This investigation, while not yet complete, has shown that the different colloids are quite unlike in their retarding effect upon phosphorus assimilation and that this

effect is more or less closely associated with their silica sesquioxide ratio.

A very extensive investigation of the chemical composition and physical characteristics of three widely divergent types of peat has been made. An effort was made so to conduct these measurements that they may become the basis of comparison with future peat investigations, and the work is being continued with the object of ascertaining how normal organic reactions may be induced in peat when mixed with soil, and in this way accentuate its uses.

Investigations are under way on the causes of lack of productiveness of certain soil types of known infertility, and also on the chemical causes of differences in productivity of different samples of the same soil type. These investigations have not been carried far enough at present to warrant statements concerning the ultimate result to be expected.

FERTILIZER AND FIXED NITROGEN INVESTIGATIONS

Plant food is constantly being lost from our cultivated soils in large quantities, chiefly through the removal of crops but also as a result of leaching, erosion, and other miscellaneous agencies. The growing tendency to farm more intensively and produce larger yields per acre is further depleting the natural plant-food resources. Fortunately, nature has provided for the restoration of a part of the food removed, but the maintenance of soil fertility at a high level of production requires in addition that the farmer artificially supply certain of the elements removed. The substances which need to be considered in such a fertilizer program are nitrogen, phosphates, and potash.

The chief aim of this unit is to assist the farmer and the fertilizer industry in devising methods for the most economical production and use of these fertilizer ingredients. This entails the use of much fundamental chemical data that can only be procured by a comprehensive research program. The research activities are now concentrated to a large extent on the development of new manufacturing processes and the improvement of those already in use; the production of new compounds; the study of the practicability of using new sources of raw products or of utilizing by-products from other industries; and the determination of the chemical and physical properties of the final products. An intensive study of the various phases of fertilizer production is especially urgent at present in order that this country may no longer be dependent on foreign sources; it is also necessary for the industry to keep abreast of that abroad and be able to meet increasing foreign competition.

NITROGEN

The nitrogenous ingredients used in fertilizers have until comparatively recently consisted chiefly of organic materials from plant and animal sources, sodium nitrate from the natural deposits in Chile, and ammonium sulphate produced as a by-product from the coke industry. It has become increasingly apparent, however, during the last 25 years that in order to insure a supply of nitrogen sufficient to meet national demands of either peace or war an addi-

tional source of nitrogen is essential. European countries early took the lead in this field by pioneering the development of various nitrogen-fixation processes. This bureau has been endeavoring to promote the growth of such nitrogen-fixing industries in the United States. The three nitrogen-fixation methods that have been given most consideration are the arc, cyanamide, and synthetic ammonia processes. Research at present is confined to the latter, since the possibilities of cheapening the cost of ammonia production by this method seem much more promising. Such rapid progress has been made in recent years that it seems probable that this country will soon be entirely independent as far as nitrogenous fertilizers are concerned. Last year approximately 100,000 tons of ammonia were produced in this country from atmospheric nitrogen. This bureau has contributed in a major way to this industrial development by its own researches, by closely cooperating with the industry, and by training a considerable percentage of the personnel now responsible for production.

AMMONIA SYNTHESIS

In the production of ammonia by the synthetic process the pure nitrogen and hydrogen gases are mixed in the proper proportions and subjected to high temperatures and pressures in the presence of a catalyst. The catalyst, consisting of iron containing small percentages of such compounds as aluminum oxide and potassium oxide, greatly increases the rate at which the two gases combine. In fact, nitrogen gas is so unreactive that the whole process depends directly on the presence of a material that can activate it. A considerable part of the early research activities of this laboratory was devoted to the discovery of suitable catalytic materials. The research activities are now more concerned with the study of the factors which influence and determine the activity of these substances. By studying the fundamentals of catalytic reactions a sound basis is established for the improvement of catalysts and incidentally for safeguarding the future of the nitrogen industry. Much of the information being obtained is also directly applicable to numerous other chemical industries where catalysts are in common use.

The recent investigations have gone far toward determining the mechanism by which ammonia catalysts function. The indications are that the iron catalysts are particularly effective in ammonia synthesis because nitrogen can react with active iron atoms on the surface to form an iron nitride. This nitride in turn is capable of reacting with hydrogen to produce ammonia and form again the catalytic iron. Another series of experiments has shown that water vapor, one of the substances known to have a poisoning effect on synthetic ammonia catalysts, reacts with the active surface iron atoms to form a catalytically inert oxide of iron. Nearly complete restoration of activity results when pure hydrogen is again passed over these materials. The most modern developments in the fields of physics and chemistry are being applied to the study of these various reactions.

The production and purification of hydrogen used in the manufacture of synthetic ammonia is also a catalytic process. The hydro-

gen produced by the passage of steam over hot coke (water-gas process) contains about 35 per cent carbon monoxide, a substance which is very poisonous for synthetic ammonia catalysts. The removal of this impurity is effected most economically by taking advantage of its reducing properties and causing it to unite with steam to form more hydrogen. Commercially this is accomplished by means of catalysts, but with those in general use at present the conversion is incomplete. During the past year new catalysts have been developed which operate at lower temperatures and give more complete conversion. This work has not only resulted in improved water-gas catalysts but has furnished some new and valuable fundamental data concerning the oxides of iron and cobalt and their reduction that will be of use in the commercial production of these metals.

HIGH-PRESSURE STUDIES

In the commercial production of ammonia the combination of nitrogen and hydrogen gases takes place at high pressures. Under such conditions the physical properties of the gases can not be estimated even approximately by the laws governing the behavior of gases at low pressures. Accordingly, in order to design high-pressure apparatus and completely to understand the chemical equilibria involved, the behavior of the gases alone and in mixtures must be studied in detail over a wide range of conditions of temperature and pressure. Repeated requests from the nitrogen industry for such information emphasizes the need for continuation of such studies. During recent years detailed studies have been made with the two gases concerned in ammonia synthesis, namely, hydrogen and nitrogen; more recently the work has been extended to include carbon monoxide and methane, both of which are of interest in connection with the production of hydrogen. The solubility of all four of these gases in water at 25° C. and at pressures up to 15,000 pounds per square inch is now being determined. The specific heats of these gases at high pressures can now be calculated from the data obtained. Much of the information is of direct value in many other industries where high gas pressures are used.

Special metals or alloys are required where corrosive gases or liquids are used, particularly if high pressures are involved. Tests of a number of different steels exposed for long periods of time to high temperatures and highly compressed hydrogen-nitrogen-ammonia mixtures have just been completed. A study has also been made of the corrosion of iron and numerous alloys by phosphoric acid of varying degrees of purity.

UREA PRODUCTION

Ammonia gas, the end product of the synthetic ammonia process, must be converted into nitrogenous compounds having chemical and physical properties best adapted for use as fertilizers. One of the possibilities being investigated is the production of urea, a highly concentrated nitrogenous fertilizer, from ammonia and carbon dioxide. These two gases, both products of the synthetic ammonia process, unite to form a solid compound, ammonium carbamate,

from which urea may be obtained by heating to a temperature of 150° C. in a closed vessel. A small-scale plant, constructed for the production of urea in this way, has been operated to obtain further information on the conditions favorable to urea formation. The data obtained have more completely defined the factors influencing the conversion of ammonium carbamate to urea and the means of controlling these factors in commercial operation. An exploration of the thermal conditions in the autoclave in which the conversion is carried out has indicated possible economies in operation through the conservation of heat; it has also furnished information on certain features of operation.

Because of the corrosive action on ordinary structural metals of the molten material in the urea autoclave, a new series of tests on 12 of the most promising metals was carried out under actual working conditions of temperature, pressure, and flow. The results show that ordinary metals are rapidly attacked under these conditions, but that a nickel-chromium steel of high nickel content is the most resistant of the materials tested. Much additional fundamental information on various phases of the process has been obtained and analytical difficulties overcome.

Although urea is a readily available fertilizer for plants it has the disadvantage of being rather hygroscopic, that is, it absorbs moisture from the air readily. Various efforts are being made to overcome this, particularly by combining it with other substances, such as formaldehyde. Attempts have also been made to obtain urea particles with a nonhygroscopic surface film, and partial success has been obtained. From the products obtained by reaction of aldehyde and urea, definite compounds are being isolated, and these, as well as the coated materials, are being tested as to the availability of their nitrogen for plant growth.

NITRATE PRODUCTION

Various nitrate fertilizers may be produced readily from synthetic ammonia. In the first step in this process oxygen is made to combine with ammonia by means of a catalyst, such as platinum, to form nitrogen oxides. The oxides can then be converted easily into various nitrates for direct use as fertilizers. The platinum catalyst performs a function in this reaction analagous to that performed by iron in ammonia synthesis. This platinum catalyst is likewise easily poisoned by certain impurities in the gases involved. Studies, conducted on the formation of the nitrogen oxides, as well as on the effect of certain poisons on the catalyst, are furnishing information of both scientific and industrial importance.

PHOTOCHEMISTRY OF NITROGEN

A constant search for entirely new methods of rendering nitrogen chemically active is being conducted. As a direct result of this research policy evidence has recently been obtained which indicates that light of a very short wave length will serve as an activator of nitrogen. This suggests numerous possibilities and at the same time may explain some of the facts already known. For instance, in the arc process for nitrogen fixation, now no longer used to any great

extent commercially, three main factors are at work, any one of which may cause nitrogen to combine with oxygen. These are electricity, heat, and light. Until recently an electrical or thermal mechanism seemed to have been rather generally assumed, but the results obtained in this bureau indicate that the photochemical effect of ultra-violet or very short wave lengths produced in the arc may also be an important factor. These studies are not, however, being conducted with the idea of developing an improved arc process; the purpose is more fundamental, namely, to get at the scientific explanation of how and under what conditions light can so radically modify gaseous nitrogen. In recent years spectroscopy has furnished detailed knowledge of the structure of the nitrogen molecule; we are now in position to try to alter this structure so as to render this exceedingly inert substance chemically active.

NITROGEN FIXATION BY LIVING ORGANISMS

The great bulk of the nitrogen used by crops is nitrogen previously fixed by living organisms. We have no way of estimating the yearly quantity of fixation through biological channels, but we do know that the total supply fixed commercially is but a small percentage of that constantly being fixed by natural agencies. The three types of nitrogen-fixing organisms, responsible for most of the fixation, are being studied. These consist of the free-living soil organisms, such as *Azotobacter*; the nodule bacteria which live on the roots of leguminous plants; and certain blue-green algae. The purpose of this work is to determine the mechanism by which these lower forms of plant life are able to utilize inert nitrogen gas. Such living organisms fix nitrogen at ordinary temperatures and pressures and require no appreciable energy other than for growth processes. If nature's apparently simple system were known, the information might be applied to the development of very simple commercial fixation methods. The possibilities are inviting, and an intensive study is being made.

Investigations on *Azotobacter*, conducted during the past year, have furnished considerable information that has a direct bearing on the chemistry of the fixation process. It has been determined that no appreciable quantity of energy is required for fixation; furthermore, that either the element calcium or strontium is essential. A very small concentration of a readily available nitrogenous compound is sufficient to prevent all fixation. The behavior of the organisms, particularly with respect to nitrogen fixation, was determined at varying pressures of nitrogen and other gases. Studies of the effect of the growth-stimulant humic acid, extracted from soil, were made to determine if there is a corresponding effect on the fixation process.

Recent researches on legume-nodule bacteria have concurred with earlier findings in showing that the organisms do not fix nitrogen when growing apart from the host. In recent experiments the bacteria were grown under a variety of pressures of nitrogen, hydrogen, and oxygen. Additional studies are in progress which are expected to furnish more information regarding the relations existing between these bacteria and their host. Conditions are also being worked out

for the growing of leguminous plants under sterile or pure culture conditions and using artificial illumination.

Cultures of blue-green algae, which can use free nitrogen, were isolated from soil during the past year. These are the only chlorophyll-containing plants definitely known to be able to fix nitrogen without the aid of bacteria. The organisms grow practically as well in the absence as in the presence of fixed nitrogen, using sunlight as the sole source of energy. We know that these organisms are found widely distributed in soils, fresh-water lakes, and streams. No doubt they are responsible for considerable fixation, but their economic importance can not be stated from our present limited knowledge. Optimum conditions for growth are being determined prior to the beginning of chemical studies relating to the mechanism of nitrogen fixation.

RELATION OF FREE NITROGEN TO ORGANIC COMPOUNDS

The large quantities of nitrogen fixed in nature annually are stored up in the cells of the nitrogen-fixing organisms almost wholly in organic forms, principally as proteins and amino acids. We do not know the first step in the fixation process, but very likely even this is organic in nature. The purpose of the research program is to attack this problem directly by cooperation with those working with the living nitrogen-fixing organisms, and by a study of certain organic compounds or materials which appear to possess peculiar properties with respect to nitrogen. The work is aimed eventually at a nitrogen-fixation method which corresponds more closely to nature's system.

Certain organic compounds, such as those containing the azo and diazo groups, are being closely studied, since the nitrogen in these is closely related to molecular nitrogen in that they readily split off free nitrogen, leaving the rest of the molecule intact. It is hoped by a study of the energy relations involved in such reactions to throw light on new mechanisms for nitrogen fixation.

Another phase of the work deals with chlorophyll, the plant substance responsible for the fixation of carbon in nature. The energy-containing materials, synthesized by means of the chlorophyll, using sunlight as a source of energy, are essential for biological nitrogen fixation. In the case of the nitrogen-fixing algae the question arises as to how closely the chlorophyll present plays a part in the fixation process. In the case of bacteria the rôle is necessarily an indirect one. The relationships between nitrogen fixation by organisms, their processes of photosynthesis, and utilization of energy are so interwoven that it becomes highly expedient to treat the subject as a whole in the research program. Fortunately, this laboratory is well equipped for such a comprehensive study. Any results obtained should be of direct interest to those working on various plant problems and in other branches of agriculture. During the past year most attention has been given to the preparation of pure chlorophyll; its properties and reactions will be studied later.

POTASH

Progress in the development of an American potash industry is encouraging, the current annual production of potash salts being more than 100,000 tons, with a value of \$3,000,000. Nevertheless,

we still spend about \$23,000,000 annually for imported salts, of which \$18,000,000 is for agricultural potash. The purpose of the research work being conducted in this bureau is to work out methods for the production of potash at low cost from our available potash-bearing minerals. Sufficient progress has been made to warrant confidence that national independence with respect to this fertilizer material is now within sight.

Several methods are now in use or being developed for potash manufacture, but these may for convenience be grouped under two general types, namely, wet extraction and furnace methods. In the wet extraction processes the potash is produced by crystallization of natural brines or by treatment of the mineral with such reagents as mineral acids, certain alkalies, and nitrogen oxides in the presence of water. The furnace methods differ radically from all others in that the potash salts are volatilized and recovered directly from the furnace gases.

WET EXTRACTION METHODS

At the request of the Bureau of Mines the possibilities of the ammonia-carbon-dioxide treatment of the Texas potash saline mineral, polyhalite, have been considered and the essential data established. The entire feasibility of this procedure for the convenient separation of the potash, as sulphate, from its associated compounds of calcium and magnesium is indicated. Ammonium sulphate, a standard nitrogenous fertilizer, is produced as a by-product, the sulphate radical being derived from the mineral. The geographical location of the Texas deposits imposes the condition that the potash produced be in as highly concentrated form as possible if the product is to be widely distributed over the agricultural area of the United States in competition with the foreign potash distributed from the various ports of entry.

Another potash-bearing mineral, alunite, which occurs in large deposits in southern Utah, is being studied. While this mineral represents an entirely logical raw material for potash and alumina manufacture because of its high content of these constituents and the relative ease with which they may be separated, heretofore the processes applied have failed to meet the economic requirements of competitive conditions. Contributory to this situation is the fact that the alumina, a by-product of importance if not essential to the success of the proposed manufacture, has not been obtained sufficiently pure to enable it to enter the preferred market. This has been due to the fact that certain impurities, particularly silica, naturally present in the potash-bearing mineral, accumulate in increased concentrations in the alumina. A process has been devised and tested with affirmative results whereby the silica is eliminated as fluosilicic acid. Further work in progress has as its objective the elimination of iron. Improvements in heat treatments are expected to yield more uniform products, reduce fuel costs, simplify plant equipment, and reduce losses. A further objective is the utilization of the lower-grade alunite, as well as the high-grade mineral to which past operations have been restricted, with a view to increasing the potash potentialities of that raw material.

Enormous deposits of another potash-bearing mineral, leucite (wyomingite), occur in Wyoming. Fortunately, large deposits of high-grade phosphate rock and various other raw materials useful in fertilizer manufacture, together with abundant and cheap fuels, occur near by. Various researches are in progress to develop chemical processes best suited to this unique industrial situation. The production of available potash from leucite by treatment with the oxides of nitrogen and the various industrial acids is being studied, particularly from the viewpoint of by-product recovery.

Other potash-bearing materials, such as the greensands of New Jersey and the shales of Georgia, are being subjected to lines of attack similar to those used for leucite. In the case of the acid-extraction of greensand, iron and aluminum salts and adsorptive silica (glaucosil) are obtained as valuable by-products.

FURNACE METHODS

Fundamental research on the furnace treatment of various minerals for the volatilization of potash from its ores by blast-furnace procedures is yielding promising results. Electrical precipitation is used in this method for the recovery of the potash salts present as finely divided particles in the furnace gases. Preliminary results indicate the entire practicability of the method, particularly so when the furnacing of the leucite is combined with that of phosphate rock to yield both phosphoric acid and potash. The combination of these two fertilizer essentials to form the highly concentrated fertilizer salt, potassium phosphate, is contemplated as a logical means of reducing distribution costs. These costs must be given serious consideration where the fertilizer resources are far removed from the fertilizer-using areas. The blast furnace offers itself as a useful nucleus around which to assemble other chemical activities, due to the large volume of surplus gas it generates. The technology of potash recovery by blast-furnace methods, once developed as a part of the problem of smelting potash silicates, should also be applicable to the recovery of potash now currently liberated and lost in the iron and cement industries.

PHOSPHATES

In American fertilizer practice phosphoric acid represents an item of expense almost as great as nitrogen. The annual cost to the farmer is probably nearly \$80,000,000. Fortunately this country has large deposits in Florida, Tennessee, Idaho, and a few other States. In the present mining methods usually only the better-grade materials are used, the remainder being discarded as waste. The primary aim of the phosphate-research program of this bureau is to work out methods for more economically converting these phosphate-bearing minerals into suitable available fertilizer materials with the conservation of important by-products. It is desired particularly to develop methods which will make practical the utilization of the low-grade phosphate rock.

A study of the complete chemical composition of the various grades and types of phosphate rock is being made. This information is necessary as a basis for work on methods of phosphoric acid

production and for the recovery of any impurities which appear to have commercial value. X-ray studies have shown that phosphate rock consists of complex calcium phosphate having the general structure of the crystalline apatites. Consideration is being given to the possibility that a part of the available phosphate in fertilizer reverts to such forms when placed in the soil. The relation of the various impurities of phosphate rock, such as carbonates, sulphates, and fluorine, to the chemical constitution of the natural rock is being investigated. This question has an important practical bearing on the concentration of crude phosphates by flotation processes which are coming into use, particularly in the Florida phosphate fields. Results have shown that fluorine is definitely combined as a part of the phosphate-bearing mineral. The composition and properties of the waste-pond phosphates of Florida have been given special consideration. Vegetation, as well as chemical tests, indicate that the availability of this material is only slightly greater than that of ground phosphate rock regardless of the finely divided condition in which it naturally occurs.

Furnace methods discussed above in connection with potash manufacture are being applied with minor variations to the production of phosphoric acid. Sufficient experimental results have already been obtained to indicate definitely that these methods will lower costs, allow the utilization of low-grade materials now discarded, and produce highly concentrated products. This will result in a considerable saving in bags, handling, and transportation. Results so far made public have attracted the attention of many chemical manufacturers, both in this and foreign countries.

Most of the phosphoric acid manufactured in this country is now produced by the sulphuric acid process. Possible improvements in this method have been given consideration. A study has been made of the chemical composition of crude and concentrated phosphoric acids made from Florida pebble and Tennessee brown-rock phosphates produced by acid treatment. The possibility of substituting dilute phosphoric acid for sulphuric acid in the production of phosphate fertilizers is being considered.

Among the important by-products of phosphate production are fluorine compounds, particularly the fluosilicates. These offer interesting possibilities as substitutes for arsenic compounds in the manufacture of insecticides. During the past year an investigation of the volatilization of fluorine during the manufacture of phosphoric acid by furnace methods was made. Results obtained thus far indicate that about 25 per cent is driven off, principally as silicon tetrafluoride. Such volatilization in this case is no greater than that occurring during the manufacture of superphosphate by the sulphuric acid process.

CONCENTRATED FERTILIZERS

The trend in fertilizer manufacture in recent years has been toward the production of more concentrated products. This has been brought about partly by the fact that more concentrated ingredients are available from the synthetic ammonia plants, by-product coke ovens, and the various phosphate and potash producing plants. There has also been a desire to eliminate a large percentage of the

cost of bags, handling, and transportation so as to increase the profit to the farmer per dollar spent. There has been a tendency not only for the production of materials having a high content of one of the three fertilizer elements, but also for the production of single salts having two or even three of these elements present. This bureau is taking a leading part in working out methods of production of these various concentrated fertilizer materials and is studying their chemical and physical properties, suitability for mixture with other materials, and the properties of the various promising mixtures. Special attention is being devoted to the problem of obtaining mixtures that are suitable for use in drills; also to the type of machinery best suited to uniform field distribution.

One of the problems of particular interest at this time is the production of ammoniated superphosphate. Ordinary superphosphate, produced by the sulphuric acid process, will absorb either aqueous or anhydrous ammonia to the extent of about 6 per cent. In actual practice, however, from 2 to 2.5 per cent is now generally considered the practical limit, since larger additions cause a reversion of the phosphate to less available forms; at least this is the case as indicated by the present official methods of analysis. Chemical and vegetation tests are being made to determine more accurately the maximum practical percentage of ammonia which may be added to superphosphate. Since anhydrous ammonia is the cheapest and most concentrated of the nitrogen products that it is customary to prepare, it is desirable to use as much of it in this manner as is practical. By combining anhydrous ammonia, superphosphate, and potassium salts a high-grade mixture can be prepared from the cheapest materials on the market.

In continuation of previous work on the preparation of potassium nitrate it has been discovered recently that this salt may be produced by the treatment of potassium chloride with the oxides of nitrogen. In previous work a saturated solution of potassium chloride was used with the resulting production of the undesirable by-products, hydrochloric acid and nitrosyl chloride. By the dry method only the latter by-product is formed. For a successful commercial procedure, however, it will be necessary to utilize the nitrosyl chloride or recover the nitrogen contained in it. The various possibilities are being considered. The cost of fertilizers to the farmer may be reduced either by lowering the purchase price or by improving the quality and methods of use so as to produce better results on the crop without proportionately increasing the cost. Most of the fertilizer research in the past, conducted in this bureau, has been devoted to lowering the cost of production. More recently, considerable attention has been given to the improvement of drilling qualities and methods of application. In cooperation with the Bureau of Public Roads, studies of various types of fertilizer distributors in relation to the physical properties of the fertilizers have been made. Field tests in cooperation with several other organizations have indicated that more efficient distributors, better methods of application, and proper drilling qualities of the fertilizer, may make their use at least 20 per cent more profitable to the farmer than at present.

COOPERATIVE ENTERPRISES

Aside from the main activities, already discussed, much work of a cooperative nature is being carried on, both within the department and with outside agencies. A special effort has been made to make available to all those interested the highly specialized methods and apparatus developed for the specific problems at hand. Particularly is this true with regard to the projects dealing with catalysis, high-pressure gas studies, X ray, spectroscopy, and other problems involving modern physics. The application of such specialized methods offers exceptional opportunities for rapid advances in many lines of agricultural research. For instance, during the past year the X ray has been successfully applied to the identification of silicate minerals present in the colloidal material of soils. Mention has already been made of the use of the same methods for the study of catalysts and identification of the minerals present in phosphate rock. Likewise, photochemical studies are being applied to furnish fundamental information on the molecular structure of various compounds.

The application of improved modern methods to biological problems is proving especially fruitful. The use of gas-analysis methods furnishes a quick and accurate means of studying the rate of growth and metabolism of bacteria, algæ, and other small plants. Much of the information obtained on the relation of oxygen and nitrogen gases to nitrogen-fixing bacteria, their energy requirements, and the various factors which affect fixation was obtained advantageously by such methods rather than by those more commonly used by biologists. Likewise, during the past year ultra-violet light was successfully used for obtaining cultures of algæ free from bacteria. Previous attempts to make the same separation by ordinary biological methods repeatedly met with failure. There is room for a broader application of the same ideas into many other lines of research.

Certain activities may be classed as almost entirely cooperative. The analytical laboratory performs an important function in connection with the various research projects by working out new methods and furnishing data on the composition of the intermediate and final fertilizer products. The engineering section is called upon to design special equipment for practically every line of research being conducted, and also furnishes information to various branches of the fertilizer industry. Considerable attention has been devoted to the design of high-pressure equipment, a field in which the available information is exceedingly meager. Many questions dealing with the economics of fertilizer production are answered for the public and the industries. In fact, the policy of the bureau is to make all types of information readily available to those who wish it, both through publications of various kinds and directly through letters and personal contacts.

**PUBLICATIONS OF THE BUREAU OF CHEMISTRY AND SOILS
ISSUED DURING THE YEAR JULY 1, 1929, TO JUNE 30, 1930**

TECHNICAL BULLETINS

- No. 128. The Alteration of Muscovites and Biotites in the Soil.
No. 141. The Spontaneous Combustion of Hay.
No. 162. Tests of various Aliphatic Compounds as Fumigants.
No. 163. Inheritance of Composition of Washington Navel Oranges of Various Strains Propagated as Bud Variants.
No. 169. Comparative Data on Wearing Quality and Other Properties of Vegetable-Tanned and of Chrome-Retanned Sole Leather.
No. 170. A Pipette Method of Mechanical Analysis of Soils Based on Improved Dispersion Procedure.
No. 178. Properties of Soils Which Influence Soil Erosion.
No. 182. Factors Affecting the Mechanical Application of Fertilizers to the Soil.

CIRCULARS

- No. 95. Subsoil an Important Factor in the Growth of Apple Trees in the Ozarks.
No. 98. The Wonderful Variety of Pomegranate.
No. 110. Specific Gravity and Baumé Gravity Tables for Turpentine.

JOURNAL OF AGRICULTURAL RESEARCH ARTICLES

- Can Nodule Bacteria of Leguminous Plants Fix Atmospheric Nitrogen in the Absence of the Host.
Effects of Various Fumigants on the Germination of Seeds.
The Chemical Composition of Colloidal Material Isolated from the Horizons of Various Soil Profiles.
The Properties of Arachin and Conarachin and the Proportionate Occurrence of these Proteins in the Peanut.

SOIL SURVEYS

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| Butler County, Nebr. | Lac qui Parle County, Minn. |
| Adams County, Nebr. | Warren County, Iowa |
| Wichita County, Tex. | Wilson County, N. C. |
| Summers County, W. Va. | Hidalgo County, Tex. |
| Monroe County, Wis. | Moody County, S. Dak. |
| Pierce County, Wis. | Salinas Area, Calif. |
| Muskegon County, Mich. | Willacy County, Tex. |
| Chico Area, Calif. | Monroe County, W. Va. |
| Columbia County, N. Y. | Carroll County, Iowa. |
| Linn County, Oreg. | Hyde County, S. Dak. |
| Howard County, Iowa | Chickasaw County, Iowa. |
| Herkimer County, N. Y. | Oroville Area, Calif. |
| Soda Springs-Bancroft Area, Idaho | Calumet County, Wis. |
| Quitman County, Ga. | Nuckolls County, Nebr. |
| Bradley County, Ark. | Nash County, N. C. |
| Webster, County, Nebr. | Rockingham County, N. C. |
| Nevada County, Ark. | Essex County, Mass. |
| Alpena County, Mich. | Wayne County, Ga. |
| Roscommon County, Mich. | Kossuth County, Iowa. |
| King City Area, Calif. | Lake of the Woods County, Minn. |
| Northampton County, N. C. | Clayton County, Iowa. |
| Middlesex County, Mass. | Brown County, S. Dak. |
| Salem Area, N. J. | Nacogdoches County, Tex. |
| Cass County, N. Dak. | Wayne County, Ind. |

MISCELLANEOUS

Report of Conference on Spontaneous Heating and Ignition of Agricultural and Industrial Products. (Joint publication of the National Fire Protection Association, the United States Department of Commerce, and the United States Department of Agriculture. Published and printed by the Government Printing Office.)

YEARBOOK ARTICLES

Sweet Potatoes High in Food Value and Vitamin Content.
Cotton-Gin Fires Frequent; Chief Cause is Static Electricity.
Insecticidal Properties of Fluorine Open Wide Field for Investigation.
Hides and Skins Have Potential Value Often Lost by Mishandling.
Starches Imported for Some Uses, Though U. S. Has Surplus Cornstarch.
Mayonnaise Produced Commercially Since 1906 for Growing Trade.
Wheat That is Slightly Germinated Helps Flour When Sparingly Blended.
Nitrogen is Fixed in Nature Almost Wholly by Microorganisms.
Nitrogen's Functions in Plant Growth Make Cheap, Ample Supply Essential.
Gases Response to High Pressure and Temperature Shown.
Fertilizer's Value Measured in Tests in North Carolina.
Fertilizer Applications That Show Most Profit Are Difficult to Make.
Chlorophyll, Cause of Greenness in Plants, is Influenced by Nitrogen.
Potash Development in United States Requires By-product Utilization.
Light-Wave Lengths Yield Information Important to Farmer.
Soil Activities Affected in Complex Manner by Plowing in Green Manure.
Soil Color is Clue to Presence or Lack of Desirable Qualities.
Soils Under Various Conditions Hoard, Bank, or Waste Plant Food.
Fertilizer Materials for Cotton Growing Must be Well Chosen.
Soil's Acidity Can Be Accurately Measured by the pH Value.

