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REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS, 1936

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY AND SOILS,
Washington, D. C., August 31, 1936.

HON. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1936.

Sincerely yours,

HENRY G. KNIGHT, *Chief.*

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INTRODUCTION

The Bureau of Chemistry and Soils is a research organization engaged in the application of chemistry and related physical sciences to the study and classification of soils, the study of fertilizer and soil-amendment materials for maintaining soil productivity, and the study of agricultural products as regards utility, the prevention of deterioration and losses, and the expansion of uses. The work of the Bureau contributes to the stabilization and prosperity of American agriculture through effecting greater efficiency in production and wider utilization of agricultural products and is therefore essential to the welfare of the Nation. It also benefits industries engaged in processing agricultural products for food uses, in converting agricultural raw materials by chemical and mechanical means into nonfood products, and in manufacturing fertilizers. Indirectly it benefits all people of this country, because they are almost wholly dependent upon American agriculture for food and raiment and the fulfillment of many other wants, and are therefore affected by efficiency in the production and utilization of agricultural products.

The Bureau is making fundamental studies on the composition, chemical properties, and physical properties of soils, soil colloids, and soil minerals in their relation to soil formation, soil texture, erodibility, and productivity, the results of which find practical application in soil classification, soil utilization, and soil conservation and help to explain variations in the yield, composition, and food value of crops. Practical studies are being made on the occurrence and toxicity of selenium in soils and plants, on the effects of arsenical insecticides upon soils, on the causes of nonfertility in certain soils, and on the value of peat as a soil amendment.

Through the Soil Survey Division, the Bureau is making an inventory of the Nation's soil resources by classifying soils according to origin, characteristics, and usefulness for various agricultural purposes and is mapping soils according to classes and types by counties or other small units. The soil-survey reports and maps enable individual farmers to work out cropping systems by which they can make the best of their soil resources. Land classification, based on the results of the soil survey, also furnishes information of great value in developing governmental policies of land utilization, in determining the feasibility of reclamation projects, in applying the results of experimental work in crop production and farm management, and in land appraisal.

For the purpose of maintaining soil productivity at the lowest possible cost through economical utilization of the country's resources of plant-food elements, the Bureau is investigating the availability and suitability of raw materials for making fertilizers: is developing new and improving old processes for converting atmospheric nitrogen, phosphate rock, and potash minerals into efficient fertilizer materials; is making new compounds of plant-food elements and studying their properties with special reference to suitability for use in mixed fertilizers; is designing fertilizer mixtures which promote crop growth without increasing soil acidity, with resultant injury to crops in subsequent years; and is improving the form of mixed fertilizers to prevent segregation of materials and facilitate distribution in the field. In order to develop basic data required for solving some of the practical problems, fundamental research is in progress on catalysis, the mechanism of nitrogen fixation by living organisms, the fixation of nitrogen with organic substances, physical and thermodynamic properties of solids, liquids, and compressed gases, chemical kinetics, activation of gases, and molecular structure as revealed by X-ray and electron diffraction and spectroscopic studies.

In connection with the work on agricultural products, the Bureau is carrying on basic research on the chemistry of plant pigments, cuticle waxes of fruits, proteins, lignin, turpentine, and resin acids of pine gum; also on the nature of enzyme action, in the pharmacology of insecticides that may contaminate fruits and vegetables, and in microbiology as it relates to food spoilage, food preparation and preservation, industrial fermentations, and the curing of hides and skins. Applied research on agricultural products includes investigations on the suitability of primary and secondary agricultural products for food and non-food purposes, studies on the causes and prevention of deterioration and losses, and technological investigations on the utilization of agricultural products for food and nonfood purposes.

During the past year the Bureau planned and organized three new projects as a part of the Department's program of basic research in agriculture, provided

for in the Bankhead-Jones Act of June 29, 1935. These are: (1) Research into the industrial utilization of soybeans and soybean products, (2) the chemistry of enzymes and of enzyme action at low temperatures, and (3) a study of the allergens of agricultural products. In addition, this Bureau planned work in cooperation with the Bureau of Plant Industry on a Bankhead-Jones project for the study of plant viruses. Since actual experimental work on these new projects had not yet started or was just getting under way at the close of the year, no report of progress is included in this report.

On July 1, 1935, the three-unit organization of the Bureau of Chemistry and Soils was discontinued, and further changes in organization were made during the year. The unit of Soil Investigations became the Soil Survey Division and the Soil Chemistry and Physics Research Division, and the unit of Fertilizer Investigations became the Fertilizer Research Division, all coordinate with the divisions previously included in the unit of Chemical and Technological Research and new divisions created through realinement of work. Naval Stores Research, which was previously a part of the Industrial Farm Products Division, was made a separate division. The former Color and Farm Waste Division was abolished, and its activities were merged with the remaining activities of the Industrial Farm Products Division, the name of which was changed to Industrial Farm Products Research Division. The Oil, Fat, and Wax Laboratory was made a part of the Carbohydrate Research Division. The editorial section of the Bureau was reorganized as the Information Division, and the business offices were combined into a Business Administration Division. The present Bureau organization consists of the offices of the Chief of Bureau and Assistant Chief and the following Divisions: Carbohydrate Research, Chemical Engineering Research, Fertilizer Research, Food Research, Industrial Farm Products Research, Naval Stores Research, Protein and Nutrition Research, Soil Chemistry and Physics Research, Soil Survey, Business Administration, and Information.

Results of the research work of the Bureau during the fiscal year 1936 are reported briefly in the following pages. Fuller information concerning many of the subjects discussed may be obtained from the 231 publications emanating from the Bureau during the year and listed at the end of this report.

CARBOHYDRATE INVESTIGATIONS

SUGARCANE AND CANE SUGAR

The introduction by the Bureau of Plant Industry of new varieties of sugarcane better suited to conditions in continental United States has occasioned the cooperative investigation of the chemical composition and properties of the juices of new sugarcane varieties at a number of test-field locations. Comparable data indicate that the juice of CP 29-320, released in 1935 for commercial cultivation, is similar to that of cane variety Co. 281, except that it does not have the high lime content characteristic of the latter variety. Preliminary tests were made on the juices of 20 recently developed cane varieties which have not yet been released for commercial cultivation but which have shown some promising results from an agronomic point of view.

Data obtained during the past three seasons were assembled for use in publications to show the influence of the method of clarification and of variety, soil type, and fertilizer on the quality of the juice, sirup composition and color, and the composition and quality of sugar produced. This information has an important bearing on the relative value of different sugarcane varieties and clarification methods from the point of view of quality and yield of sugar and the proportion of molasses obtained. Work is almost completed on the preparation of a technical bulletin showing the differences in composition of nonsugar constituents in the juices of several different varieties of sugarcane.

A study of the ash from 50 samples of sugar indicated that organic salts generally constituted more than one-half of their total salt content. Physical examination of these sugars after storage for 1 or more years showed that most sugars produced by the sulphur-lime clarification process had become distinctly darker, whereas those produced by simple lime clarification were changed very little. These observations are significant in that they help to explain the frequent deterioration in color of plantation sugars between the time of production and consumption, which has caused some prejudice against plantation sugars among buyers.

More than one-third of the plantation sugar houses in continental United States, which manufacture direct-consumption sugar by the sulphitation process, find it desirable to produce high-grade first or second molasses as a byproduct. This production method is desirable under some domestic conditions, since it represents a shorter process, does not require very extensive equipment, and is therefore well suited to the smaller plantation sugar houses.

The use of this process, however, is limited by the demand for higher grade molasses. Such molasses contains sulphites, the proportion of which is limited by Federal and State food laws. Consequently the demand for edible molasses produced as a byproduct in this process is largely limited to molasses of low sulphite content. A method for reducing, or if possible eliminating, sulphites from edible molasses of this type would therefore be of considerable constructive value for extending the market for it.

A method involving the use of chlorine and hypochlorite for oxidation of sulphites in molasses was investigated. After laboratory study, a trial run was made in a plantation sugar house with satisfactory results. An improvement in flavor was noted as a result of elimination of the characteristic flavor effects of sulphites. This method will also be applied to production of sugarcane sirup by the sulphitation method. If successful, this would be of much constructive value by allowing the use of the sulphitation method for the production of sugarcane sirup in localities where the character of the soil otherwise will not make possible production of sirup of satisfactory quality. Application for a public service patent to cover this process has been made.

The investigation of the deterioration of harvested sugarcane was continued in cooperation with the Division of Sugar Plant Investigations, Bureau of Plant Industry. Its purpose is to learn the nature and cause of deterioration in sugarcane stored between the times of harvesting and grinding, to determine which varieties deteriorate least in storage, and to find means for storing reserve supplies of harvested cane for a period of several weeks without serious deterioration and loss of sugar. Storage of reserve supplies is necessary to prevent losses by freezing and intermittent shutting down of plantation sugar houses during rainy weather when the fields are impassable. During the 1935 season, particular attention was directed to the effect of various storage conditions on the composition of the entire cane stalk. Analysis of the juices only, as formerly done, required less time, but variation in the percent extraction of juice from different cane varieties made it necessary to extend the analysis to the whole stalk. Five varieties of sugarcane were stored under six controlled conditions of temperature and relative humidity. The sucrose content of all the canes remained practically unchanged after storing for 3 weeks under high relative humidity (95 percent) at temperatures between 55° and 75° F. At a lower temperature (45°) and the same humidity, there was some increase in reducing sugars, possibly due to retarded rate of respiration. Inversion of sucrose proceeded more rapidly when the canes were stored under a relative humidity of 65 percent, which allowed some drying, but the rate differed for the several varieties. Variety Co. 281 showed only a small degree of sucrose inversion; the others showed increasing inversion in the order, Co. 290, CP 28-19, CP 28-11, and CP 29-320, the last two being particularly susceptible.

Comparative storage tests on 22 varieties of new CP seedling canes, which were somewhat promising from an agronomic point of view, showed that only 3 were equal or superior to Co. 281 in keeping quality. Tests on Co. 281 windrowed before and after a heavy freeze, in comparison with standing cane of the same variety, showed that both the windrowed and standing cane remained in good condition after exposure to a temperature of 25° F.

No correlation was observed between the invertase content of different varieties of canes and their tendency to deteriorate during storage. The invertase content of sugarcane varies considerably, depending, it is supposed, on cultural conditions and increases in the harvested stalk, regardless of the conditions under which it may be stored. Data indicate that there is a greater increase in invertase content of the stalk when stored under conditions that cause most rapid deterioration. It is evident, however, that factors other than the mere presence of invertase govern the rate of inversion of sucrose in stored sugarcane.

The practice of sprinkling water over cane stored in piles, which was recommended as a result of previous work, was adopted by sugar plantations to an increasing extent last season and was found to be very effective in reducing deterioration and sugar losses.

SUGARCANE SIRUP

Sugarcane sirup ranks next to cotton as a cash crop in many counties of the States bordering the Gulf of Mexico. Competition with other sirups makes it increasingly necessary for farmers to give careful attention to the quality of their sirup in order to find an adequate market at satisfactory prices. In response to insistent requests for visual demonstration of methods developed by the Bureau for making sirup of improved and more uniform quality, several demonstrations, in which regular farm equipment was used, were made at selected points in cooperation with State extension service workers, vocational teachers, and farm sirup producers. County agents and vocational teachers, who witnessed these demonstrations and who are expected to continue the necessary instruction of sirup producers, and Extension Service sirup specialists, who have been appointed in several States where there is considerable interest in farm sirup making, will thus aid in disseminating the information on improved methods. Improved practices in sirup making resulting from future research will be made known to these sirup specialists for demonstration as rapidly as they are developed by the Bureau.

Laboratory research was started to determine the causes of the dark color and strong flavor in poor-quality cane sirup. Results obtained thus far indicate that the Maillard reaction between amino acids and reducing sugars is not the predominant cause, and that other important factors are involved. All possible factors are being studied with the object of devising means for control or prevention. Methods of preventing the production of low-grade sirup, characterized by dark color and strong flavor, would be more desirable and probably more effective than measures of correction. Low-grade sirup is hard to sell locally and often must be sold to sirup blenders at the end of the season at distress prices, sometimes as low as 20 cents a gallon, whereas sirup makers having a reputation for a good product can sell direct to consumers at prices ranging from two to four times as much.

At the request of several groups and associations of cane-sirup producers, assistance was given in planning community cane-sirup plants. The object of these groups is to use community plants for the purpose of standardizing and improving the quality of sirup.

SORGO SIRUP

Sorgo sirup is an important farm-subsistence and cash crop in 16 principal producing States. Sixty percent or more of the total annual production, which averaged over 17,000,000 gallons during the past 9 years, is marketed as a cash crop. Although the sale of sorgo sirup is an important source of income on thousands of small farms, particularly in the South, the fact that much of the sorgo sirup is of inferior and nonuniform quality greatly reduces marketing possibilities and the prices obtained.

In an effort to eliminate the difficulties which tend to prevent the production of good sorgo sirup, an investigation was made of the quality and composition of sirups prepared from different portions of the sorgo stalk at different stages of maturity. This work was done in cooperation with the Mississippi Agricultural Experiment Station, and four of the best varieties of sorgo grown in northern Mississippi were studied. The data obtained show that the quality of sorgo sirup can be greatly improved by using cane which is ripe but not overripe, as determined by the condition of the seed heads, and also by discarding a certain proportion of the cane tops. The improvement in quality and possible increase in value may offset the comparatively small loss in yield of sirup, particularly when the forage value of the tops is considered. Most of the starch, which causes "jellying" and makes it impossible to boil down the sirup to required density without scorching, is present in the upper part of the stalk and can be eliminated by topping. A study of the sucrose and reducing sugar relationship in different parts of the stalk also revealed that it might be practical to establish a practice of selecting a certain portion of the sorgo stalk for sirup production, whereby sucrose and dextrose crystallization in the sirup, which detracts from its value, could be avoided without incurring too great loss in yield of sirup. Objectionable sharp flavor or tang, which is correlated with the titratable acidity, can probably be minimized by variety selection, avoiding overripe stage of maturity, and topping to the fifth internode.

At the urgent request of sorgo-sirup makers and county agents in various sections, improvements in methods for making sorgo sirup, recently developed

by this Bureau, were demonstrated. The assembled groups included county agents and vocational teachers who were fitted by these demonstrations to continue the introduction of improved practices among farm sirup producers. Specialists were designated by the State extension services of Mississippi and Alabama to cooperate with the Carbohydrate Research Division in introducing better methods of producing sugarcane and sorgo sirups.

BET SUGAR

The advantageous marketing of beet sugar has been greatly impeded by non-uniformity of quality. Owing to this lack of uniformity certain food industries in the areas where beet sugar is produced and in adjacent areas have not used beet sugar for all their sugar requirements. Beet sugar, instead of having a maximum consumption in its own territory, is spread out over a much larger consuming territory, and the industry, including growers of sugar beets, must absorb the additional freight charges thereby incurred. There is also a price differential of 20 cents a 100 pounds in favor of refined cane sugar over beet sugar. These conditions cause serious losses to the industry, which are borne by both sugar-beet processors and growers and which can be largely eliminated by greater uniformity in quality.

Investigations on the identity of the nonsugar constituents which adversely affect the quality of beet sugar were continued, and a study was made of chemical and technological means of reducing or eliminating these constituents. Analytical methods for determining small proportions of nonsugar contaminants in sugars and intermediate products were further developed.

A photoelectric instrument for evaluating the appearance of sugars in granulated form was developed with the assistance of B. A. Brice, associate physicist in the Food and Drug Administration. The instrument measures the light reflected from a sample of sugar, thereby giving a numerical index of its appearance, free from the element of human judgment. This index, as the percent of light reflected by the sugar, was found to be influenced by both color and size of grain. The appearance of all sugar collected during the 1935 season was evaluated with this instrument and correlated with size of grain, as determined by screening tests. Since appearance is an important factor in marketing, recommendations to effect greater uniformity in size of grain were made. This information, together with the data on reflectance, size of grain, and chemical analyses of the sugars, was included in the annual beet-sugar report issued in July 1936.

Systematic examination of beet-sugar samples from practically all sugar-beet areas in the country showed that still further improvement in quality was made during the season of 1935. This is especially noteworthy, since sugar beets harvested in certain areas were decidedly inferior in quality because of adverse weather conditions.

With the cooperation of the Food Research Division beet sugars were examined with regard to their tendency to promote the growth of yeasts and contamination by thermophilic bacteria which must be negligible to conform to the requirements of certain commercial firms which use sugar in large quantities.

HONEY

The annual production of honey in the United States is about 150,000,000 pounds, with a farm value of approximately \$11,000,000. A total of about 5,000,000 colonies of bees are kept by nearly 1,000,000 honey producers. Honey as customarily marketed has not met the prevailing commercial standards for liquid saccharine products, and the sale of extracted honey and the financial return to producers have been greatly handicapped by various defects, such as turbidity, foaming, formation of surface scums, excessive color, granulation, and caramelization (when the honey is heated to only slightly elevated temperatures, which is necessary in certain consuming industries). The processing and packing of honey as now practiced results in some loss or modification of flavor, thus impairing its principal distinctive characteristics. Greater knowledge of the chemical composition of honey and improvement in technological processes for handling, packing, and also for using honey in certain industries are urgently needed. These advances in practice would not only increase the value of honey but would also extend the market by allowing uses now prevented by certain defects, for example, granulation and excessive caramelization when heated. Honey is also subject to various forms of deterioration, which occur in storage or after packing.

The development of a rapid method for processing honey was completed. This method is now being adopted throughout the United States and promises to revolutionize the handling of extracted honey. Two manufacturers of equipment have placed on the market special equipment for applying the process which requires only a fraction of the time required by previous procedures. The method prevents practically all the difficulties heretofore experienced by the industry in handling and packing extracted honey, in that it eliminates emulsified air and surface scums, prevents granulation, insures complete retention of flavor, and yields a product of brilliant clarity preeminently suited for packing in glass containers. Inquiries have been received from several European countries, and the method is expected to improve the export market for American honey in countries which have discriminated against it in the past because of certain defects in quality. This method, which has been greatly needed by the industry, is expected to improve the marketability of honey for both domestic and export use.

An investigation of the mineral constituents of honey with respect to the acid-base balance was completed. The results of this study show that honey as a food is potentially alkaline, dark-colored honeys in general being potentially more alkaline than light-colored varieties. Alkaline values of the honeys investigated varied from 0.3 for a very light-colored honey (fireweed honey) to 4.6 for a very dark variety. The average alkaline value of all samples studied was 1.5. Although this value is somewhat low, it compares favorably with some of the typically alkaline fruits and vegetables, such as oranges, peaches, lemons, bananas, beans, mushrooms, and turnips.

MILK-SUGAR PRODUCTS

In view of the fact that a large dairy-products firm producing milk sugar has become interested in commercializing a method developed in the Bureau for making lactose fondants for use in confectionery, thus effecting the possible utilization of large quantities of lactose now wasted in sweet whey, some further work on milk-sugar products was done. It was found that a smooth fondant dependent upon having the greatest possible number of fine crystals could be obtained by preventing premature crystallization of the lactose solution and by using a sufficiently low temperature during crystallization to minimize supersaturation of the liquid portion with lactose. The final product could be made in such a way that as much as 70 percent of its total sugar content consisted of lactose. Preliminary experiments were conducted, in cooperation with the Bureau of Dairy Industry, on the preparation of a lactose fondant by using lactose in the form of an impalpable powder. The advantages hoped for in such a process, which would eliminate boiling of the lactose solution, are a saving in production cost, a more exact control of sugar and moisture contents of the fondant, and better appearance of the product resulting from avoidance of discoloration by heating.

MAPLE SIRUP

Master color standards for grading maple sirup by farm producers were prepared for State agencies in producing areas, and these agencies in turn prepared color standards for distribution to producers. This service was rendered for the purpose of correcting previous lack of uniformity in quality grading and allows producers to determine independently the quality of their product.

LEVULOSE AND ARABINOSE

During the past year the first phase of the work on the preparation of levulose sirup from chicory roots was completed. The cause of slow filtration of the intermediate product, calcium levulosate, was studied and the operation of the pilot sirup plant was changed to make filtration more rapid. It was found that the rate of filtration varies with the time interval between the end of liming (to produce calcium levulosate) and the beginning of filtration. If allowed to stand for about 40 minutes, the calcium levulosate apparently becomes more granular and therefore filters with greater ease. A quantity of sirup was prepared and supplied to several possible consuming industries for trial.

The sugar levulose is hygroscopic, very soluble in water, and difficult to crystallize. These properties make it suitable for use in baking to retard loss of moisture and the staling of sweet goods, in certain confectionery products, in tobacco products to insure retention of moisture, and in certain food products where difficulty is experienced with ordinary sugars because of crystallization.

Undoubtedly there is a market for levulose if it can be produced at a sufficiently low cost and sold at a reasonable price. It is believed that this market can be satisfied best by levulose in the form of sirup rather than in crystal form. Levulose can be used satisfactorily and sometimes more advantageously in the form of sirup which can be produced at lower cost than the crystals and with a sufficient degree of purity for most purposes.

A comparatively cheap method for extracting and purifying the sugar arabinose is being developed. In this method the use of lead acetate and hydrogen sulphide, which have been employed in some procedures, was eliminated. Various plant materials may be used as sources of arabinose, but the byproduct sugar-beet pulp is probably the most feasible source in this country. The properties of arabinose might make it particularly suitable for certain types of commercial use. A quantity of arabinose was prepared and its possible uses are being investigated.

SWEETPOTATO STARCH

Starch for industrial uses is now being produced commercially from sweetpotatoes in a plant at Laurel, Miss., using a process developed by this Bureau. The plant, which was financed by the Federal Emergency Relief Administration and leased to a cooperative association of some 800 sweetpotato growers, was constructed and is being operated under the direction of the Carbohydrate Research Division. Because of insufficient seed stock and of drought during the growing season, only enough sweetpotatoes were delivered to operate the plant at about one-eighth of its capacity; that is, there were produced approximately 250,000 pounds of starch. Some growers delivered only culls and sold their market grade for food, whereas the other growers delivered run-of-the-field potatoes. A number of growers, who gave special attention to sweetpotato culture, obtained high yields (as much as 350 or 400 bushels an acre) and netted considerably more than they would have done if they had raised cotton on the same land.

During the past year improvements were made in the starch-plant equipment, particularly in the screening system, and filters for removing iron from the supply water and filter presses for pressing residual pulp were installed. The use of sulphur dioxide during milling and screening and the use of chlorine during bleaching of the starch were introduced as improvements in the process to insure a uniform white color.

A field station established at Auburn, Ala., in cooperation with the Alabama Polytechnic Institute, to promote industrial utilization of sweetpotato starch, conducted laboratory research on problems involved in the preparation of modified starches and dextrin and made factory-scale tests with sweetpotato starch as a warp-sizing material in cooperation with several cotton mills.

A research fellowship in the Bureau was established by The Chemical Foundation to accelerate the development of markets for sweetpotato starch, with the understanding that the incumbent was to devote his entire time to investigating various starch derivatives in an endeavor to find some which might be of commercial value for special purposes.

Laboratory research showed that very small proportions of certain metals particularly iron, combined with the pigment of sweetpotatoes and made it difficult to bleach sweetpotato starch. It is therefore desirable to avoid contact with iron as much as possible in the manufacturing process. The conditions required for the coagulation of the so called latex, or milky constituent, of sweetpotatoes were determined. This information has a bearing on the operation of the process for production of sweetpotato starch, particularly with reference to the separation of starch from other constituents of the sweetpotato. Comprehensive analyses were made of samples representing all lots of starch made at the Laurel factory for the purpose of determining the influence of certain steps or variations in the process on the quality of the starch produced.

FOOD RESEARCH

MICROBIAL FOOD SPOILAGE

Several years ago it was discovered that white sugar sometimes contains spores of thermophilic bacteria, which contribute to the spoilage of canned vegetables, and that certain impurities, which have a decidedly stimulating effect on the yeast spoilage of some foods, may be present. Every year since that time samples representing the year's sugar crop have been subjected to

systematic examination for such defects. In recent years the results of these examinations have indicated that the amount of yeast stimulant in beet sugars was gradually diminishing. The results obtained this year, however, showed many marked increases over the previous year. Furthermore, whereas heretofore there appeared to be a rough correlation between the amount of yeast stimulant and the amount of impurities shown by chemical analysis, no such relationship was observed this year. Samples from more than one-fourth of the sugar factories tested failed to meet the microbiological standards. This fact presents a serious problem. The canning industry is practically closed as a market for sugars which contain spores of thermophilic bacteria in excessive numbers, since the examination of sugars before purchase has become a standard procedure. The Bureau has cooperated extensively in locating sources of factory infection and in applying remedial measures. A 3-day school of instruction, attended by persons from 4 States, was held by Bureau representatives at Lansing, Mich., in order to acquaint sugar technologists and factory superintendents with the need for control and the proper laboratory tests and factory adjustments. Better control of sugar-factory practices is anticipated.

Preliminary studies have been made on the effect of freezing and cold temperatures on the micro organisms responsible for the spoilage of fruits and vegetables.

CUCUMBER PICKLES

A field laboratory has been established at State College Station, Raleigh, N. C., where investigations on the problems arising in the manufacture of cucumber pickles are being carried on in cooperation with the North Carolina Agricultural Experiment Station.

Serious problems arise in the manufacture of pickles in the Southern States, which do not exist or are of only minor importance under northern climatic conditions. The warmer temperature produces more rapid growth of the cucumbers, which undoubtedly affects ease of curing, and hastens the curing process, but allows more rapid spoilage when slight irregularities in the curing process occur.

During the few months in which the laboratory has been operating, studies have been made on the preservation of samples for analysis, on the microflora prevailing at various stages of the curing process in commercial tanks, and on the prevention of yeast film, or scum, on the surface of the brine in tanks of completely fermented and cured pickles being held for distribution. The yeast film which forms in tanks indoors or under cover destroys the acid resulting from fermentation and may ruin the pickles, so that it must be frequently skimmed off to prevent complete spoilage. Direct sunlight prevents the growth of the yeast, but exposure of open tanks out of doors has certain disadvantages, because rain dilutes the brine and the hot sun causes evaporation. It was found that a roof erected over an open tank sufficiently high to allow slanting rays of sunlight to reach the brine and sufficiently large to keep out rain prevented the formation of yeast film and saved enough labor and salt quickly to repay its cost.

WINES AND FRUIT BRANDY

Research on wine making was continued at Geneva, N. Y., in cooperation with the New York State Agricultural Experiment Station. Yeast evaluation studies showed that all wine yeasts do not react in the same way on the various grape musts; some ferment rapidly and completely, whereas others ferment slowly and leave considerable sugar in the wine. The same yeast may prove to be excellent with the must from one variety of grapes and only mediocre with the must from another variety. Some yeasts which ferment fresh musts vigorously cannot be used for champagne making because they will not "start" in a medium containing 11.5 percent of alcohol. Only certain yeasts are acceptable for champagne making. Many which ferment satisfactorily are objectionable because they produce a feathery deposit which does not settle readily.

It was demonstrated that most of the high-purity sugars on the market can be used in making champagne and that they are fully as satisfactory as the traditional rock candy for the secondary fermentation.

Studies on the pasteurization of juice to be stored for future wine making showed that temperatures about 35° F. lower than customary are satisfactory for New York State wines, and that 130 is high enough for pasteurizing musts for immediate fermentation. "Cooked" flavors do not develop when these lower pasteurizing temperatures are used.

It was demonstrated that an aging effect was produced in brandy by dispersing in it minute quantities of silver and allowing it to stand for a few days. Although there was marked improvement in flavor and aroma, careful analysis failed to show an appreciable change in the chemical constituents. This silver method, when used in connection with the chip method of quick aging, was said by commercial brandy producers to be equivalent to aging in wood from 6 to 10 months.

In connection with the research work on wines five articles were published in scientific and trade journals.

STALING OF BAKERY PRODUCTS

A number of new substances were used in bread making for the purpose of noting their effects on staling. When potato flour, fresh pineapple juice, carob bean flour, or extract from young oat plants was used, the bread kept fresh longer than usual. Methods of baking or formulas that will produce bread with better keeping quality are important, because in some cases as much as 20 percent of the bread sent to retail stores is returned to the bakery as stale, and the losses to bakers in general as a result of staling average more than 5 percent.

WAXLIKE COATINGS OF FRUITS

Research was continued during the past year on the chemical composition of waxlike plant products, particularly those on the surfaces of fruits. These waxy coatings, which protect fruits from damage by rain and from invasion by micro-organisms, are important factors in the adherence of insecticidal dusts and sprays and their subsequent removal. Certain compounds existing in these waxy coatings, which may be extracted from the wastes of fruit-processing industries, may have value for industrial uses. Further progress was made on the separation and identification of the constituents of grapefruit wax recovered from the nonvolatile residue remaining after the distillation of cold-roller-pressed grapefruit-peel oil. Solid and liquid fatty acids, a sterol, hydrocarbons, p-hydroxycoumarin, and a previously unreported ketone of high molecular weight have been isolated. Ursolic acid and phytosterolin were found in the cuticle wax of Bing cherries, but the yield of wax from dried pomace or press residue of pitted cherries was extremely small. Work on the cuticle wax of grapes showed conclusively that the principal constituent of the ether-soluble fraction was oleanolic acid. This is of interest because foreign investigators recently have reported the presence of ursolic acid in the cuticle of the grape leaf. This appears to be the first case known where the cuticles of two different organs of the same plant have elaborated two different, although isomeric, sapogenins. Grape wax extracted with petroleum ether from the pomace obtained as a byproduct in the manufacture of grape juice and wine was separated into four fractions from which the individual constituents will be isolated and identified.

TOXICITY OF INSECTICIDES TO HIGHER ANIMALS

Research was continued on the acute and chronic, chiefly the chronic, intoxications which may result from the consumption of food contaminated with insecticide spray residues.

It is known that fluorine compounds have a marked effect upon the growth of bones and teeth, and attention has been directed to the mechanism of this effect. The bone phosphatase activity of control rats and of rats on diets to which fluorine compound had been added was determined up to the age of 260 days. It was previously found that in young growing rats the phosphatase activity is less in rats poisoned with fluorine compounds than in control rats of the same age, and that as maturity approaches the values for phosphatase activity are more nearly the same. Extension of these studies showed that the phosphatase values during adult life are slightly higher in the poisoned rats than in the controls. These observations have an important and fundamental bearing on the manifestations of fluorine toxicity in young individuals as compared with mature individuals. The crystal structure of the teeth and leg bones of rats maintained for 8 months on diets containing the fluorine mineral cryolite will be examined by means of X-rays for the purpose of determining the approximate amount of fluorine in the bones and teeth and to gain information on the position of fluorine atoms in the bone structure.

Preliminary examination of the blood of albino rats maintained on diets containing various amounts of cryolite showed a reduction in hemoglobin and red-cell count. It appears that this anemia produced by fluorine may be a more delicate indication of toxicity than is mottling of the teeth. Feeding experiments were started for a systematic study of this phase of fluorine toxicity.

Paired feeding experiments on rats showed that the chronic effects of nicotine compounds are inhibition of growth and interference with reproduction, both apparently resulting from diminished food intake. Both of these effects disappeared when the rats were returned to a normal diet free from nicotine. Continued feeding of nicotine in an otherwise normal diet did not alter the blood sugar level of the albino rat.

No gross pathological changes resulted in rats fed on diets containing diphenylene oxide or phenothiazine. In man and in rabbits high acute dosage of phenothiazine produced anemia, from which spontaneous recovery took place on stoppage of administration. Rats receiving a diet containing 0.2 percent of phenothiazine for 6 months showed a 15 to 20 percent reduction in blood hemoglobin content. Normal rate of growth was interfered with only when 0.35 percent or more of phenothiazine was contained in the diet. The substance or substances excreted in the urine, following administration of phenothiazine, confer bactericidal properties on the urine. This fact indicates the possibility that phenothiazine may have therapeutic value in treating diseases of the urinary tract caused by bacteria. Experimental cystitis induced in rabbits was cured by oral administration of phenothiazine. Very promising results were obtained from the use of phenothiazine in the treatment of human cases of cystitis by a collaborating physician.

Oxidation-reduction potential measurements, applied to the phenothiazine product isolated from the urine of animals, to which this insecticide was administered orally, showed that this compound was converted to a water-soluble reversible oxidation-reduction system and demonstrated the value of this technique in gaining an understanding of the detoxifying mechanism of the body.

Feeding experiments with phenothioxin showed that this compound has about the same toxicity as phenothiazine, judged by growth curves. The observation that the fur of rats became stained with yellow, the intensity of the color varying with the dose administered, suggests that, as in the case of phenothiazine, the compound is converted to a water-soluble reversible oxidation-reduction system.

Following subcutaneous injection of methyl thiocyanate in white rats, partial excretion took place through the lungs. A dose of 40 mg per kilo of body weight was fatal in every instance; 30 mg per kilo of body weight killed about one-half of the animals. Lethal doses produced convulsions, followed by death due to respiratory failure. Long-time feeding experiments showed that a much higher dose was tolerated than might be anticipated from the acute toxicity tests. The thiocyanate group is excreted in the urine, but the fate of the methyl group is still uncertain. The acute toxicity of lauryl thiocyanate was much less than that of the methyl derivative, but in long-time feeding experiments lauryl thiocyanate was more toxic than methyl thiocyanate.

Diets containing cube or derris root did not interfere with the normal growth of rats when the concentration was below 0.06 percent. Marked retardation occurred with a diet containing 0.12 percent. Experiments with rotenone in comparison with cube and derris root indicated that the growth-inhibitory effects of cube and derris were not produced by their rotenone content.

RANCIDITY

Previous work in the Bureau demonstrated that exposure of edible oils and oil-bearing foods to certain wave lengths of light promoted rancidity and that the use of containers or wrappers which transmitted green light of wave lengths delimited by 4,900-5,800 Angstrom units retarded rancidity the most. This knowledge is being put to practical use by progressive food manufacturers. Scores of packages designed to delay the development of rancidity are already in use. The importance of preventing rancidity is evident from the fact that about \$2,000,000,000 worth of oil bearing foods are marketed yearly.

Studies on the changes taking place in oils used in the commercial production of potato chips showed that peanut oil remained fresh and free from rancidity longer than other oils tested, both before and after heating. The longer the other oils had been used, the sooner rancidity developed in the

chips. On the other hand, chips fried in fresh peanut oil and in oil which had been used some 20 hours developed rancidity at about the same time. The longer either oil had been used, the slower was the development of peroxides in the oil.

Experiments with cottonseed and corn oils indicated that the rancidity induction period was lengthened when the oil was protected from light and that rancidity was not necessarily correlated with the development of peroxides. While the oil was protected from light, rancidity was delayed, even in the presence of peroxides.

Preliminary results obtained with the vitometer indicated a parallelism between rancidity and the loss of vitamin A. Cottonseed, corn, and peanut oils which had been protected from light in glass containers protected with green paper suffered little or no decrease in content of vitamin A, whereas the same oils which were not protected from light and which became more or less rancid during the same period showed appreciable losses in vitamin A.

SOYBEANS

A study on the effect of storage conditions on the lecithin content of soybeans showed that when beans containing above 12 to 14 percent of moisture were stored at room temperature in the summer, there was a great loss in lecithin. Beans stored at low temperatures showed little loss in lecithin. Soybeans are an important source of lecithin which is used in medicine, in food products, and in increasing quantities as an emulsifier in products for industrial uses.

SPECIAL BREADS

Further study of the use of hydrogen peroxide in breadmaking showed that not only can white bread of excellent appearance be made by its use but satisfactory breads of very good crust and crumb, containing prunes, raisins, or cheese can be produced without the use of yeast as a leavening agent.

It was found that an excellent gluten bread could be made by mixing wet gluten, which may be prepared by bakers from ordinary flour, with wheat flour in the right proportions. Satisfactory self-rising flours were made by incorporating up to 50 percent of rye flour with wheat flour and self-rising materials.

EGG PRESERVATION

Following the satisfactory results in the commercial application of the Bureau's vacuum-carbon dioxide method for treating shell eggs to 2,000 cases in 1935, many more cases were treated in the same manner in the spring of 1936. With the assistance of the Bureau of Agricultural Economics, experiments were undertaken to determine the influence of the degree of vacuum and the role of carbon dioxide in the success of the process. The eggs treated in these experiments are now in storage.

PLANT PIGMENTS

Efforts to determine the exact molecular structure of the new quercetin galactoside isolated last year from the skins of Grimes Golden and Jonathan apples have been unsuccessful, but further attempts are being made.

Work was continued on the isolation and identification of pigments from Mendelian color types in corn. Several samples representing new strains of corn grown at Ithaca, N. Y., and furnished by R. A. Emerson of Cornell University, were examined, but the quantities of material available were too small to obtain the substances sought. More material will be grown this year for further research along this line.

Several pigments of the flavonol series, including kaempferol and quercetin, were isolated from dogwood flowers and bracts.

A study was also made of the pigments of pink grapefruit.

DECIDUOUS FRUIT PRODUCTS

Work was done on the preparation of apple powder, or flour, which has been used in some European countries for the treatment of certain intestinal disorders. Several varieties of apples were used and various methods of inactivating enzymes tried out. From preliminary results it appeared that satisfactory color could be obtained without the use of chemical enzyme inactivators by making thin slices, dipping them in boiling water and drying immediately at

high temperature. It was necessary to mix the powder with moisture-absorbing spreaders in order to overcome its hygroscopic property and prevent it from becoming gummy on standing. Study of vegetable spreaders is continuing.

Examination of fruits and fruit pulps, with and without addition of sugar sirup, frozen about 5 years ago and held in commercial storage at about 0° F. since that time, showed that apricot pulp, Claret plums, pineapple slices, nectarine pulp, peach halves, and strawberry pulp were of excellent flavor, good color, and in most cases good texture. Samples of whole strawberries, packed without sugar sirup, were the only ones that were badly deteriorated.

Several small packs of passion-fruit pulp were put up in cans and are being held for future examination. Improvements were made in a machine, previously designed in the Bureau, for separating the pulp and seeds of passion fruit, and a new type flash pasteurizer, especially designed for viscid liquids, was tried out on the pulp.

Satisfactory sirups and concentrates were prepared from cold-storage apples, although the acidity was lower and the flavors were not so marked as when fresh apples were used. Concentrates were also prepared from dates and from three varieties of pears. As in the case of apples, the first distillates from the concentration of pear juices were fractionated and the esters were returned to the finished products in order to restore flavor. These fractions, however, did not compare favorably with corresponding fractions from apples, either in quantity or quality. It is believed that juice concentrates will provide a profitable outlet for great quantities of cull and surplus apples, pears, and other fruits.

Research was continued on the production of wines and brandies from plums, dates, passion fruit, and other fruits. Work was started on the preparation of extracts for making cordials and for smoothing out brandies. Commercial production of date brandy is expected to begin soon. Sometimes as much as 20 percent of the dates grown in California and Arizona is low-grade fruit suitable for the preparation of sirup or brandy. The processing and marketing of this low-grade fruit in competition with the better grades lowers the prices for the latter.

Canning investigations were made on new hybrid peaches, tomato hybrids, and Young dewberries in collaboration with the Bureau of Plant Industry in its work on plant breeding.

During the year the Bureau established a new regional laboratory at Pullman, Wash., through cooperative agreement with the State College of Washington and the Washington Agricultural Experiment Station, to conduct research on the development of new products from northwestern-grown fruits and vegetables. Preparations were made for experimental work to begin with the 1936 fruit and vegetable season.

LOOSENING THE HULLS OF WALNUTS

Persian, or so-called English, walnuts having a high proportion of light-colored kernels bring better prices than those having many dark or heavily veined kernels. California growers have learned by experience that in order to get a maximum number of light kernels the nuts must be harvested early. During the early part of the harvesting season, however, the hulls of many of the nuts are still tight and cannot easily be removed. The Bureau discovered, about 3 years ago, that treatment of "sticktight" walnuts with air containing ethylene gas loosened the hulls and thereby removed the disadvantage of early harvesting. This treatment is now used by a large number of walnut growers in California.

During the past season the Bureau conducted experiments to ascertain the best temperature at which to gas the walnuts and to gain information on other problems relating to the production of high-grade walnuts. The six treating cabinets used were maintained at temperatures ranging from 50° to 100° F., with 10° intervals. It was found that the rate of hull loosening at 60° was greatly increased over 50°, slightly increased at 70° over 60°, and so on up to 90°, with a slight decrease between 90° and 100°. The color quality showed some decline during treatment, regardless of time and temperature. At temperatures above 60° there was more decline of color quality during the last 24 hours of an 84-hour treating period than during the first 36 hours and, in most cases, than during the first 60 hours. The time of the treatment, therefore, should not exceed 60 hours with a temperature no higher than is necessary to loosen a satisfactory percentage of the hulls.

It was found that "sticktight" walnuts declined in quality, after being shaken from the tree, while lying on the ground exposed to the sun. Immediate gathering of the nuts from the ground as soon as shaken from the tree is therefore advantageous where there is a large percentage of green "sticktights." It also proved advantageous to separate field-hulled nuts from "sticktights" before gassing, since the hulled nuts suffer appreciable decline in color quality on holding for any length of time before drying.

It was observed that the decline in color quality of walnuts was most rapid at high temperature and high humidity, and proportionate to the length of time the nuts were held. The rate of decline was less rapid with green "sticktights" than with hulled nuts. It appears that, in order to insure good color quality, the nuts should not be held any longer than is absolutely necessary from the time they are shaken from the tree until they are thoroughly dry.

A mechanical separator was designed and built to separate field-hulled nuts from "sticktights."

Samples of walnuts collected semiweekly over a 2-month period were examined to obtain data which may be useful in determining maturity.

CITRUS FRUIT PRODUCTS

Experimental work was continued in the Florida and Texas citrus fruit laboratories on citrus products, including orange and grapefruit juices, grapefruit concentrate, orange oil, citrus candy, alcoholic citrus beverages, grapefruit marmalade and base, and grapefruit vinegar; and on the effect of tartar emetic sprays on the composition of grapefruit. Much of the work on citrus products and their processing was in cooperation with firms interested in or engaged in the commercial production or utilization of citrus products. Commercial production was also promoted through demonstrations, consultations, correspondence, lectures, and the distribution of publications.

The Florida laboratory cooperated in the installation of a plant for packing orange juice, according to the method evolved by the Bureau, which consists of deaeration and flash pasteurization with specially designed equipment. This plant, which is packing 1,600 12-ounce bottles of juice an hour, hopes to increase its capacity, as at present it is unable to supply the demand. The establishment of this plant afforded an excellent opportunity to study the Bureau's process carried out on a commercial scale. Information was obtained on the effectiveness of deaeration on the preservation of vitamin C, on the bacterial content of the juice before and after pasteurization, and of the air in different parts of the plant. A new type of deaerator was designed, and a laboratory model, having a capacity of between 150 and 175 gallons of juice an hour, was constructed. Preliminary tests showed this to be more efficient than the commercial equipment in use.

Experiments on accelerated aging of concentrated and unconcentrated orange oil by oxidation showed that the objectionable turpentinelike odor which develops on aging could be practically prevented by evaporating most of the limonene under vacuum. It appeared that concentrating 3 volumes down to 1 volume by this procedure was sufficient.

A number of yeasts were studied as to their comparative value in fermenting citrus juice. Among these, *Saccharomyces ellipsoideus* Hanson was best. Addition of sulphur dioxide, 50 parts per million, in the form of sodium bisulphite, proved effective in preventing bacterial contamination during the fermentation of orange musts into wine. Experiments with sulphur dioxide in fermentations on a commercial scale showed that where the must had become infected it was necessary to add 100 parts per million of sulphur dioxide. Improvement in quality of fermented citrus products resulted from the addition, in small quantities, of ammonium carbonate, distillers' malt, or other easily assimilable nitrogenous yeast nutrient to the must, in order to stimulate the growth and activity of the pure yeast. The use of ammonium carbonate, 7 pounds per 1,000 gallons, on a commercial scale in a lot of 5,000 gallons, gave satisfactory results. Laboratory distillation experiments on orange wine with a pot still, column still, and a continuous still with plates showed that the pot still produced a better quality of brandy and spirits than was obtained with either of the others. It was found that the rancid fatty oils which are always present in orange brandy and are largely responsible for the harshness of the new product, could be removed by rectifying to proof, chilling to 10° F., and filtering off the separated fatty oils, thus yielding a smoother product.

New wines were prepared from oranges, grapefruit, sweet lemons, sweet limes, and tangelos at the Texas laboratory. Examination of wines made during and prior to the 1935 season indicated that an 18-percent alcohol content could be easily attained when the acidity was below 0.8 g of citric acid per 100 cc. The Bureau's Burgundy 4123 gave the best flavor of the yeasts tested. A minimum of 6 months in wood or 12 months in glass was required to age grapefruit wine satisfactorily at ordinary temperature. Steaming and soaking of new kegs was necessary to avoid excessive woody flavor in the wine. Blending grapefruit brandy with 10 percent of grapefruit wine improved the flavor, making it more fruitlike.

Incidental to work on problems relating to the manufacture of citrus candy, in cooperation with a manufacturer, which resulted in several helpful suggestions, a type of yeast was isolated from citrus candy which fermented sugar solutions of 70-percent concentration and withstood the effects of 0.1-percent sodium benzoate and 150 parts per million of sulphur dioxide. Further studies are contemplated on the characteristics of this yeast.

Texas grapefruit juice which had been concentrated from 4 volumes to 1 volume and stored 18 months below 40° F. proved satisfactory for preparing reconstituted juice or carbonated beverage base. Grapefruit soda water retained its original quality after having been stored 1 year at ordinary temperature. A blended juice, offering some promise as a commercial product, was prepared from 2 parts of Valencia orange juice and 1 part of either Marsh or Duncan grapefruit juice. The mixture appeared to be more stable than straight orange juice at ordinary temperature. Samples of grapefruit vinegar prepared at the Texas laboratory were well received, and a commercial firm is manufacturing this product. A new method was developed for making grapefruit marmalade and base. With only slightly higher labor cost and slightly lower yield this procedure gives a marmalade of better appearance and less bitter taste than that prepared by the original method.

Preliminary data obtained in the analysis of grapefruit from trees sprayed periodically throughout the year with different concentrations of tartar emetic indicated that the sprays had no effect on the composition of the fruit.

A 2-year cooperative study of changes in the composition of Texas grapefruit during ripening was completed. As a result, changes which were well received by growers and shippers were made in existing maturity requirements.

ENZYME STUDIES

Studies were continued on the nature of enzyme action, particularly where such knowledge was needed in connection with other projects under food research.

A study of the gas exchange of egg white in contact with air indicated the presence of an incomplete respiration system, carbon dioxide being evolved without corresponding consumption of oxygen. Addition of crude trypsin preparations completed this system by supplying some factor, the nature of which is not yet known. Glucose is not oxidized in the air by egg white in the absence of this unknown factor. In the course of this work the existence in egg white of a powerful oxidizing ferment for citric acid was recognized. A definite bactericidal action of trypsin preparations when added to egg white was also noted. By taking advantage of this and also performing the tryptic digestion at low temperatures, it was possible to produce liquified egg white that was practically sterile.

A short study of oxidation in egg yolks revealed that an oxidative change (probably simultaneous oxidation and reduction) occurred slowly in frozen egg yolks and gradually decolorized them. The chemistry involved, which is highly complicated and not yet worked out, would probably explain the commercial deterioration of frozen egg yolk on long storage.

In a study of the action of the peroxidase-peroxide system on ascorbic acid (vitamin C), it was found that ascorbic acid was rapidly oxidized by the peroxide, the presence of peroxidase not being required. This information is of practical value to the citrus-products industry.

An article entitled "Proteolytic Enzymes of Flour", published in the Journal of Cereal Chemistry for January 1936, summarized the results of an investigation on the action of the protein-splitting enzyme of wheat flour, the identification of which was reported last year. Knowledge concerning this enzyme was applied to advantage in modifying the baking quality of a type of flour which yields doughs that are hard or not sufficiently pliable. Flours of this type, called "bucky-dough flours", are apparently derived from wheat grown under

drought conditions. Additions of proteinases of the type occurring in normal flours and of substances capable of activating inactive proteinase already present in the flour produced softer and more pliable doughs. Two public-service patents covering the commercial application of this discovery were applied for. A more intimate study of this modification of flour proteins by cysteine, glutathione, and active papain is in progress.

Efforts were made to dry apricots without darkening by using as enzyme inhibitors cysteine hydrochloride and pineapple juice, previously proved to be effective with apples. Because the skins prevented direct contact of the inhibiting agents with the fruit pigment, the fruit, cut in halves, was impregnated with the inhibitor solution under vacuum. When apricots thus impregnated were dried at a low temperature, fairly good results were obtained. In order to give the dried fruit the color of sulphured apricots it was necessary to add a small quantity of acid. Although dried apricots prepared with cysteine or pineapple juice were inferior in color and appearance to well-sulphured fruit, they were markedly superior in taste and odor. Peeling of apricots with alkali before treating with inhibitor solution and drying improved the color of the product, but the color was no better than that of peeled fruit dried without inhibitors. Peeling alone, which apparently removes most of the coloring matter beneath the skin, might be worth while in the production of unsulphured dried apricots. Washing with some kind of diluted acid was essential after peeling with alkali.

An active proteolytic enzyme, different from all well-known proteinases, was found to be present in cantaloup juice. This enzyme is concentrated under the skin of the melon and is more active in green melons than in ripe ones. The fact that this enzyme is most active in nearly neutral solutions (on casein substrate) may give it special value. The enzyme may be precipitated from water solution by ammonium sulphate and dried without much loss of activity.

PRESERVATION OF FRUITS AND VEGETABLES BY FREEZING

Examination of frozen packs of strawberries, raspberries, and blackberries, prepared in 1934 and stored at -5° and 15° or 20° F., furnished additional evidence that moderate storage temperature (15° or 20°) is more destructive to micro-organisms than is a subzero temperature. Placing solid carbon dioxide in some of the containers just before sealing had little or no effect in reducing the number of micro-organisms and added nothing to the palatability of the fruit.

Experiments were made to verify previous findings regarding relative microbial kills at -5° and 15° F. and to determine, if possible, the reason for observed greater kills at the higher temperature. In strawberries frozen alone, with sugar, or with sugar sirup, and in milk frozen without previous pasteurization, the destruction of mixed micro-organisms was greater at the higher temperature. In frozen apple cider, on the other hand, the evidence from weekly examinations during 20 weeks of storage (before completion of the experiment) indicated greater microbial destruction at the lower temperature. Experiments to determine relative destruction at -5° and 15° , and in some cases at various degrees of acidity, were made on pure cultures of several micro-organisms suspended in water, in 1-percent gelatin solution, and in 5-, 10-, and 40-percent sucrose solutions. It was not possible to correlate all the findings from these experiments. Individual behavior of different microbial species at freezing temperatures was strikingly indicated. No striking microbial differences were noted between frozen peas stored at -5° and those stored at 20° .

Experimental frozen packs to determine the influence of variety on the quality of frozen fruits were prepared from different varieties of strawberries, raspberries, blackberries, sweet and sour cherries, blueberries, and peaches, grown in Oregon and Washington. Most of the work on strawberries, raspberries, and blackberries was done in cooperation with representatives of the Bureau of Plant Industry, Western Washington Experiment Station, and Department of Horticulture of Oregon State Agricultural College, for the purpose of selecting seedlings and hybrids that were promising from a commercial standpoint.

Experiments made to determine the effects of different methods of scalding and packing on the quality and composition of frozen packed peas showed that there were no marked changes in the dry matter, carbohydrates, and ether extract resulting from scalding with live steam or boiling water at sea level for periods ranging from 60 to 85 seconds. After being stored for almost 1

year at -5° and 15° F., scalded peas that had been packed dry showed practically no change in composition, whereas scalded peas packed in 2-percent salt brine lost about 15 percent of dry matter and about 40 percent of total sugar, calculated on the basis of fresh weight.

In experiments with various scalding temperatures for different periods of time before freezing and storing, it was observed that scalding at 210° F. for 30 seconds resulted in a much more satisfactory product than was obtained by scalding at low temperatures (around 160°) for longer periods (up to 180 seconds). In fact, the product obtained by the latter procedure showed considerable deterioration in color and flavor.

The enzyme catalase was completely inactivated by scalding at 200° or 210° F. for 30 seconds. With scalding temperatures of 180° and 160° , the catalase activity decreased very rapidly in the first 30 and 60 seconds, respectively, but the enzyme was not completely inactivated after 180 seconds.

Studies on biochemical changes in shelled raw peas intended for freezing showed in general that it is unsafe to delay the processing for more than 6 to 8 hours at moderate summer temperatures, but that the peas may be held safely for at least 24 hours when covered with crushed ice, or for 48 hours in storage at 32° F. Scalded and cooled peas cannot be held for more than 2 or 3 hours at ordinary summer temperature before freezing without serious changes in quality. They may be stored at 32° , however, for 10 hours before freezing at 0° and still give a good frozen-pack product.

It was found that a good quality of frozen-pack Stratagem peas could be obtained from peas held in the pod at ordinary summer temperatures for 9 to 12 hours or at 32° F. for 123 hours after harvesting.

A study of chlorophyll changes in frozen-pack peas showed that the characteristic color change of scalded peas stored at 20° F. is caused by the action on the chlorophyll of the natural acids present in the cell sap of the peas, with the formation of phaeophytin which is olive green or yellow.

INDUSTRIAL FARM PRODUCTS RESEARCH

CELLULOSE

Work has been continued in cooperation with a firm in Maui, Hawaii, which has undertaken to commercialize the Bureau's improved nitric-acid process for separating high-grade cellulose from sugarcane bagasse. For a period of 5 months one of the Bureau's chemists directed the work of a pilot plant at Paia, supervised the preparation of the bagasse for pulping, and determined the best conditions for carrying out the three steps of the pulping process and for recovering the nitric-acid solution for reuse. The process was carried out in the pilot plant to the point of bleaching the product. The preparation of samples of bleached cellulose to be submitted to prospective users was carried out on a smaller scale. New equipment is being procured to increase the yield of the pilot plant to 1 ton of cellulose per run.

In studies on the suitability of the nitric-acid pulping process for separating cellulose from crop wastes other than sugarcane bagasse, runs were made on a laboratory scale with whole cornstalks and on depithed cornstalks to determine comparative acid consumption. In runs with the whole stalks the consumption of nitric acid was much greater than with the depithed stalks. The pith content of cornstalks is large in comparison with bagasse, and apparently it will be necessary to remove this pith mechanically before the nitric-acid process can be used economically on cornstalks. As with bagasse, used nitric acid proved to be better than pure nitric acid as a pulping agent, in that it was less injurious to the resulting pulp. The used nitric acid contained acetic, formic, oxalic, and other organic acids resulting from reaction with the ligno-cellulose material, and these were obviously beneficial. Conditions during recovery of the used nitric acid by distillation and concentration were adjusted to minimize the losses of volatile organic acids, which, without such adjustment, ranged from 7 to 10 percent of acid calculated as nitric.

In a comparative study of three methods for determining the cellulose content of ligno-cellulose materials, more than 40 analyses were made of cornstalks, rye straw, wheat straw, and bagasse, with spruce wood as a reference material. The object of this work is to provide data for use in correlating published results of cellulose determinations by different methods and to obtain more definite knowledge regarding the alpha-cellulose content of the various crop wastes.

Cooperative experimental test runs with cornstalks, flax straw, artichoke tops, and wheat straw were made in the pilot plant of a commercial firm which has developed equipment for the production of paper pulp from straw by a continuous soda-cooking process at atmospheric pressure. The results show that satisfactory pulp can be produced from all these materials, but that flax straw is the most promising as a source of high-quality pulp. The possibility of producing better grades of bleached pulp from wheat straw was indicated. Cornstalks and wheat straw were digested with no particular difficulty. Artichoke tops proved hard to digest, and the production of paper pulp from this material would probably involve higher cost for additional soda or pressure cooking. Because of its unusual resistance to wetting by water, the pith from artichoke tops appeared to have potential value as an absorbent in the manufacture of dynamite.

The methods for producing cellulose esters were studied, especially with the idea of producing such esters directly from raw ligno-cellulose materials without preliminary purification. A preliminary report is being assembled.

UTILIZATION OF FARM WASTES BY DESTRUCTIVE DISTILLATION

The large continuous-process retort for destructive distillation of farm wastes at Ames, Iowa, was not operated because of alterations and re-erection in the new laboratory building. Other forms of continuous-process destructive-distillation equipment were studied in various commercial plants. Small-scale runs were made in an electrically heated laboratory retort on materials not previously tested, including apricot and peach pits, walnut shells, raisin seeds, and sunflower-seed residues. Preliminary experiments were made on the effect of chemicals added to the raw materials for catalytic purposes. Visits were made to plants in California which have undertaken to utilize pits, seeds, and shells from fruit- and nut-packing establishments, for the purpose of assisting in commercial development. Samples of the products were sent to Ames for testing. A survey was made of the situation regarding black walnut shells and pecan shells in the central South. Tar oils were prepared from farm wastes for a study, by the Bureau of Entomology and Plant Quarantine and interested private groups, of their insecticidal and insect-repellent values. The results of all work to date on destructive distillation of farm wastes and related materials are being prepared for publication in bulletin form.

UTILIZATION OF FARM WASTES BY FERMENTATION

Continuing the investigation on the fermentative mechanism involved in the bacterial decomposition of vegetable materials, experiments were made on the anaerobic fermentation of wheat straw as well as of cornstalks. This year more attention was given to the character of the fermentation residues than to the production of gas. A study of the break-down of individual constituents of vegetable materials, such as pentosan, cellulose, and pectin, was started. The pilot plant for the production of fuel gas by aerobic fermentation of farm wastes was redesigned and re-erected, ready for operation.

Laboratory work on the production of isopropyl, butyl, and ethyl alcohols from the hydrol waste of corn-product plants was completed, and any further work will be on a pilot-plant scale. Further study of the chemical mechanism of the fermentation process resulted in a provisional theory which is being prepared for publication.

In connection with the production of organic acids by fermentation, considerable attention was given to the development of analytical methods for determining quantitatively the constituents of fermented liquors.

LIGNIN

Fundamental investigations were continued on the chemistry of lignin, one of the major constituents of wood and crop wastes, which is removed from cellulose in the production of paper pulp and lost in the effluent from pulp mills. In order to get a better understanding of the basic substance from which lignin is derived, dehydrogenation experiments with selenium were carried out. An oil was obtained, which offers considerable promise of furnishing additional information on the chemical structure of lignin. Its composition is being investigated. Three lignin fractions isolated from oat straw differed somewhat in their elementary composition, one containing considerably more carbon than the other two, which apparently contained the same number of carbon atoms but differed in their hydrogen-oxygen ratios. The percentage of methoxyl was the same in all three fractions. Each of two of the fractions contained four

hydroxyl groups, two of them being more acidic than the others and probably phenolic or enolic in character. The lignin fractions isolated from oat straw were closely related to corresponding fractions previously isolated from barley straw.

A comparative study of the various methods for the quantitative determination of lignin in plant materials was completed. Wilstätt's fuming hydrochloric acid method, which appeared most promising from preliminary work, was studied in detail and was modified to obtain optimum temperature conditions and to provide the proper time for the reaction and for the preliminary treatment of the plant material. The modified method was accepted by the Association of Official Agricultural Chemists as the official tentative method for lignin determination. Data obtained showed greater accuracy for the modified method than for any of the other commonly used methods studied.

Chemical, bacteriological, and vegetative experiments with ammoniated waste sulphite liquor, a lignin product recently developed by this Bureau, showed that it is nontoxic to plants and that its nitrogen content of approximately 11 percent is slowly but completely available. It appears, therefore, that waste sulphite liquor, which is produced in enormous quantities, may be used advantageously for the production of an organic nitrogenous fertilizer by treating with aqueous ammonia under pressure at a temperature of 220° C.

MOLD FERMENTATION PRODUCTS FROM CORN SUGAR

As a result of further studies on the semiplant-scale production of gluconic acid by submerged mold growths in rotating aluminum drums under increased air pressures, previous mechanical difficulties were overcome, a strain of *Aspergillus niger* better adapted for large-scale work was discovered, a new method of sprouting the mature spores was developed, and optimum conditions of aeration and rotation were worked out, under which yields of gluconic acid in excess of 80 percent in 18 hours were obtained, using 15-percent glucose solutions. When these yields are compared with those obtained originally, about 60 percent in 14 days, using surface growths of the mold in shallow aluminum pans, the great advantage of this new method of controlling oxidative mold fermentation is obvious.

Various factors influencing the fermentative production of dextrolactic acid from glucose by a selected strain of *Rhizopus oryzae* were studied in small-scale laboratory experiments in glass equipment. Although knowledge of this fermentation process is far from complete, promising results have been obtained. With submerged growths, yields as high as 67 percent in 5 days were obtained, whereas with surface growths under optimum conditions the yield of lactic acid ranged from 60 to 65 percent in 16 days.

A survey was made on the possible fermentative value of 25 species of *Mucor*. The organisms studied showed very little promise of value under the experimental conditions used.

Studies on the nitrogen nutrition of certain species of *Penicillium* and *Aspergillus* showed that the nitrogen assimilation by fungi, particularly as it affects acid formation from glucose, is closely related to the acidity of the medium. Certain ammonium salts which were entirely unsuitable at pH 3 gave good results at pH 6.5.

In a study of the inhibiting effects on acid production from glucose caused by the products of organisms which frequently appear as contaminants in fermentation cultures it was found that gluconic acid produced by one species of *Penicillium* strongly inhibits gluconic acid formation by either *P. chrysogenum* or *Aspergillus niger*.

The results of a study on the carbon balance in citric acid formation from sugar by molds were contrary to the most widely accepted theory in that the yield of citric acid was much higher and the yield of carbon dioxide much lower than possible with the theoretical mechanism. Further work will be done to determine the true mechanism of this reaction. The solution of this problem may have great practical significance not only in the commercial production of citric acid by molds but also in its formation by higher plants.

CHEMICAL WEED KILLERS

Realizing the enormous losses to agriculture caused by weeds, and with the purpose of making effective weed killers available to farmers at low cost, Congress authorized the Department to make chemical weed-eradication investigations. During the past year, in collaboration with the Bureau of Plant Industry,

a semi-industrial scale electrochemical plant for the manufacture of sodium chlorate was designed, installed, and put in operation at the Arlington Experiment Farm. This experimental unit, of 30,000 pounds annual capacity, has furnished data and general practical information which made possible the preparation of preliminary estimates on the cost of producing this important herbicide.

FAST DYES FOR AGRICULTURAL FIBERS

Investigations bearing on the production of fast dyes for agricultural fibers were concluded during the year, with a study of conditions affecting the conversion of halogenous compounds into amines by ammonolysis. The results indicate that it is advantageous to use a higher ammonia concentration than is customary in this synthesis and that cupric as well as cuprous compounds may be used as catalysts. It is necessary to use cuprous compounds when the amine being prepared is readily susceptible to oxidation, but cupric compounds and auxiliary oxidants may be employed to advantage when the amine being prepared is comparatively resistant to oxidation. The relationship of ammonia concentration to amination, in both catalytic and noncatalytic reactions, was significantly altered by changes in temperature. This study has led to a better understanding of the fundamental factors involved in amination by ammonolysis, which is of great importance in the synthesis of antirraquinone compounds essential as intermediates for certain fast dyes. Two public-service patents relating to the production of dye intermediates were granted.

BIOLOGICAL STAINS

Work was continued, in cooperation with the Commission on Standardization of Biological Stains, on the chemical and spectrophotometric examination of dyes, and on the synthesis of biological stains and dyes of antiseptic or therapeutic value. Work on the ketonimines was concluded, with analysis and determination of physical constants of all the new compounds prepared in the course of the work and not previously reported on, and the results were prepared for publication. A procedure was developed for purifying magentas for therapeutic uses, which can be incorporated as a regular step in the ordinary method of manufacture. Many previously rejected commercial samples were rendered usable when treated by this procedure. Work was started on the synthesis of phloxine, in order to determine the cause of variation in the staining value of commercial samples and to provide reliable reference samples. Numerous services, involving chemical and spectrophotometric analyses of dyes and the furnishing of information on dyes or samples for use in scientific investigations, were performed for other Government agencies, universities, and industrial-research organizations.

FARM FABRICS

Work on the mildew-proofing of cotton fabrics for outdoor use on farms and elsewhere was concluded with a study to determine whether the precipitation of chromium or copper compounds, or both, on canvas in water-insoluble form is essential to impart mildew resistance to mineral-dyed khaki canvas. The data obtained indicated that chromium hydroxide precipitated on cotton duck, either alone or in combination with iron compounds, imparts little or no mildew resistance, whereas copper compounds precipitated alone or in combination with iron, or iron and chromium, have a decided inhibitive effect on the development of mildew.

HIDES AND SKINS

Research is being undertaken to discover chemicals that can be added to salt in very small quantities, in order to make it more effective as a preservative for hides and skins prior to tanning, thus helping to reduce an annual loss of around \$10,000,000, resulting from spoilage and waste of hides and skins due to poor curing.

Curing and tanning experiments initiated in 1935 on a semicommercial scale were continued with test packs of calfskins. The skins cured with treated salt kept exceptionally well under adverse curing and storage conditions. After being stored for 90 days they were made into chrome calf shoe-upper leather by a cooperating tanner. The chemicals added to the salt for curing did not interfere in any way with any of the numerous steps in the processing of the skins into chrome-tanned leathers. Their possible effects on vegetable-tanning processes have not been determined. The skins cured with treated salt produced

leathers that graded and selected better than the leathers from control skins cured with salt alone. The control skins were in an advanced stage of spoilage after the storage period and would have been seriously damaged if storage had been continued much longer.

Although the two treatments used in the curing experiments were highly effective, it is believed that chemicals can be found which are even more effective and more nearly ideal for adding to salt for curing hides and skins. Sodium trichlorphenate, used in one of the treatments, did not prevent reddening of the skins, indicating that there was some bacterial action during curing. Sodium silicofluoride, used in the other treatment with paranitrophenol, may be a little too acid.

Some study was made of halophilic chitinovorous bacteria. Although this research is fundamental, it has a practical aspect in that it may open up a new avenue of approach in determining some of the causes of permanent stains and other grain damages to hides and skins during curing. Bacteria were isolated from many solar salts, collected from widely distributed points, that were able to grow on and destroy chitin which is closely related to chondroitin, a constituent of certain proteins of skin and connective tissue.

Representatives of the Bureau continued to cooperate in an advisory capacity with the Federal Surplus Relief Corporation and the Federal Surplus Commodities Corporation in launching their program of gradually selling Government-owned hides and skins, more than 2,000,000 of which had accumulated from the cattle-killing measures of drought relief and livestock reduction in 1934. Efforts were made to dispose of these raw materials for leather in the most orderly manner and with the least disturbing influence on the trade.

In order to obtain quantitative data on the effects of long-time cold storage on calfskins, the importance of which was emphasized by experiences with the Government-owned hides and skins stored since 1934, storage studies were started with about 300 calfskins from the Federal Surplus Commodities Corporation.

TANNING MATERIALS

The results of the investigation on waste bark from the Pacific coast hemlock, as a source of commercial tanning extract, were prepared for publication in bulletin form. They show that it is possible to make a satisfactory tanning extract from this waste bark, about 400,000 cords of which are removed annually from saw logs and pulpwood in Washington and Oregon, and to deliver it to consuming markets in the East at competitive prices. A large number of wearing tests on sole leathers tanned in part with Pacific coast hemlock-bark extract, in strict comparison with sole leathers tanned without hemlock-bark extract, showed an average of 7 percent longer wear for the former.

Samples of shin oak from the Southern Great Plains Field Station at Woodward, Okla., were examined to determine whether this plant, which grows in expansive bushy stands in the West, could be used as a commercial source of tannin. The tannin content of the entire plant (about 11 percent in the air-dried material) is probably too low for profitable utilization. The leaves, however, which constitute about 50 percent of the plant, contain from 21 to 22 percent of tannin on the moisture-free basis and are therefore worth considering as a commercial source of tannin, assuming that it is feasible to gather and handle them separately and that the tannin is of a kind that will make satisfactory leather.

Walnut hulls from California were found to offer no promise as a source of tannin, because of their low tannin content (not over 6 percent) and their content of much soluble matter other than tannin, which gave extracts an objectionable color.

A study of the tannin content of the perennial legume *Lespedeza sericea* was continued in cooperation with the Bureau of Plant Industry. The data obtained indicate that some strains or lots of lespedeza may contain enough tannin to interfere with assimilation by cattle, thereby rendering them unsuitable for forage or hay. The Bureau will assist the Bureau of Plant Industry in its efforts to acquire information regarding the influence of environment on the tannin content of lespedeza and to breed strains of this plant free from or low in tannin.

LEATHER

As a result of recent contributions of research to the theory, causes, and prevention of the decay of leather, many of which have been made by this Bureau, progressive members of the leather industry have come to realize the

importance of developing leathers inherently resistant to acid decay or of devising treatments for preventing this decay.

Studies on the decay of leather during the past year dealt especially with the inherent resistance possessed by combination vegetable-chrome tanned leathers. After accelerated aging for 9 weeks in an atmosphere containing acidic sulphur compounds, leathers of this type lost only 5 to 12 percent of their strength, whereas vegetable-tanned leathers made from the same hide lost 35 to 40 percent of their strength.

An experimental leather containing sodium chloride, calcium acetate, sulphite cellulose extract, and cube gambier proved highly resistant to acid decay. Natural nontannins from sumac leaves, chestnut wood, myrobalan nuts, oak bark, quebracho wood, mangrove bark, wattle bark, and sulphite cellulose extract, when added individually to a sumac-tanned leather, imparted pronounced resistance to decay. On the other hand, the addition of the various natural tannins from these same materials gave practically no protection.

The addition of natural nontannins to chrome-tanned leather and to combination vegetable-chrome tanned leather had no significant protective effect. This was contrary to expectation and obscures the exact role of nontannins as protective agents in leather.

The repeatedly observed shorter life of catechol-tanned leathers, in comparison with pyrogallol-tanned leathers, was explained in large measure by the important finding, from experiments with rigidly comparable sets of leathers, that pyrogallol-tanned leathers pick up acid from the air at a slower rate than do catechol-tanned leathers.

Two American tanners, who have become interested in making more durable leathers along the lines indicated by the findings of the Bureau's research work, submitted special combination vegetable-chrome tanned cowhide grain leathers for testing. Tests were completed on one sample of leather, which showed that it had exceptional resistance to acid decay, owing, in part, to its high initial pH. Whether this leather, which was in the rough stage, can be satisfactorily finished without material sacrifice of its resistant quality remains to be determined.

The importance of more durable bookbinding leathers was recently stressed in the second interim report of the Bookbinding Leather Committee in England and in the 1935 report of the Public Printer in this country. The latter cited the work of this Bureau as showing that early rotting of bindings may be prevented by the substitution of chrome-tanned and combination vegetable-chrome tanned leathers in place of vegetable-tanned leathers, and by the development of leathers containing protective agents. Information from this Bureau regarding the essential characteristics of leathers resistant to decay is being used by the Government Printing Office for guidance in inviting American tanners to supply special leathers. Just recently a lot of full chrome-tanned sheepskin leather, the first leather of this character purchased by the Government Printing Office for bookbinding, was used in place of the usual vegetable-tanned law sheepskin. It worked through the bindery in an entirely acceptable manner and was satisfactory in all respects, with the exception of a minor matter of finish that can be corrected readily.

NAVAL STORES RESEARCH

CHEMISTRY OF NAVAL STORES (TURPENTINE AND ROSIN)

Heretofore turpentine and rosin have been practically the only commercial products obtained directly from pine gum. Recently, with the object of extending the market for pine-gum products, the Bureau has separated pine gum into a number of liquid and solid fractions which differ widely in chemical and physical properties and therefore, possibly, in their suitability for industrial uses. It is believed that some of these gum fractions can be used directly in industrial products. From some of them products have been made in the laboratory which resemble rosin in appearance but differ from ordinary rosin in chemical properties. They are highly transparent, and some are nearly colorless, being much lighter than the highest grade of rosin produced commercially in this country (grade X) and equal to the palest grade of French bleached rosin (7A). These various rosinlike products differ markedly from one another chemically. The lighter colored ones contain larger proportions of acids of the more stable types, such as pimaric, which is less subject to changes by oxidation, and should therefore be more valuable than ordinary rosin for the

manufacturing of high-grade soaps and ester gum. Some of them may have advantages over ordinary rosin for use in varnish and paper size. So-called abietic acids, free from contaminating material, have been prepared from the resin acids of the gum. These may be converted into esters for use in varnishes and lacquers.

During the past year about 35 gum products and special rosins varying in grade from I on the American scale to 7A on the French scale were made in the laboratory from longleaf and slash pine gum, some of which in normal commercial practice would yield an I or a K grade of rosin. Similar products, but not so numerous, were made from the same grade of gum in pilot-scale experiments on gum fractionation at the naval stores station at Olustee, Fla. Cooperative experiments were initiated with rosin-consuming industries to test out the relative merits of some of these products.

It is customary to consider the acids in rosin, both free and combined, as abietic acid and its isomers. Discrepancies have been noted, however, in calculating the total acid content of rosin from the saponification number, by assuming that all the acids are abietic acid and its isomers. When normal butyl alcohol was used as solvent in the determination of saponification number of rosins, higher saponification numbers were obtained than would be possible if all the acids present were of the abietic type. These apparently anomalous saponification numbers are due in part to the presence of volatile water-soluble acids.

Since strained and dehydrated pine gum is now being offered to the consuming industries in tank carlots, it is necessary, in connection with shipping regulations, to know the flash point of this material. It was 41° C. with the Tag closed tester. The flash point of gum spirits of turpentine was 37°, and that of gum diluted with 50 percent of turpentine was 39°.

Market conditions often require that turpentine be stored for a year or more. Prolonged storage in iron tanks, the usual containers, ordinarily results in changes, including discoloration of the turpentine due to reaction with the iron. The Naval Stores Research Division has found that water-free turpentine can be stored in full closed containers, in the presence of uncoated iron, for at least 1½ years without any appreciable change, but the possibility of keeping turpentine anhydrous during prolonged storage in tanks under commercial storage conditions has not been determined. In laboratory experiments crystalline hydrated oxalic acid suspended by a cotton bag in turpentine containing free water and stored in an uncoated iron container protected the turpentine for more than a year against apparent change. Larger scale tests on the effectiveness of oxalic acid in preventing discoloration of turpentine by iron and to determine whether the oxalic acid contaminates the turpentine are in progress.

Work on the composition of steam-distilled wood turpentine was continued, with special attention to the terpene alcohol fractions and high-boiling non-terpenes. Although steam-distilled wood turpentine conforms to the gross physical specifications for gum spirits of turpentine, and like gum spirits contains α -pinene as the main constituent, it differs from gum spirits in some important respects. For example, β -pinene, which constitutes a substantial portion of the terpenes in gum spirits, occurs in steam-distilled wood turpentine in insignificant proportions. Moreover, monocyclic terpenes, which are present in only small proportions in gum spirits tailings, constitute a substantial part of the wood turpentine hydrocarbons in the forms of dipentene, terpinene, and terpinolene. The presence in steam-distilled wood turpentine of traces of benzaldehyde, furfural, phenol ethers, and terpene alcohols, particularly fenchyl alcohol, also markedly differentiate it from gum spirits. Work is in progress to make one or more of these compounds characteristic of wood turpentine serve as the basis for a method of differentiating chemically between gum spirits of turpentine and steam-distilled wood turpentine. Reasonably satisfactory means for evaluating quantitatively the several alcohols in wood turpentine have been worked out, and an improved micromethod for alcohols, applicable to some of the very small fractions involved, has been devised. Traces of nonterpene compounds, such as phenolic and phenol ether derivatives, have been found in steam-distilled wood turpentine, and evaluation of phenol ether has been made by micro-methoxyl determinations.

In efforts to develop new uses for rosin, studies are being made in cooperation with other bureaus of the Department on the value of copper resinate and other metallic resinates as mildew-proofing agents for cotton fabrics, on the value of resinates as carriers for insecticidal metallic salts, particularly for the control of clothes moths, and on the value of various compounds containing

rosin for use as expansion joint filler in concrete roads and walks. Encouraging results have been obtained. It was discovered that the interaction of rosin, rubber, and bentonite, or similar mineral substance, produces a spongelike resilient product which possesses good adhesive quality and is both compressible and expansible, owing to its peculiar air-cell structure and rubber content. Bituminous compositions now used as joint fillers expand and exude from the joints in warm weather but do not go back into place in cool weather. If rosin and rubber compositions can be made weather-resistant they should find a ready market as joint fillers capable of absorbing large quantities of rosin.

TECHNOLOGY OF NAVAL STORES

The naval stores station in the Osceola National Forest at Olustee, near Lake City, Fla., is operated by the Bureau as an experimental and demonstration plant for introducing improvements in the equipment for and technique of processing pine gum to reduce costs and improve products, and for improvements in practices of handling the gum and its products to prevent deterioration and losses.

A new setting has been built for the fire still. This embodies the latest improvements in design and provides means for obtaining engineering data to determine distribution of heat to the kettle, effective heat for the distillation, and heat losses. Approximately 800 barrels of gum were distilled on the fire still in order to study its operation and to obtain information on various kinds of gum, regarding yield of turpentine, yield and quality of rosin, proportion of chips and dross, proportion of water in the gum, and fuel consumption per charge. The results of these tests were compiled and published so that individual operators might use them for comparison with their results in commercial production of turpentine and rosin.

In further work on the development of a steam turpentine still, and in connection with the work on gum cleaning, about 1,100 barrels of gum were distilled on the steam still. This work has shown the adaptability of the present design of a 25-barrel copper still to all classes of uncleaned gum containing a normal proportion of chips. Improvements in operating the steam still were developed whereby the brightness of the rosin produced was much higher than that of rosin made from similar gum in previous work with the same still. Further evidence was obtained that the yield of turpentine from a given gum is higher when run on the steam still than when run on the fire still. Although the first cost of a steam still is high in comparison with that of a fire still, the cost of maintenance is very low. The advantages of the steam still over the fire still, including great reduction in fire hazard, greater ease of operation, greater speed of distillation, higher yield of turpentine, and brighter rosin, contribute to its commercial feasibility, particularly for central stills and large operations.

In the gum-cleaning work, progress has been made in the development of a refining process for gum, scrape, or mixed gum and scrape. The process includes two separate operations, namely, the removal of the solid matter, such as chips, bark, and sand, by straining and filtration, and the separation of water-soluble contaminating matter, such as tannin, by washing. With the object of eliminating the second operation, some experiments were made on filtering the hot rosin after distilling off the turpentine and straining off the trash and chips. Preliminary results were promising, but certain difficulties remain to be overcome.

Cleaning of gum prior to distillation eliminates the necessity of straining the rosin, results in less loss of rosin on chips, and gives higher yields of rosin which is brighter and of higher grade. In the distillation of 730 barrels of uncleaned gum, there was obtained an average yield of 69.5 percent of rosin having a brightness of 80.1 percent as compared to perfectly clean rosin of the same color. The waste, including chips, rock dross, and batting dross, amounted to 5.8 percent. In the cleaning and distillation of 541 barrels of gum, there was an average waste of 2.3 percent, including chips and filter trash, and there was obtained an average yield of 75.7 percent of rosin having a brightness of 89.6 percent.

W. C. Smith, of the Naval Stores Research division, and R. W. Frey, of the Industrial Farm Products Research Division, collaborated in working out a process for removing tannin and other water-soluble material from crude pine gum by filtering through the shredded scrap of chrome-tanned leather. This process is covered by United States Patent 2039481 of May 5, 1936, which is assigned to the Secretary of Agriculture who may license interested parties to use it without payment of royalties.

In cooperation with the Southern Forest Experiment Station, data were obtained on 100 trees treated individually to show the effect of the height of face and frequency of dipping on the composition of gum, grade of rosin, and yield of scrape. An experiment was started to determine whether the flow of gum from longleaf pine could be stimulated by applying hydrochloric acid to the fresh streak.

A report on tests with various kinds of turpentine cups over a 3-year period is being prepared for publication. Tests are in progress on cone-shaped cups of aluminum, bakelite, and glass, and on ordinary metal and clay cups provided with covers. Glass cups installed during the winter, when the contents were frequently frozen, showed no breakage. It was found that old gum can be removed from used aluminum cups without damage to the metal by means of a 10-percent soda solution to which 1 percent, by volume, of water glass (sodium silicate) has been added. The small quantity of water glass required to inhibit the action of sodium carbonate on aluminum does not materially increase the cost of the cleaning process.

Advice on the stalling problems of individual producers and on other matters relating to naval stores production was given through correspondence to 194 persons and firms, orally to the operators and visitors at 18 stills visited by members of the station staff, and to many of the 504 persons who visited the Naval Stores Station. Blue prints, line prints, and pencil sketches for still buildings, stills, and various kinds of equipment, to the number of 236, were distributed in response to requests from numerous operators.

COOPERATION WITH STATES IN NAVAL STORES WORK

Cooperative agents employed jointly by this Department and State agencies continued to introduce and demonstrate to producers and processors of pine gum in Florida and Georgia the improved practices and equipment for production of turpentine and rosin developed by the Bureau of Chemistry and Soils, and to explain and encourage the adoption of improved practices for protecting the forests developed by the United States Forest Service and the State forestry departments.

In Florida, assistance was given to about 350 persons on problems relating to the production of naval stores. The cooperative agent directed the erection of 18 turpentine fire stills according to plans and specifications approved by the Bureau, and he assisted in the installation of 12 recording still thermometers, 12 covered turpentine separators, 5 dehydrators, 6 still sheds, and 7 cooper's winches.

In Georgia the cooperative agent visited 170 naval stores operators and assisted them in connection with various problems in woods work and processing practices. He furnished plans and specifications and otherwise assisted in the construction of 7 complete naval stores plants and supervised the construction of 17 fire-still settings, according to specifications of the Bureau. Still settings, which conform to the Bureau's specifications and which serve as models for neighboring operators, are located in 41 of the 64 counties of the Georgia naval stores territory.

NAVAL STORES STATISTICS

In order to assist naval stores operators in adjusting production of turpentine and rosin to probable demand, the Bureau published statistics on industrial consumption and stocks for 1934-35 on July 31, 1935, and for 1935-36 on May 29, 1936. The report for 1934-35 was published with the collaboration of the Agricultural Adjustment Administration. An act of Congress, which became effective August 15, 1935, authorizes the Secretary of Agriculture to collect and publish annually, and at such other times and on such date or dates as he shall prescribe, statistics on production of turpentine and rosin as well as on the industrial consumption and total stocks.

OIL, FAT, AND WAX INVESTIGATIONS

BLACK-WALNUT OIL

With a view to the possible utilization of the small nut particles which accumulate as a byproduct of the black walnut shelling plants, an investigation was made on the properties and composition of the oil expressed from them. The oil contained about 88 percent of unsaturated and 5.5 percent of saturated fatty acids. It gave an iodine number, by the Hanus method, of

about 135 and a saponification value of 193.6. Apparently the oil, which belongs to the lower range of the drying-oil class, is useful for the manufacture of paint and varnish, particularly in combination with oils having greater drying powers. It is also useful for soap manufacture, since it yields a hard sodium soap with good lathering property and, after suitable refining, may be used as a salad and cooking oil. The press cake, containing particles of shell, may be used as feed for poultry.

RAISIN-SEED OIL

A sample of refined raisin-seed oil was tested for its constants and analyzed for individual saturated and unsaturated fatty acids. The results indicate that the oil belongs in the lower range of the drying-oil class, the iodine number being 129. Considerable quantities of this oil, expressed from the seeds obtained as a byproduct of the raisin industry in California, are now being used in the paint industry, particularly in the production of protective coatings for canvas. The refined oil is used for coating raisins and also in salad dressings and certain cosmetic preparations. A sample of raisin seeds examined in the laboratory contained about 17 percent of oil and about 8 percent of moisture. The average oil content of the raisin seeds crushed commercially for oil and meal is said to be 15 percent.

TUNG AND OTHER DRYING OILS

Six large samples of tung fruits, grown in Mississippi and received through the Chemical Division of the Bureau of Foreign and Domestic Commerce, were examined with regard to average weight of fruits, proportion of nuts to fruits, proportion of kernels to nuts, and oil content of nuts. The fruits were from plantings in three different types of soil. Four plantings had not received any cultivation for some years, but the other two had been continuously cared for. Although the fruits of the different samples varied widely in weight, as well as in the proportion of kernels, only two samples had kernels containing less than 64.7 percent of oil, and in both cases the fruits were from uncultivated trees. The oil content of the kernels ranged from 53.6 to 70.1 percent. The kernels from the two samples of fruit from cultivated trees contained 64.7 and 70.1 percent of oil, respectively. The oils from all samples varied only slightly in their composition and constants. The average of the iodine number of oils from the six samples by the Wijs method was 164.5. From the commercial point of view the oils were of equal value and satisfactory in quality.

An investigation on the composition of oiticica oil was completed. Oiticica oil is expressed from the seeds of the tree *Licania rigida* of the Rosaceae family. This tree is indigenous to Brazil. Experimental plantings have been made by the Division of Plant Exploration and Introduction of the Bureau of Plant Industry in the southern part of Florida and in the Canal Zone. Oiticica oil has very strong drying power and is used to some extent, after suitable treatment, as a substitute for tung oil in the manufacture of paints and varnishes.

MISCELLANEOUS SEED OILS

Elderberry seeds, obtained as a byproduct in the manufacture of elderberry jelly, were found to contain 22 percent of oil having an iodine number of about 166. The high iodine number indicates that the oil has strong drying power. If produced commercially, elderberry-seed oil could probably be used in the manufacture of paints and varnishes and other products in which drying oils are used.

The fruits, seeds, and oil of the small tree *Pyrularia pubra*, commonly known as the buffalo or oil-nut tree, were examined at the request of the Division of Plant Exploration and Introduction of the Bureau of Plant Industry. The samples of fruits were collected near Bluefield, W. Va. The nut kernels, which constituted 67.8 percent of the fruits, contained 58.5 percent of oil having an iodine number of 104.6 and belonging to the semidrying class of oils. Further investigation is needed to determine the uses for which the oil and other parts of the fruit are suitable.

Mimosa seed from North Carolina, when extracted with solvent, yielded a yellow oil having an iodine number of 134.4. This oil belongs in the lower range of the drying-oil class and would probably exhibit drying properties similar to those of soybean oil. The low oil content of the seed, about 10 percent, makes commercial production impractical.

Seeds of the plant *Simmondsia californica*, which were offered to the edible-oil seed crushers during the year, were found to contain over 51 percent of light yellow oil. However, the high proportion of unsaponifiable constituents, 48.3 percent, indicated that the oil would not be suitable for food purposes; also that it would not be of any interest to manufacturers of soap or products made with drying oils.

Kapok oil, which is expressed from the seeds of *Ceiba pentandra* by mills in California, was tested for its constants and analyzed for its individual fatty acids. This is a nondrying oil which, after refining, is well adapted for use in the preparation of salad dressings, as a cooking oil, and for hydrogenating to solid shortening. The oil content of kapok seed from different localities ranges from 20 to 25 percent.

Samples of mahogany tree seeds and oil were examined at the request of the Haitian Department of Agriculture, to determine the feasibility of producing the oil commercially. The material extracted with petroleum ether from decorticated seeds amounted to 53 percent of their weight, but it was found to be a mixture of oil and resins containing about 8 percent of unsaponifiable matter. It was not suitable for food and possessed no outstanding characteristics that would make it valuable for technical purposes.

HALIBUT-LIVER OIL

In collaboration with the Bureau of Fisheries of the Department of Commerce and the Food and Drug Administration of this Department, 20 authentic samples of halibut-liver oil were tested for refractive index, iodine number, saponification value, acid value, and unsaponifiable matter. The greatest variations were in iodine number (112.3 to 161.6) and in unsaponifiable matter (4.65 to 20.15 percent). The previously known low and high limits for unsaponifiable matter in authentic halibut-liver oil from fish caught in the Pacific Ocean have been extended by this investigation.

PROTEIN AND NUTRITION INVESTIGATIONS

STUDIES ON THE DIGESTIBILITY OF PROTEINS

Information regarding the digestibility of proteins when eaten by animals may be gained from laboratory experiments on the completeness or rapidity with which proteins are broken down into their constituents when treated in liquid media under varying conditions with digestive enzymes. Laboratory digestion studies were continued on casein with special reference to the rate at which the amino acid cystine is liberated when casein is treated with the enzyme trypsin. Casein is assumed to be a complete protein, as regards nutritionally essential amino acids and is used to supply protein requirements in basal rations for feeding experiments in vitamin work and as a standard of comparison in determining the nutritive value of different protein foods. Previous work in the Bureau had shown that treatment of casein with dilute alkali, commonly used for the preparation and purification of casein for scientific purposes, largely destroyed the nutritionally essential amino acid cystine, and that the use of so-called purified casein prepared with dilute alkali would lead to erroneous conclusions in feeding tests. It had also been found from previous work that digestion of casein with trypsin is more complete than with pepsin and that with the former cystine is liberated at an early stage of the digestion in slightly alkaline media but is partly destroyed by the alkali. Trypsin digestion of casein in a medium a little on the acid side of neutrality (pH 6.8) liberated cystine completely but more gradually, and the full amount could be recovered. Experiments showed that cystine alone, after treatment with a weak alkali solution (pH 8 to 9) for 4 hours, was not destroyed to any extent. When treated under the same conditions, but in the presence of casein and trypsin, more than half of the cystine was destroyed. Experiments on the effects of the weak alkali solution on casein, with and without trypsin, after 24, 48, and 72 hours, showed that in every case the destruction of cystine was three times as great with trypsin as without it. It was also shown that, in tryptic digestion of casein in alkaline medium, the destruction of cystine was greater with sodium hydroxide than with sodium carbonate.

Digestion studies with pepsin were made on toxic gluten prepared from wheat containing selenium to see whether the selenium compound could be concentrated in some fraction of the split products. The results are reported below in connection with the subject of selenium in toxic wheat.

It has been observed in the Bureau's work on proteins and nutrition that the amino acids, which are nonsugar-forming in metabolism, are the ones which are nutritionally indispensable, whereas the sugar formers are dispensable, with the possible exception of the sulphur-containing amino acids. This relationship suggests a possible new method of approach for determining whether a given amino acid is synthesized by the animal organism.

CYSTINE, TRYPTOPHANE, AND TYROSINE CONTENT OF PROTEINS

In order to evaluate the biological properties of proteins it is necessary to have as accurate information as possible with regard to their contents of amino acids, particularly those known to be nutritionally essential. Although existing data were obtained by the best methods available at the time of each investigation, recently improved methods for the determination of cystine and tyrosine have shown that much of the data concerning the quantities of these amino acids in various proteins are erroneous to a considerable degree. For this reason the cystine and tyrosine content of a large number of proteins was redetermined by more recent improved methods. These amino acids and tryptophane were determined in other proteins, for which no previous figures were available. The greatest differences between the new and old values were observed in the case of cystine. Values much lower than those previously recorded were found for cystine in the proteins of beans. The new values are more consistent with results obtained in feeding experiments. In general, proteins of oil seeds showed minor differences between the new values and those previously recorded.

High figures for tyrosine were obtained on the proteins of Chinese and Georgia velvetbeans, albumin from the jackbean, proteins of cantaloup seed, zein from corn, proteins of rice, arachin from peanuts, casein, alcohol-soluble protein from milk, sweetpotato proteins, and sesame-seed globulin. High figures for tryptophane were obtained on the protein from oranges and one protein from sweetpotatoes. The alcohol-soluble protein from rice was lacking in tryptophane.

PROTEINS IN LOCUST BARK

There appear to be two kinds of wild locust trees which are very similar, but one is attacked by the locust borer and the other is resistant to it. Work done in this Bureau some years ago showed that the inner bark of the common black locust contains a surprisingly large quantity of protein which is toxic to animals. A paper entitled "Proteins of the Common Locust Tree", published by the Bureau in 1925, came to the attention of agencies interested in the possibilities of the locust tree for preventing soil erosion, and at their request samples of bark from 11 resistant and 10 nonresistant locust trees, collected in Ohio and Indiana, were examined for their protein content, with the object of determining whether any relationship exists between the content of protein and resistance to the attacks of the locust borer. Almost identical percentages of protein were found in the barks of resistant and nonresistant trees. The protein content averaged 21.5 percent on the weight of air-dried material. Although the results showed no relation between total protein content of the bark and resistance to borer attack, this fact does not exclude the possibility that protein is the determining factor, since the proteins from the different types of tree might vary in their composition and one might be deficient in the toxic component. This possibility was not investigated because the great amount of time required for such an investigation could not be spared from regular projects.

SAFFLOWER-SEED MEAL

Unusually high percentages of protein were found in samples of three commercial safflower-seed products prepared for use as feedstuff. If the proteins contain the nutritionally essential amino acids in adequate quantities and are satisfactory from the standpoint of digestibility, safflower-seed meal should serve as an excellent protein concentrate for feeding purposes. Safflower seed is a source of drying oil suitable for use in paints and other industrial products. Only insignificant quantities have been produced in this country.

AMINO ACID CONTENT OF WHEAT

Until recently no satisfactory method was available for determining the total amino acids in staple foods, such as cereals, flour, meals, and seeds. Direct hydrolysis, as used with purified proteins, is not applicable to such food mate-

rials, because hydrolysis in the presence of starch and other nonprotein substances results in the decomposition of the amino acids, cystine, tryptophane, and histidine. It was shown in last year's report that this difficulty had been largely overcome in the case of flour by hydrolyzing extracts obtained by treating the flour with suitable solvents which removed the nitrogenous compounds practically quantitatively. The percentages of the nutritionally essential amino acid, present in a white commercial wheat flour, as determined by this improved procedure, were shown in the report of 1935. Studies on the quantitative determination of nutritionally essential amino acids in staple food products were extended to whole-wheat flour in 1936. The resulting figures for the cystine, tryptophane, tyrosine, lysine, and arginine content were lower than the corresponding figures similarly obtained in previous analyses of patent flour. A sample of whole-wheat flour prepared from Marquis hard spring wheat was found to contain, in addition to the amino acids mentioned, 0.28 percent of histidine, a nutritionally essential amino acid having special interest because it constitutes between 7 and 8 percent of blood hemoglobin.

INTERNATIONAL VITAMIN STANDARDS

During the past year the Bureau, which was chosen several years ago by the health organization of the League of Nations to receive and distribute the international vitamin standards to vitamin investigators in the United States, continued to issue these standards on request to investigators in colleges, universities, and agricultural experiment stations.

SELENIUM IN TOXIC WHEAT

One of the most fundamentally important questions in connection with the study of seleniferous soils, a subject of much interest because of its importance to agriculture and public health, is the identity of the toxic organic selenium compound or compounds present in plants grown on such soils. Studies were continued on the isolation and identification of the selenium compound previously shown to be present in the protein of wheat grown on seleniferous soil. Progress was made on the concentration of the selenium compound in certain amino-acid fractions obtained by hydrolyzing gluten from toxic wheat with sulphuric acid. By using fractionation methods commonly applied to the separation of amino acids, a small amino acid fraction, consisting apparently of homogeneous crystals which contained about 2 percent of selenium, was isolated. Although the compound has not yet been obtained sufficiently free from amino acids to characterize its chemical properties clearly, its apparent stability suggests that the selenium is either in a ring structure or is tied to several carbon atoms in its most highly oxidized form. Some evidence exists that there may be more than one selenium compound in the hydrolyzed gluten.

By partial digestion with pepsin, 78 g of toxic gluten were separated into four fractions of split products of the gluten. These were analyzed for selenium and for cystine. Fraction 1, weighing 2.5 g, contained no selenium or cystine. Fraction 2, weighing 9 g, contained 58 percent of the total selenium present in the gluten taken for digestion. This fraction also contained 10.5 percent of the total cystine. Fraction 3, weighing 1 g, contained no selenium and only about 1 percent of the total cystine. Fraction 4, weighing 65.5 g and representing 84 percent of the weight of gluten digested, contained about 41 percent of the total selenium and 89 percent of the cystine. Partial digestion of toxic gluten with pepsin thus offers a promising method for concentrating 58 percent or more of the selenium in a small fraction amounting to about one-tenth of the original gluten. The results provide additional evidence that the selenium is present in organic combination with the protein and also throw light on the question of possible correlation between the selenium and the cystine in the protein molecule.

DUST EXPLOSION INVESTIGATIONS

Nine explosions in industrial plants were investigated by the Bureau during the past year. Grain dust, soybean dust, and fertilizer dust each was responsible for one of the explosions; wood dust was responsible for two; aluminum dust or powder for three; and in one the explosive material was hexane vapor. These explosions resulted in the death of 20 persons, injury to 50 persons, and a property damage of about \$919,000.

The most serious explosion investigated during the year occurred in a soybean processing plant at Chicago on October 7, 1935. It resulted in the death of 11 men, injury to 45 persons, and a property loss of about \$600,000. In this plant soybeans were stored, ground, and processed to obtain oil, meal, and other products. The oil was extracted from the ground beans by means of an inflammable solvent, hexane. Apparently the first ignition occurred in the bean-preparation building, where dust clouds were present in and around the grinding machinery, and the flash spread quickly to the adjoining section of the plant where hexane vapors were present. The resulting explosion demolished the bean-preparation, extraction, and protein departments.

About 2 weeks after the explosion in the soybean plant at Chicago a somewhat similar explosion, though on a smaller scale, occurred at Momence, Ill., where a small rural unit had been set up to extract oil from soybeans, and the same solvent was being used as had been employed in the Chicago plant. The solvent vapors exploded, killing two men and injuring two others. The property loss amounted to about \$5,000.

These two explosions show the need for additional research on dust explosion and fire prevention in industries where new processes are being employed and new products obtained in the utilization of agricultural products.

EXPLOSION EXPERIMENTS AT ARLINGTON EXPERIMENT FARM

Sparks produced by the impact of metals against hard surfaces, as when a stone or other hard material enters grinding machinery or metal strikes against the side of a concrete bin, are believed to have started many of the dust explosions in industrial plants, which have been investigated by the Bureau. In an effort to determine the soundness of this belief, experiments were made in the test structure at Arlington Experiment Farm on the ignition of air-suspended dusts by means of sparks from an emery wheel turning against steel, the device being controlled from the outside. Explosions of sulphur dust and aluminum powder were started by sparks formed in this way. Air-suspended organic dusts were not ignited by the sparks, but it was possible to ignite a pile of wood dust by directing the sparks into it, and such burning material could start a dust explosion. Efforts are being made to determine the conditions under which organic dust clouds can be definitely ignited by metallic sparks.

Tests were continued to determine the breaking strength of glass used in explosion vents. Ribbed glass of several different weights and extra-thin picture glass were used in these tests, and recommended methods of scoring to weaken the glass were tested.

EXPLOSIBILITY TESTS

During the year 73 dust samples were tested in the laboratory, to determine their explosibility. Of these samples, 6 were submitted by the Bureau of Agricultural Economics, 4 by the Bureau of Plant Industry, 3 by individuals, and the rest by 24 manufacturing firms.

In order to eliminate the fire and explosion hazard in dusting cranberry bogs with pyrethrum powder from airplanes, work was undertaken to determine the proportion of inert dusts, such as finely divided clay and calcium carbonate, that must be mixed with the pyrethrum to prevent propagation of flame. The results of laboratory tests indicated that at least 70 percent of clay was required to completely prevent flame propagation. Flame propagation was prevented when 60 parts of calcium carbonate were mixed with 40 parts of pyrethrum. Calcium carbonate or limestone is therefore a better diluent than clay for this purpose.

In order to determine the effect of the degree of fineness on the explosibility of dusts, a large number of tests for maximum pressure and rates of pressure rise were made with powdered sucrose and cellulose, separated into six ranges of particle size by means of screens. These tests indicated that sucrose with particle size larger than 0.104 mm and cellulose with particle size larger than 0.208 mm do not form explosive dust clouds.

EDUCATIONAL WORK ON PREVENTING DUST EXPLOSIONS

The Bureau cooperated actively with several States in presenting the results of dust-explosion prevention work at schools of instruction for firemen, 10 of which were held in Pennsylvania, Virginia, New Jersey, New York, Ohio, Illinois, North Carolina, and Georgia. Illustrated talks were given, using the film strip and motion picture on dust explosions. Demonstrations were given also with a miniature elevator and a cheesecloth bag.

Addresses dealing with the prevention of dust explosions were given before a number of organizations at special meetings and conventions. Among the more important meetings were the following: National Fire Protection Association, Atlantic City, N. J.; National Safety Congress, Louisville, Ky.; Upper Mississippi Valley Safety Conference, Chippewa Falls, Wis.; Fox River Valley and Lake Shore Safety Conference, Manitowoc, Wis.; Society of Grain Elevator Superintendents of North America, Duluth and Minneapolis, Minn.; South-Eastern Underwriters Field Engineers, and Engineering and Chemistry Departments, Georgia School of Technology, Atlanta, Ga.; Maryland State Mining School, Frostburg, Md.; International Association of Fire Fighters, staff of the Provincial fire marshal of Ontario, and Royal Canadian Institute, Toronto, Canada.

The addresses made at some of these meetings were given wide circulation through publication in trade journals. In addition, eight specially prepared articles dealing with dust explosions and their prevention were published in periodicals.

Conferences on dust-explosion prevention and the practical application of the research work of the Bureau on this problem were held with the representatives of 15 organizations and manufacturing firms.

On October 7, 1935, during Fire Prevention Week, talks on dust explosions by representatives of this Department and the Department of Labor, supplemented by the noise from a series of dust explosions in the room, gallery, and tower of the test structure at Arlington Experiment Farm, were broadcast over a Nation-wide radio hook-up as part of the Farm and Home Hour program.

Dust-explosion demonstrations were given for a number of visitors, including representatives of manufacturing firms and 4-H clubs. Dust explosions were also staged for a commercial motion-picture news reel and in connection with the preparation of the Department's new motion picture entitled "Dangerous Dusts", which includes lecture and explosion sound effects. This film was shown for the first time at the meeting of the National Fire Protection Association in Atlantic City on May 12, 1936.

The chairman and secretary of the dust-explosion hazards committee of the National Fire Protection Association, both members of the Bureau's staff, prepared for publication the new flour- and feed-mill code, the new code for wood-working plants, revisions of the terminal elevator code, the code for starch factories, and the code for installation of pulverized fuel systems. These codes were published in the United States Department of Labor Bulletin 617 as a supplement to United States Department of Labor Bulletin 562.

FARM FIRES

Large-scale experiments on spontaneous ignition of hay, such as those carried on during the past few years, were not possible during the 1935 season because of inadequate funds. An opportunity was afforded, however, to make some interesting observations on small lots of hay put up for a number of cooperative studies by the Bureau of Dairy Industry. Serious heating developed on one lot of chopped hay, principally alfalfa, and the services of this Bureau were enlisted for the purpose of controlling the possible fire hazard and of making appropriate observations from the spontaneous heating and ignition standpoint during the course of the experiment.

The chopped hay in question, approximately 6 tons, had an average moisture content of about 28 percent when stored. The maximum moisture content shown by any subsample was 30.6 percent. Four days after storing the maximum temperature of the hay was 56° C. Seven days after storing the temperature in one corner of the mow, 4 feet below the surface, reached 90°. Observations were continued for more than 2 months, but no higher temperature was observed. Temperatures between 80° and 90° prevailed during the second and third weeks after storing, after which there was a gradual but steady decline. Removal of the hay started 100 days after storing, at which time the maximum temperature recorded was 59.4°. Examination showed that the hay was well dried out and practically free from mold. The central part, however, was dark brown and apparently had lost much of its feeding value. At no time during the progress of the experiment was steaming observed at the surface of the hay, but about 2 weeks after storing a small area of the barn siding on the north side, about 6 feet above the ground line, was damp and hot.

A large-scale experiment on a first cutting of alfalfa hay (1936 crop) was started to determine the effect of open alleyways and elevated false floors on

drying out of undercured long hay in storage and dissipation of the heat produced. Air velocities and temperatures in the mow are being recorded, and samples of the hay and gases evolved by it are being collected for laboratory examination. This study should throw considerable light on the problem of the storage of hay without abnormal spontaneous heating, which is of much practical interest to the farmer.

Considerable progress has been made in laboratory experiments on the effect of heat on hay in the absence of air and under conditions approximating those that may prevail in a heating mow. The object is to get further evidence bearing on the tentative conclusion from previous work that purely chemical oxidations of highly unstable unsaturated organic compounds, formed in hay by micro-organisms or by the heat of microbial activity, occur in heating hay.

A manuscript embodying the results of an investigation, previously completed, on the extent and character of the losses of organic substance resulting from the spontaneous heating of undercured hay was prepared for publication.

In order to obtain more definite information regarding the fatty substances of hay, which are destroyed to a large extent by spontaneous heating, a study was made of the petroleum ether extract, approximately 2 percent, of alfalfa meal. In addition to fats, it contained unsaponifiable matter consisting of a sterol, a primary alcohol, a mixture of hydrocarbons, and an unidentified oily substance. Further investigation of these petroleum ether soluble constituents of alfalfa is in progress.

In connection with the studies on spontaneous heating of stored hay, field investigations were made on farms in certain parts of Maryland and Pennsylvania, during the haying season of 1935, in order to ascertain the general practice with reference to haying methods, moisture content of hay when stored, and storage conditions.

In connection with fire prevention and control, attention was given to hand fire extinguishers and to minimum requirements of water supply on farms for motorized fire apparatus. An address entitled "Water Supplies on Farms for Fire Department Use" was presented before the American Society of Agricultural Engineers.

Members of the Bureau's chemical engineering staff cooperated with organizations interested in fire prevention by participating in conferences and meetings and in the work of committees on which they held membership. These organizations included telephone, insurance, and fire apparatus manufacturers' associations, the American Society of Agricultural Engineers, the National Fire Waste Council of the Chamber of Commerce of the United States, and the National Fire Protection Association and its committees on farm fire protection and spontaneous heating and ignition. Members of the Bureau's staff revised and enlarged the section on spontaneous heating and ignition in the eighth edition of the Crosby-Fiske-Forster Handbook of Fire Protection, which was published by the National Fire Protection Association. The American Society of Agricultural Engineers was assisted in the revision of its comprehensive report on farm fire prevention and control. The National Fire Protection Association was assisted in the preparation of the farm fire protection committee's report, entitled "Water Systems for Fire Protection on Farms", which was published in bulletin form.

FERTILIZER INVESTIGATIONS

The fertilizer investigations of the Bureau cover work along widely different lines. Basic research is conducted on the elements and compounds contained in fertilizer materials, whereby their ultimate structures, vapor pressures, compressibilities, and other physical and chemical properties are determined by X-ray analysis, spectroanalysis, and other procedures, in conjunction with mathematical and statistical methods for the utilization and interpretation of the data obtained. Laboratory procedures are devised for the preparation of potential fertilizer materials in quantities sufficient for studies of their reactions with each other, and for vegetative tests ranging in size from greenhouse pot tests to large-scale field tests, in cooperation with other divisions of the Department and with State agricultural experiment stations. Fertilizer materials are made in semicommercial or pilot-plant operations, which serve to demonstrate the feasibility of commercial production to the industry. Economic and statistical studies of fertilizer production and utilization are also made. The projects are planned and carried through to meet the needs of the fertilizer manu-

facturer, the agronomist, the farmer, and the consuming public. In cooperation with the Association of Official Agricultural Chemists, the Fertilizer Research Division has important duties in safeguarding the farmers' interests by standardizing methods of fertilizer analysis.

NITROGEN

CATALYSIS IN NITROGEN FERTILIZER INVESTIGATIONS

Most of the early work of the Bureau on catalysis was directed toward a search for efficient catalysts for use in the production of synthetic ammonia from mixtures of nitrogen and hydrogen, an undertaking that met with success and placed the synthetic ammonia industry of this country on a firm foundation. Present activities are directed mainly toward gaining an understanding of the fundamental principles underlying catalytic action, in order that the knowledge thus acquired may serve to point out the manner in which catalysts and catalytic processes pertaining to the manufacture of fertilizer materials can be perfected. The knowledge gained in these studies is also useful in connection with other chemical processes based on catalytic reactions.

The method, mentioned in the report of 1935, for measuring the areas of catalyst surfaces by determining the adsorption isotherms of gases near their boiling points has been found to be applicable to four types of iron-synthetic ammonia catalysts—those containing no promoter, those containing both aluminum oxide and potassium oxide, and those containing either of these—as well as to other finely divided materials such as glaucosil, pumice, nickel oxide supported on pumice, nickel catalysts on pumice, chromium oxide gel, and crystalline chromium sesquioxide catalysts. The isotherms of nitrogen and argon at -183°C . have been found convenient for use in such surface measurements. An interesting result of this work has been the discovery that Polanyi's potential theory of gas adsorption, which has never been applied to gas adsorption by metals, is applicable to the low-temperature adsorption of gases by iron catalysts. It was furthermore shown for the first time that sufficient potassium oxide diffuses out of the individual crystals of a doubly promoted iron synthetic-ammonia catalyst to cover about 60 percent of the surface of the sample, even though the total potassium oxide content is only about 1 percent. This discovery helps to make clear the marked improvement effected by adding 1 percent of potassium oxide to an iron catalyst already containing about 1 percent of aluminum oxide.

In studies to determine the kinetics of the synthesis of ammonia over various catalysts, the dependence of the rate of the reverse reaction of the decomposition of ammonia on the partial pressures of hydrogen and ammonia and the temperature coefficient of the reaction were determined over platinum catalysts by both static and flow methods.

In studies of a method for producing hydrogen for ammonia synthesis by the oxidation of phosphorus vapor with carbon dioxide and subsequent reaction of the resultant carbon monoxide with steam, the phosphorus was shown to be converted quantitatively into phosphorus pentoxide at $1,000^{\circ}\text{C}$. in only a few seconds, when a considerable excess of carbon dioxide was present. When too little carbon dioxide was used, some lower oxide of phosphorus, the composition of which is not definitely known, was formed. It was also found that phosphorus pentoxide can be reduced at $1,000^{\circ}$ with carbon monoxide, a lower oxide of phosphorus and finally elemental phosphorus being formed.

PHYSICAL CONSTANTS OF GASES AND FERTILIZER SALTS

Extensive and precise knowledge of the physical properties of the substances involved in any chemical reaction is needed to design equipment adapted to the most economical manufacture of the product of that reaction. Furthermore, the suitability of the end product for utilization as a fertilizer material frequently depends on its physical properties.

Data obtained in a study of the compressibility of a 3:1 mixture of hydrogen and nitrogen showed that the results reported by previous investigators are not sufficiently accurate, particularly at high temperatures. Discrepancies were found, even at 0° and 25°C ., that would seriously affect the calculation of derived thermodynamic quantities.

It was found that the partial molar volumes of ammonia and hydrogen in the liquid phase do not conform to any simple law.

The molecular structure of the potash mineral alunite was studied by means of X-ray diffraction analysis. In cooperation with the Bureau of Plant Industry, the effect of X-rays on corn seeds and tobacco plants was determined.

New knowledge regarding the structure of oxalates and sugar hydrazones was gained from electron density analyses. The degree of atomic separation in the sulphur molecule and the crystal structure of the rare element, polonium, were determined successfully with electron diffraction apparatus.

By means of ultraviolet absorption spectra, the heat of reaction in the formation of 2 gram molecules of nitrous acid from 1 of nitrogen trioxide and 1 of water was ascertained to exceed 10,000 calories. It was found that nitrous acid in the gaseous phase can be precisely determined by an optical method.

In cooperation with the Bureau of Plant Industry, spectroanalyses were made of the differences in the mineral-element content of toxic and nontoxic specimens of the roots of *Tephrosia (Clatca) virginiana* which was under investigation as a source of insecticide. In cooperation with the Bureau of Animal Industry, absorption spectra were determined on beef extract at various concentrations.

Measurement of the absorption of light by nitrogen pentoxide, a problem of long-standing difficulty, was made possible by using mixtures of nitrogen pentoxide with ozone.

Organic molecules that contain hydrogen atoms bonded in an abnormal way to an oxygen atom in the molecule (so-called hydrogen bond) were identified in considerable number in a study of infrared absorption spectra. The infrared absorptions of a number of simple ortho-substituted phenols were measured for the purpose of developing a method of spectrum analysis for the new type of infrared spectra, characteristic of the imino, amino, hydroxyl, and methine groups in solutions.

Mass-spectrographic analysis was used to determine the relative abundance in nature of the different isotopes of the alkalis, lithium, rubidium, and potassium. The abundance ratio of two potassium isotopes (atomic weights 39 and 41) was found to vary in potassium from different sources, although in potassium from ocean water the ratio was remarkably constant. In potassium from plant tissues it was found that the ratio was affected by differences in variety, section, and age of plant, and fertilizer used. New isotopes of potassium, sodium, and lithium were discovered. These have atomic weights of 40, 22, and 5, respectively.

NITROGENOUS FERTILIZER MATERIALS

In experiments on the ammoniation of peat it was discovered that the use of salts of zinc, iron, copper, or aluminum, or of both zinc and manganese as catalysts, increased the active insoluble nitrogen of the products, as determined by the permanganate methods. It was also found that the formation of water-soluble nitrogen was favored by the presence of moisture during the ammoniation, although high moisture contents decreased the amount of nitrogen fixed. Grinding of the product considerably increased the availability of the insoluble nitrogen. Work on the pretreatment of organic materials to make them suitable for use as nitrogen carriers showed that in the treatment of peat prior to ammoniation higher strengths of acid caused the formation of more hydrolyzed products which, on ammoniation, contained nitrogen of higher activity than the untreated product.

In studies on the preparation for fertilizer use of magnesium compounds that are also carriers of nitrogen new compounds of urea with magnesium sulphate and magnesium nitrate have been made. These high-nitrogen compounds offer possibilities for use in fertilizers, with the elimination of some of the undesirable properties of urea itself and have the further advantage of introducing the secondary plant nutrient, magnesium, into fertilizer mixtures.

A new rapid analytical procedure, which gives accurate results, was devised for determining urea in fertilizer mixtures that contain ammonium salts and yield colored solutions. The method proved applicable also to urea solutions that contain free ammonia.

BIOCHEMICAL AND ORGANIC NITROGEN INVESTIGATIONS

In connection with the study of nitrogen fixation by bacteria, the decomposition of the nitrogenous compounds, arginine and allantoin, by *Azotobacter* was investigated in detail with regard to extent of oxygen consumption, carbon dioxide and ammonia production, pH activity functions, and identification of the intermediates formed. It was determined that *Azotobacter* can reduce nitrates to nitrites, but not to ammonia or to nitrogen gas under the conditions studied.

Investigations on the solubility relations of nitrogen in heavy suspensions of *Azotobacter*, legume nodule bacteria, and yeast showed that the solubility relations do not account for the previously observed kinetic nitrogen pressure functions. An uptake of nitrogen over and above that dissolved by the water present in the suspensions was observed, from 5 to 10 times as much being dissolved by either yeast or *Azotobacter* cells, on the basis of their dry weight.

Preliminary studies to determine whether healthy legume roots and nodules excrete nitrogen, as claimed by certain European workers, gave negative results, but these studies are not completed. In studies to ascertain the cause of the stimulation of growth and respiration of legume nodule bacteria and of *Azotobacter* by natural humic acid, the stimulation of *Rhizobia* was found to be due primarily to the essential bacterial growth substance previously discovered by this Bureau, whereas the growth response of *Azotobacter* was due to available iron, molybdenum, and vanadium. In work dealing with factors affecting nodule formation on legumes it was learned that sucrose is favorable to legume nodule formation, likewise a high concentration of legume bacteria, whereas nitrogen compounds, except in traces, are harmful. The presence of older plants under sand-culture conditions frequently favored nodulation. A study of the metabolism of resting legume bacteria to determine the utilization of various energy sources in the absence of growth disclosed that carbohydrates are utilized, but that the rate of respiration is very low. The accessory growth factor, coenzyme R, previously found by the Bureau to be essential for the growth of certain strains of legume nodule bacteria, had no appreciable effect on the rate of dextrose utilization by the nongrowing cells.

In studies to ascertain the changes in the metabolic processes occurring at various stages of growth in the large-scale cultivation of *Azotobacter vinelandii* on urea as a source of nitrogen, the urea was found to be rapidly hydrolyzed to ammonia and carbon dioxide in the early stages of growth, and a simultaneous hydrolysis of the sucrose in the medium also took place with the formation of glucose and fructose. After a rapid rise in the pH of the medium as a result of the urea hydrolysis, the pH gradually decreased in some cases and the medium became almost neutral in reaction. The glucose and fructose were gradually utilized during the growth of a good crop of bacteria. In some cases, however, the pH remained at the high level without utilization of the sugars and with the death or inhibition of growth of the bacteria. This difference in behavior under seemingly identical conditions was not found to be caused by different rates of aeration or by differences in the temperature used for sterilization of the urea and is still under investigation. The glucose and fructose are used by the bacteria, partly as a source of energy and partly for conversion into other products.

Experiments to ascertain the effects of high pressures on the rate of fixation of nitrogen by *Azotobacter vinelandii* indicated that the metabolic processes are slowed down by pressures ranging from 200 to 1,000 atmospheres.

The problem of fixing nitrogen by reaction with organic substances apart from life processes received further attention. When treated with active nitrogen, benzonitrile and tetrahydronaphthalene yielded solid dark-colored polymerization products and appreciable amounts of the poisonous nitrogen compound, hydrogen cyanide; isoprene yielded scarcely any polymerized material but a considerable quantity of simple nitrogenous liquids which under suitable conditions evolved ammonia. Efforts to effect combinations between Grignard reagents of the aliphatic and aromatic types and atmospheric nitrogen at 1,000 atmospheres pressure failed to show any reaction with the nitrogen.

POTASH

In further studies of procedures for the production of potassium metaphosphate, a material of considerable promise for fertilizer purposes because of its high plant-food concentration, it was found that nonhygroscopic metaphosphate containing 40 percent of potash and 56 to 58 percent of phosphoric acid could be produced by heating a suitable mixture of monopotassium phosphate, potassium chloride, and phosphoric acid, obtained in a preliminary step by treating potassium chloride with phosphoric acid. Incidentally it was found that, by heating at 500° C. a mixture of potassium chloride and phosphoric acid that contained a 20-percent excess of potassium chloride above the equimolar ratio, 97 percent of the phosphoric acid was converted to metaphosphate directly, thus replacing a two-stage process by a single operation.

The new salt, calcium phosphate chloride, mentioned in last year's report in connection with investigations to utilize the byproduct, hydrochloric acid, pro-

duced in the conversion of potassium chloride into other potash salts, was found to be a combination of 1 molecule of monocalcium phosphate with 1 of calcium chloride and 2 of water. In endeavors to make more basic compounds of this kind the tribasic chlorophosphate, identical with the mineral chlorospodiosite, was produced by the addition of monocalcium, dicalcium, or tricalcium phosphate to melted calcium chloride. It had a citrate solubility of 50 percent. The same compound was also detected in cooled melts of phosphate rock and calcium chloride.

Investigation of methods for utilizing nitrosyl chloride, a gaseous byproduct obtained in the production of potassium nitrate from potassium chloride and oxides of nitrogen, showed that passage of the nitrosyl chloride over wet phosphate rock resulted in the formation of oxides of nitrogen, which may be used to treat additional potassium chloride, and a water-soluble phosphatic material. Drying of this material at 130° C. converted it to a water-insoluble but citrate-soluble form.

When sodium chloride was treated with oxides of nitrogen, sodium nitrate was formed. This observation suggests the possibility of treating naturally occurring sylvite with oxides of nitrogen from the oxidation of ammonia for the production of mixtures of potassium and sodium nitrates.

A study of the data obtained during the operation of the experimental blast furnace for smelting Wyomingite showed that under present market conditions the independent smelting of Wyomingite for its potash content is commercially impractical. Although the data for combined smelting of Wyomingite and phosphate rock were too meager to allow positive conclusions to be drawn, they seemed to indicate that such a process for producing byproduct potash is feasible.

PHOSPHATES

Intensive laboratory work was continued on the preparation, properties, and chemistry of calcined phosphate which is produced by the action of water vapor on phosphate rock at high temperatures. The process offers attractive possibilities for the production of phosphate fertilizer at a lower cost than is obtainable by processes now in use. The maximum rate of reaction between water vapor and phosphate rock at 1,400° C. was obtained with a single-grain layer of particles in the case of Tennessee brown-rock phosphate. With Florida pebble phosphate the maximum rate occurred in a layer of particles several grains thick. The calcined phosphate prepared from certain samples of phosphate rock suffered considerable reversion of the citrate-soluble phosphoric acid to the citrate-insoluble form when maintained for short periods at temperatures between 200° and 1300°, although that prepared from other samples showed little or no reversion under the same conditions. In general the reversion of calcined phosphate at elevated temperatures was markedly increased by the presence of water vapor in the furnace atmosphere. A study of the action of ferric oxide and of aluminum oxide on pure hydroxyapatite showed that aluminum oxide, and ferric oxide to less extent, functions similarly to silica in promoting the formation of citrate-soluble phosphate when phosphate rock is heated at high temperatures in the presence of water vapor.

Work on the reactions of calcined phosphate with other fertilizer materials to ascertain its suitability for incorporation in various fertilizer mixtures showed that the loss of ammonia from ammonium sulphate caused by calcined phosphate is prevented by keeping the mixture dry or by the addition of from 700 to 1,000 pounds of superphosphate per ton of calcined phosphate.

Preliminary tests indicated that the plant-food value of calcined phosphate is as high as that of superphosphate. Commercial production of calcined phosphate, which contains almost twice as much phosphoric acid as does superphosphate, should result in lower transportation cost per unit of plant food to the consumer.

The 2-percent citric-acid method used for analyzing basic slags proved better than the neutral ammonium citrate method for determining the available phosphoric acid in calcined phosphate.

Hydrated monocalcium phosphate and anhydrous calcium sulphate were found to be the principal constituents of ordinary superphosphate. It was discovered that freshly prepared superphosphate contains fluorine-bearing acids in addition to a larger quantity of free phosphoric acid. The fluorine-bearing acids, mostly hydrofluoric, disappear almost completely during the curing process as a result of precipitation and volatilization. The rapid rotting of fertilizer bags that contain mixtures of superphosphate and potassium chloride proved to be caused by volatile acids, such as hydrochloric and hydrofluoric, liberated by the action

of free phosphoric acid on the potassium chloride and on fluorine compounds derived from phosphate rock. Superphosphate made with waste sulphuric acid from the refining of petroleum had no bad effects on plant growth or the nitrifying bacteria of the soil.

Evaluation of the data obtained during the operation of the experimental blast furnace for smelting phosphate rock showed that only heat at or above 2,255° F. was available for carrying out the required reduction of the phosphate by solid carbon. Variations of the base-acid ratio of the charge between the limits of 0.82 and 1.12 did not appreciably affect either the heat requirement or the efficiency of the reduction process. Obviously, high blast-temperatures are a prerequisite to the economic smelting of phosphate rock for the production of fertilizer.

MIXED-FERTILIZER TECHNOLOGY

In order to prevent segregation of the various materials in a fertilizer mixture it is desirable to granulate the mixture so that each grain contains the different fertilizing elements in the same proportions. In seeking to produce granulated fertilizer mixtures, a method was developed that comprises adjusting the moisture content to the optimum for the mixture to be granulated, heating in a rotating drum to 60° to 90° C., and then drying and cooling by passage through a rotary kiln countercurrently to a stream of air. This procedure proved to be applicable to the granulation of any commercial fertilizer mixture and to yield any desired size of grain.

Work in connection with determining the relative burning effects on plants of various fertilizers in soils of different types disclosed that the temperature of a fertilizer-treated soil may change considerably without an appreciable change in concentration of the soil solution; that the extent to which the inorganic nitrogenous materials—sodium nitrate, ammonium nitrate, ammonium sulphate, and monoammonium phosphate—are "fixed" in Norfolk sandy loam, when applied at the rate of 80 pounds of nitrogen per acre, varies from 6 percent for sodium nitrate to 80 percent for monoammonium phosphate, whereas in Cecil clay loam the extent of the fixation of the same materials varies from 61 to 92 percent; and that potassium sulphate is fixed to a greater extent than potassium chloride in both soils.

In studies to determine the suitability of acid-neutralizing materials for use in fertilizer mixtures it was shown that both limestone and dolomite react with diammonium phosphate with evolution of ammonia, and that loss of ammonia also occurs when calcined phosphate or blast-furnace slag is mixed with ammonium sulphate.

The effect of degree of ammoniation on the rate at which the magnesium in dolomite is converted into available form when mixed with double superphosphate was shown by determinations of water-soluble and citrate-soluble magnesium in ammoniated physiologically neutral dolomite-double superphosphate mixtures that were 4 months old. Some of these mixtures had been ammoniated to 2 percent; the others, to 7.5 percent. The mixtures which had been ammoniated to the higher degree contained from 80 to 95 percent less water-soluble magnesium and from 48 to 57 percent less citrate-soluble magnesium than did those ammoniated to the lower degree.

In seeking the cause of the reversion of phosphoric acid in ammoniated fertilizer mixtures that contain dolomite, it was disclosed that the loss of available phosphoric acid was due to the heat developed by the reaction between ammonia and superphosphate and that the reversion can be prevented by cooling the mixture after ammoniation or by adding the dolomite to the mixture after it has been ammoniated and allowed to cool.

A study of the hygroscopicity and caking tendencies of different phosphatic fertilizer materials showed that, in general, the substitution of calcined phosphate for ordinary or double superphosphate in a fertilizer mixture results in lower hygroscopicity and improved mechanical condition. Increased hygroscopicity may result in some instances where the calcined phosphate reacts with other constituents. The presence of formamide in fertilizer mixtures containing superphosphate tends to promote caking, but this tendency is lessened when the superphosphate is previously ammoniated.

In tests of mixtures of calcined phosphate with various fertilizer salts, the citrate-insoluble phosphoric acid content remained practically constant under different atmospheric humidity conditions, and the water-soluble phosphoric acid content remained substantially constant except in mixtures containing alkali carbonate, where higher humidities greatly increased the water-soluble phosphoric acid content.

In mixtures of urea with superphosphates, no decomposition of urea was observed to take place below about 57° C. Extensive hydrolysis of the urea occurred at 80° and 100°, but in most cases the ammonia produced was completely absorbed by the acidic components of the superphosphates. Losses of ammonia were not observed except when the mixtures were maintained at about 100° for several days. The hydrolysis of the urea was caused by reaction with free water, water of crystallization, or the water of constitution in monocalcium phosphate. In a study of the 30° isotherm of the system urea-magnesium sulphate-water it was disclosed that part of the water of crystallization of magnesium sulphate heptahydrate is replaced to form a new compound, $MgSO_4 \cdot CO(NH_2)_2 \cdot 3H_2O$, and that the water thus liberated is the cause of the stickiness so frequently observed in mixtures containing these substances. The results indicate that magnesium sulphate when used in the preparation of fertilizer mixtures that contain urea should be in the anhydrous state to avoid stickiness in the mixtures.

Improvements were made in analytical methods applicable to fertilizers for the quantitative determination of free acid in superphosphate and of magnesium and citrate-insoluble phosphoric acid.

A survey of fertilizer consumption in the United States showed that a large number of unnecessary grades of mixed fertilizers are manufactured. The elimination of these by the selection of a suitable list of grades as standard for each State (this has already been done in a number of States) would benefit both the fertilizer industry and the consumers. A study of methods for reducing the cost of fertilizers revealed that the elimination of filler from fertilizers would save the farmers a large sum of money annually, estimated at \$7,500,000. This saving is about the same as would result from cutting the present wholesale price of phosphoric acid in half. Substantial savings would also result from the purchase of double-strength mixtures.

SOIL CHEMISTRY AND PHYSICS

SELENIUM INVESTIGATIONS

The first detailed report on the occurrence and distribution of selenium in the soils of the United States was published during the past year. This report, Technical Bulletin 482, shows that selenium, a toxic substance to people and animals, is present in quantities large enough to make it an agricultural problem in the soils and vegetation in some parts of the country. A second bulletin on the same subject is in press.

Selenium is a twin sister to sulphur. It came into notoriety rather suddenly after nearly a century of research for the cause of such troublesome Western States livestock diseases as alkali disease and blind staggers. Until about 4 years ago selenium occupied a modest place in the list of the 80 or more chemical elements, ranking about fortieth in order of abundance. Today it is in the limelight, because it is known to be injurious to people and animals when taken in sufficient quantities. The main danger, however, appears to be with animals, as the result of studies by the Public Health Service indicate that, as a rule, human beings are not apt to get enough selenium in the ordinary diet to harm them. On the other hand, animals that feed largely on seleniferous plants suffer such physical disorders as the loss of hair and hoofs. Death occurs if animals are forced to live on such plants very long, and in many instances acute poisoning and death result from single doses of highly seleniferous vegetation.

The result of surveys indicate that toxic seleniferous areas are ordinarily found in soils derived from certain geological formations, particularly the Pierre and Niobrara shales. Investigations indicate a large area of soils, developed from these shales, in the Great Plains States as capable of producing toxic vegetation. The area where this survey is being made includes parts of Wyoming, Montana, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, Utah, Arizona, and New Mexico. The amount of selenium found in some of these soils was negligible, whereas in others it was great enough to produce vegetation that would kill animals. Selenium is widely distributed throughout the soils of the world, and studies are now under way to find out to what extent it is contained in the principal agricultural soils of the United States, Hawaii, and Puerto Rico.

Studies thus far indicate that the selenium in the soil today came from volcanoes. The shales that have been found to contain selenium are, for the most part, of the Cretaceous period and produce extensive soil areas. The soils de-

rived from these shales, or other seleniferous material, may retain enough selenium to produce toxic vegetation where the rainfall is too low to allow percolation through the soil. As yet no selenium problem has been found where the rainfall is heavy. The problem appears to be most serious in regions with an annual rainfall of less than 20 inches.

The amount of selenium that a plant may take from a seleniferous soil depends on four things—the amount, distribution, and form of selenium in the soil profile; the kind of plant; the portion of the plant examined; and the composition of the soil, especially its available sulphur content. The few observations made of the distribution of selenium in plants indicate that it is higher in the seeds, blossoms, and leaves; lower in the stems; and least in the roots.

During the past year soils from the erosion experiment stations were studied and examined by newly developed methods for certain elements which occur only in very minute quantities, and which are not ordinarily included in soil analyses. Selenium, arsenic, copper, cobalt, nickel, zinc, barium, chromium, and vanadium were found in determinable quantities in each of the 11 soil profiles examined. The quantities varied from less than 0.1 part per million for selenium, cobalt, and nickel to as much as 708 parts per million for barium.

It is becoming apparent that these and other trace elements play an important role in soil behavior, as well as plant nutrition, and even the food value of agricultural products. There is need for more knowledge concerning the content of the various trace elements in the agricultural soils of the country. Such knowledge is needed in connection with a comprehensive cooperative research project being planned by the Bureau to determine the effects of soil, fertilizers, climate, crop rotation, cultivation, and variety of plants on the constituents of plants and their value for food.

SOIL COLLOID INVESTIGATIONS

In order to gain further insight into the nature of inorganic soil colloids, which are the active components of all soils, new studies were made on the relation between chemical composition and various of the colloids separated from the great soil groups; on the relation between the vapor pressure and combined water content in four typical soil colloids; and on the hydrolysis of the soil-forming minerals, anorthite and orthoclase, under the influence of water and electro-dialysis.

The colloids of the lateritic soil group, which have a low silica-alumina ratio, were found to have much weaker acidic qualities than those of Chernozem soils, which have a high silica-alumina ratio. The titration curves are of such markedly different form that these two groups are readily differentiated by this means. The curves for colloids of true Podzols are widely different for adjacent horizons of a particular profile. Experimental work on the acidity of soil colloids was completed, and the results are set forth in a Technical Bulletin now in press.

Studies of the vapor pressure-water content curves of four typical soil colloids showed that such curves are characteristically different for different soil groups. This makes them useful in soil classification.

Hydrolysis of the calcium feldspar, anorthite, was found to proceed at a rather rapid rate in comparison with other soil minerals. Analysis of the original material and of the products of hydrolysis showed that there is a linear relation between removal of calcium oxide and the acquisition of combined water. X-ray examination showed that the hydrolysis of anorthite results in the formation of a crystalline clay mineral. Hydrolysis of the potash feldspar, orthoclase, was found to be much slower than hydrolysis of the calcium feldspar, anorthite. This is in accord with the observation that orthoclase persists in nature after anorthite has been completely weathered.

The results of studies on the composition and constitution of the colloids of certain of the great groups of soils were published in Technical Bulletin 484, which presents analytical data, including mechanical and chemical analyses of the soils and chemical analyses of the colloids for eight soil profiles representing six of the great groups of soils. The results show that the colloids of the great groups of soils differ from each other, and that there exists a chemical basis for the characteristics manifested in the field. The Chernozems are characterized by high silica-sesquioxide and silica-alumina ratios and by uniformity of colloid composition throughout the profile. The Prairie colloids have distinctly lower silica ratios than the Chernozems but are essentially free from carbonates. The colloid profile is constant in composition. The

Gray-Brown Podzolic colloids are not sharply different in silica ratios from the Prairie colloids but show more variation in profile. The lateritic and Laterite groups have low silica-alumina ratios but very high silica-base ratios. Like the Chernozem group, the lateritic group has a colloid which is remarkably constant for the whole profile. The Podzol soils reflect in colloid composition the extensive fractionation which has taken place within the profiles. The Gray-Brown Podzolic group shows podzolic fractionation to a less degree than the Podzols themselves. The colloids of all the great groups are characterized by an essentially constant water-alumina ratio.

The injurious effect of arsenical insecticides on the productivity of soils was found to vary with the amount of colloid and with its chemical composition. Soil colloids high in iron oxide seemed to have the greatest effect in rendering calcium arsenate nontoxic.

Data obtained in work on dry-land soils indicated that environmental conditions tend to produce a colloid of the pyrophyllitic acid type; that is, approaching the ideal composition of the inorganic complex, $3\text{H}_2\text{O}\cdot\text{Al}_2\text{O}_3\cdot 4\text{SiO}_2$. The most uniform characteristic of the colloids of dry-land soils is the ratio of water-vapor absorption at 99-percent humidity to that at 75-percent humidity, which has a mean value of 2.14.

NONFERTILE SOILS

In studies of nonfertile soils, it was found that barium is present in comparatively large quantities in the soils from the barite areas of Virginia and Tennessee. Considerable quantities of barium are taken up by plants growing on such soils. Barium probably interferes with the absorption of sulphate ions and may have some direct toxicity to plants. Vegetation from podzolic soils was found to be low in calcium and magnesium and abnormally high in manganese and aluminum, and there was evidence that manganese replaced calcium in the mineral composition of the leaves.

SOILS FROM EROSION EXPERIMENT STATIONS

Soils from the erosion experiment stations were studied with regard to the relationships between their physical constants. The data on eight physical constants, including the new constant for minimum water of saturation, indicated that the inorganic colloid and organic-matter content of the soils largely control the values of the constants and that variations in the chemical composition of the soil colloids exert a minor influence, except in the case of the lower plastic limit.

PEAT AND MUCK INVESTIGATIONS

In order to gain information on the chemical structure of peat, a study was made on the behavior of humic acid from peat, of humic acid from soil, and of corn-cob lignin, when subjected to treatment with bromine and water at 110° C. The yield of tetrabromquinone, the product of bromination, was as high as 10.4 percent with corn-cob lignin, whereas that from soil humic acid was as low as 1 percent. Peat humic acid gave intermediate yields. The chemical behavior of the brominated humic acid preparations appeared to vary according to the degree of decomposition of the material from which the preparations were obtained. Comparisons with the behavior of corn-cob lignin indicated, in general, that the humic acid fraction of peat becomes less similar to lignin as decomposition advances. The results of this study have been published.

Studies on certain moisture relationships of soil as affected by admixture of peat indicate that it is not advisable to use peat as a soil amendment for the sole purpose of conserving the supply of available moisture, except possibly in the case of a decomposed type of peat with a sand or a very sandy soil. A paper, entitled "The Comparative Moisture-Absorbing and Moisture-Retaining Capacities of Peat and Soil Mixtures", is now in press.

SERVICE WORK

As a service to the various research projects on the chemistry and physics of soils and to the Soil Survey Division of this Bureau and other governmental agencies, 605 mechanical analyses of soils and 139 complete chemical analyses of soils and soil colloids were made. In addition, a number of miscellaneous chemical determinations and physical tests were made. About 100 mechanical analyses of soils were made for the United States Army. Incidental to the routine work on the chemical analysis and physical examination of soils, two papers have been published which are listed at the end of this report.

SOIL SURVEY

The object of the soil survey is to classify and map the soils of the United States and to describe their characteristics, particularly in reference to the growth of various crops, grasses, and trees. The ultimate purpose of this research is to provide accurate soil maps of the country which are necessary for the classification of rural lands, and for the factual basis in the development of rational programs of land use, consistent with conservation and the welfare of the agricultural people, whether planned by public agencies or individual farmers. The work comprises the determination of the character of soils, definition of soil types, development of a uniform system of soil classification, delineation upon maps of the boundaries of each soil type, and the interpretation of the capabilities of the soils for the production of crops, grasses, and trees under different kinds of management.

During the year about 20,000 square miles of rural lands in 31 States, Puerto Rico, and Hawaii were mapped by the Soil Survey Division. This brings the total area covered by the soil survey to more than one-half of the arable lands of the Nation, and completes the soil survey of Puerto Rico. Essentially all of this work is accomplished in direct cooperation with local agencies, especially the State agricultural experiment stations. In this way both the broader perspective of the Federal organization and the more detailed local knowledge of the State agencies are utilized to the best advantage, each supplementing the other.

The soil maps, together with the accompanying reports giving descriptions of the soils and their uses, provide farmers, research workers, extension leaders, and local officials with a practical working handbook of the land for the area covered. In order that the results of experiments on farm land may be utilized in connection with general land problems it is necessary that information be given regarding the type of soil on which the experiments are made. Once an accurate map of the soil types is made, the results may be extended to individual farm areas having the same soil types. The continued extension in the use of soil maps wherever they are available for determining land-use policies testify to their accuracy and value.

This Bureau is cooperating in soil-survey work with the seven States having an interest in the watershed of the Tennessee River. The agricultural experiment stations of these States are cooperating also with the Tennessee Valley Authority for expediting the completion of a detailed soil survey of that area, which is absolutely essential in developing systems of agriculture for the improvement of the land and the protection of the reservoirs.

Scientists of the Soil Survey Division have given much time to assisting State and Federal agencies in the interpretation of existing soil maps in connection with various programs involving the use and conservation of rural lands.

Information obtained from the survey of areas in Western States has permitted an extension in the acreage of certain special crops, and has indicated the areas where the accumulation of salts and the development of alkali would be a menace to irrigation projects. In many of these western areas, after the soil map is completed, the soil types are classified in accordance with their potentialities for irrigation, in order that serious mistakes may be avoided.

The selection of soils suitable for the extension of fruit crops and other special crops has been greatly expedited by the use of soil maps.

In the last 2 or 3 years scientists of the Soil Survey Division, with the assistance of cooperating scientists in the State experiment stations, have been developing a system for rating the various soil types according to their productivity and adaptation for crops. Such a system involves consideration of the inherent productivity of the soil as well as its productivity under different systems of management. Although this is a very difficult matter, progress has been made with this research and an increasing number of published soil surveys contains tables showing these productivity ratings.

A few years ago a detailed soil survey was initiated in North Dakota at the request of the local people as a basis for the classification of lands for the purpose of appraisal for taxation. This work is being continued, together with cooperative projects along similar lines proposed by other States.

In July 1935, C. F. Marbut's work entitled "The Soils of the United States" was issued as part 3 of the Atlas of American Agriculture. This publication gives the accumulated results of the soil-survey work and brings into a focus the findings regarding soils as gained by Dr. Marbut and his associates during the last 35 years. This publication includes a large map of the United States in 12 sections showing the distribution of the soils of the country according to 137 differentiated and 6 undifferentiated soil groups.

Tables 1 and 2 show the details of the work done by the Soil Survey Division during the fiscal year 1936, the areas covered, and their distribution.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1936*

State or Territory	Area	Area surveyed	
		Sq. miles	Acres
Alabama.....	{ Elmore County.....	1 79	50,560
	{ Lee County.....	104	66,560
	{ Macon County.....	136	87,040
Arizona.....	{ Casa Grande Area.....	1 473	302,720
California.....	{ Santa Cruz Area.....	1 382	244,480
	{ Wasco Area.....	1 790	505,600
Colorado.....	{ Washington County.....	263	168,320
Georgia.....	{ Dade County.....	186	119,040
	{ Hall County.....	1 79	50,560
Hawaiian Islands.....	{ Hawaiian Islands.....	699	447,360
Idaho.....	{ Bingham County.....	1 191	122,240
	{ Bartholomew County.....	401	256,640
Indiana.....	{ Brown County.....	52	33,280
	{ Allamakee County.....	43	27,520
	{ Cerro Gordo County.....	1 402	257,280
	{ Decatur County.....	1 102	65,280
Iowa.....	{ Jackson County.....	1 291	186,240
	{ Story County.....	1 198	126,720
	{ Allen County.....	1 68	43,520
	{ Calloway County.....	242	154,880
Kentucky.....	{ Clinton County.....	1 88	56,320
	{ Mason County.....	1 221	141,440
Minnesota.....	{ Pine County.....	1 286	183,040
Mississippi.....	{ Tishomingo County.....	203	129,920
	{ Cass County.....	236	151,040
Nebraska.....	{ Cherry County.....	39	24,960
	{ Frontier County.....	1 599	383,360
	{ Lancaster County.....	1 102	65,280
	{ Sarpy County.....	240	153,600
New Hampshire.....	{ Grafton County.....	1 551	992,640
	{ Sullivan County.....	250	160,000
New York.....	{ Albany-Schenectady Counties.....	1 178	113,920
	{ Cattaraugus County.....	1 963	616,320
	{ Niagara County.....	1 110	70,400
North Carolina.....	{ Clay County.....	1 179	114,560
	{ Henderson County.....	481	307,840
	{ Madison County.....	247	158,080
North Dakota.....	{ Morton County.....	1 720	460,800
Ohio.....	{ Tuscarawas County.....	1 137	87,080
	{ Choctaw County.....	1 108	69,120
	{ Creek County.....	132	84,480
	{ Garfield County.....	1 243	155,520
Oklahoma.....	{ Major County.....	1 331	211,840
	{ Pontotoc County.....	1 240	153,600
	{ Tulsa County.....	1 59	37,760
Oregon.....	{ Umatilla County.....	1 170	108,800
Pennsylvania.....	{ Bucks County.....	1 214	136,960
Puerto Rico.....	{ Island.....	1 999	639,360
Rhode Island.....	{ Newport-Bristol Counties.....	106	67,840
South Carolina.....	{ Charleston County.....	158	101,120
	{ Pickens County.....	1 91	58,240
	{ Hamilton County.....	280	179,200
Tennessee.....	{ Humphreys County.....	344	220,160
	{ Jefferson County.....	1 50	32,000
	{ Lincoln County.....	296	189,440
	{ Roane County.....	257	164,480
Texas.....	{ Brown County.....	1 97	62,080
	{ Fannin County.....	1 101	64,640
	{ Kaufman County.....	1 468	299,520
	{ Maverick County.....	1 770	492,800
Utah.....	{ Virgin River Valley Area.....	1 32	20,480
	{ Salt Lake Valley Area.....	1 149	95,360
	{ Albermarle County.....	1 138	88,320
Virginia.....	{ Isle of Wight County.....	1 73	46,720
	{ Mecklenburg County.....	1 79	50,560
	{ Russell County.....	89	56,960
Washington.....	{ Washington County.....	1 293	187,520
	{ Kittitas County.....	1 210	134,400
West Virginia.....	{ Yakima County.....	1 83	53,120
Wyoming.....	{ Greenbrier County.....	221	141,440
	{ Campbell County.....	255	163,200
Total.....		19,147	12,254,080

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, 1936, and the areas previously reported

DETAILED

State or Territory	Work dur- ing 1936	Work pre- viously reported	Total	
	Sq. miles	Sq. miles	Sq. miles	Acres
Alabama.....	319	59,517	59,836	38,295,040
Arizona.....	473	4,482	4,955	3,171,200
Arkansas.....		15,547	15,547	9,950,080
California.....	1,172	37,390	38,562	24,679,680
Colorado.....	263	5,865	6,128	3,921,920
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.....	265	36,187	36,452	23,329,280
Hawaii.....	699		699	447,360
Idaho.....	191	12,525	12,716	8,138,240
Illinois.....		6,770	6,770	4,332,800
Indiana.....	453	21,192	21,645	13,852,800
Iowa.....	1,036	50,409	51,445	32,924,800
Kansas.....	68	16,786	16,854	10,786,560
Kentucky.....	242	5,542	5,784	3,701,760
Louisiana.....		17,431	17,431	11,155,840
Maine.....		2,197	2,197	1,406,080
Maryland.....		13,959	13,959	8,933,760
Massachusetts.....		8,811	8,811	5,639,040
Michigan.....	309	32,384	32,693	20,923,520
Minnesota.....	286	12,581	12,867	8,234,880
Mississippi.....	203	30,740	30,943	19,803,520
Missouri.....		37,177	37,177	23,793,280
Montana.....		3,287	3,287	2,103,680
Nebraska.....	1,216	67,892	69,108	44,229,120
Nevada.....		652	652	417,280
New Hampshire.....	1,801	1,589	3,390	2,169,600
New Jersey.....		9,895	9,895	6,332,800
New Mexico.....		2,565	2,565	1,641,600
New York.....	1,251	36,284	37,535	24,022,400
North Carolina.....	907	48,100	49,007	31,364,480
North Dakota.....	720	21,803	22,523	14,414,720
Ohio.....	137	18,513	18,650	11,936,000
Oklahoma.....	1,113	24,170	25,283	16,181,120
Oregon.....	170	15,821	15,991	10,234,240
Pennsylvania.....	214	22,475	22,689	14,520,960
Puerto Rico.....	999	2,766	3,765	2,409,600
Rhode Island.....	106	1,584	1,690	1,081,600
South Carolina.....	249	26,833	27,082	17,332,480
South Dakota.....		8,286	8,286	5,303,040
Tennessee.....	1,227	11,460	12,687	8,119,680
Texas.....	1,436	65,294	66,730	42,707,200
Utah.....	181	2,915	3,096	1,981,440
Vermont.....		1,175	1,175	752,000
Virginia.....	672	14,826	15,498	9,918,720
Washington.....	293	12,095	12,388	7,928,320
West Virginia.....	221	23,683	23,904	15,298,560
Wisconsin.....		26,659	26,659	17,061,760
Wyoming.....	255	12,327	12,582	8,052,480
Total.....	19,147	929,581	948,728	607,185,920

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.....	675	11,636	12,311	7,879,040
Montana.....	160	51,783	51,943	33,243,520
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
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.....		9,124	9,124	5,839,360
Washington.....		16,540	16,540	10,585,600
Wisconsin.....		14,425	14,425	9,232,000
Total.....	835	636,224	637,059	407,717,760

SPECIAL WORK OF THE SOIL SURVEY

For the successful prosecution of many of the activities of the Federal Government and cooperating State agencies it has been necessary for soil-survey scientists to interpret the available soil data in terms of the particular objective at hand. As the soil-survey data are fundamental and basic for almost all kinds of agricultural activities, thousands of private individuals and organizations, as well as public agencies, seek the advice and assistance of soil scientists of the Bureau as to the location of soil types adaptable to various crops and how the various soil types may be managed. Requests of this kind have greatly increased in the last few years. Typical of these special services the following may be mentioned:

SHELTERBELTS

Soil scientists from this Bureau have worked in cooperation with the Forest Service in determining the classification of soils according to their capabilities for growing various species of trees. Results of this research have been published by the Forest Service as a part of a comprehensive report on the possibility of shelterbelt planting in the Great Plains.

SOIL EROSION

For many years scientists in the Soil Survey Division have called attention to the serious injury, through erosion, to soils when they are improperly used. The fundamental nature of the soil type determines its erodibility under different methods of management. The soil maps serve as a basis for erosion surveys and erosion-control projects. In many cases where these maps have been unavailable, soil scientists of this Bureau have assisted in making special studies and maps for the use of Federal and State agencies charged with the responsibilities for erosion control. Scientists of the Bureau are assisting the Tennessee Valley Authority, Soil Conservation Service, and other agencies toward this end.

FARM CREDIT

Land appraisers of the Farm Credit Administration have made wide use of the soil-survey maps and reports. They have been assisted by several scientists of the Soil Survey Division's staff in conducting schools for land appraisers in order that they may recognize the individual soil types and understand their capabilities for agricultural use. Scientists from this Bureau have assisted several other agencies, such as the War Department and the Puerto Rican Reconstruction Administration, in developing accurate systems for appraisal of rural lands.

IRRIGATION STUDIES

In addition to the attention given to the possibilities of land for irrigation in connection with the regular soil-survey projects, special reports have been prepared in regard to the suitability of land for irrigation in areas under the jurisdiction of the Indian Service and other governmental agencies.

PEAT LANDS

Work has been continued in the investigation of peat lands in cooperation with other Federal and State agencies, particularly from the point of view of relationship of such soils to the conservation of land and prevention of floods. A special report describing the characteristics and distribution of various kinds of organic soils and peat in the Pacific Coast States is in press.

SELENIUM

The Soil Survey Division has continued to assist in the selenium investigations being carried on by the Bureau. Examinations of soils and vegetation in several States, where excess selenium in the soil is an important factor in their utilization, are still in progress. The results of these researches have been incorporated in reports published by the Bureau.

SOIL SURVEYS OF PUERTO RICO AND HAWAII

Under an allotment of funds from the sugar-processing tax, the soil survey of Puerto Rico has been carried through to completion, and about one-half of the field work required for the soil survey of Hawaii has been finished. It is now

planned that the Hawaii soil survey will be completed during the next calendar year. Detailed soil maps are necessary as a basis for planning agricultural adjustments and developments in these areas.

INFORMATION AND PUBLICATIONS

During the fiscal year, Department publications from this Bureau were 32 soil-survey reports, 5 technical bulletins, 2 circulars, 3 miscellaneous publications, 9 articles in the Journal of Agricultural Research, and 180 articles in outside publications. In cooperation with the Press and Radio Services, the Bureau furnished information on various phases of its research.

The following list shows the publications from the nine research divisions of this Bureau.

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SOIL SURVEYS

- Alabama*
- Perry County.
- Arizona*
- Tucson area.
- Colorado*
- Brighton area.
Longmont area.

Indiana

Ohio and Switzerland Counties.

Iowa

Monroe County.

Kansas

Bourbon County.
Marion County.
Neosho County.
Woodson County.

Louisiana

Livingston Parish.

Michigan

Luce County.
Montmorency County.
Oscoda County.

Minnesota

Hubbard County.

Mississippi

Greene County.

Montana

Gallatin Valley area.

Nebraska

Valley County.

New Mexico

Lovington area.

New York

Chemung County.

North Carolina

Franklin County.

Oklahoma

Craig County.
Grant County.
Kiowa County.
Le Flore County.
Texas County.

South Carolina

Dillon County.

Texas

Polk County.
Randall County.
Scurry County.

Virginia

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Wisconsin

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