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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF CHEMISTRY.

EXHIBIT

OF THE

BUREAU OF CHEMISTRY

AT THE

PAN-AMERICAN EXPOSITION,

BUFFALO, NEW YORK, 1901.

PREPARED UNDER THE DIRECTION OF

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CHIEF OF BUREAU,

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., July 1, 1901.

SIR: I have the honor to transmit to you herewith the manuscript of a description of the exhibit of the Bureau of Chemistry at the Pan-American Exposition, Buffalo, N. Y., 1901, with the request that it be published as Bulletin No. 63 of the Bureau of Chemistry.

H. W. WILEY, *Chemist.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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EXHIBIT OF THE BUREAU OF CHEMISTRY AT THE PAN-AMERICAN EXPOSITION, BUFFALO, NEW YORK, 1901.

INTRODUCTION.

The exhibit of the Bureau of Chemistry will be found in the central part of the north wing of the Government building. It has been so planned as to illustrate three of the important features of the work of the Bureau, namely, the study of pure and adulterated foods, the beet-sugar industry, and the testing of road-making materials. It was impracticable to include in the exhibit a number of lines of investigation which are now in process or which have been completed during recent years. The results of many of these have been published, and are shown in a collection of publications which forms a prominent feature of the exhibit. These will be found on the table marked "1." (See Pl. I, frontispiece.) Since 1883, 62 bulletins and 7 small pamphlets, designated as circulars, have been issued, containing in all 7,989 pages. Numerous contributions have been made by members of the Bureau to the Yearbook of the Department of Agriculture. The reports of sugar-beet investigations since 1897 have been published as a part of the special report to Congress on this subject. The results of the food investigations hitherto published are contained in the nine parts of Bulletin 13 (1,374 pages). In addition to the work reported in the regular publications of the Bureau, a considerable amount of research work has been done which has been reported from time to time in various scientific periodicals.

Much of the time of the working force of the Bureau is required for cooperative work carried on with or at the request of other branches of the Department of Agriculture and the other Executive Departments of the Government.

EXHIBIT OF PURE AND ADULTERATED FOODS.

By W. D. Bigelow.

In this exhibit it is desired to illustrate principles and not to call attention to individual frauds. Interest would have been added had it seemed best to display all the samples under their original labels. It is apparent, however, that such a policy would have been unjust to all manufacturers of pure foods whose goods were not exhibited, and would have discriminated against adulterated foods exhibited in favor of those omitted. It seemed essential, therefore, to transfer all samples to uniform glass bottles, and thus avoid discrimination with its consequent injustice. On approaching the exhibit its most conspicuous feature is the series of silk fabrics, dyed with the aniline coloring matter contained in a large assortment of foods and food adjuncts. The method by which these fabrics were dyed precludes the possibility of the presence of any vegetable coloring matter. The color of the fabric is due in every case to aniline color added to the food as an adulterant.

CASE 2.[1]

The top shelf contains samples of substances which are used to adulterate alcoholic liquors and vinegar. The three samples of vinegar flavor, though given different names, are identical in composition. It is intended that this article shall be added to dilute acetic acid, which is then artificially colored and the product sold as cider vinegar or wine vinegar. Although the mixture thus formed does not closely resemble pure vinegar, it is sold in large quantities in localities where food laws are not enforced.

It is well known that alcoholic liquors soften with age, and various devices are employed to give new liquors the flavor of old. Among other methods may be mentioned the addition of various chemicals, of which the aging oil on this shelf is an illustration.

The alcoholic liquors on the market are sometimes artificially prepared by flavoring and coloring diluted alcohol. The peach-brandy essence shown on the same shelf is sold for the manufacture of peach brandy. It is directed to mix together 40 gallons of proof spirit, one-half pound of this essence, 1 quart of sugar sirup, and a sufficient amount of coloring matter advertised by this same firm to give the desired color.

The bead oil which is exhibited on the same shelf is a solution of soap which is sometimes added to distilled liquors to produce a "bead," and thus give the article the appearance of age.

Hop extract, a sample of which is shown, is often obtained by extracting inferior hops, and the exhausted residue is then sometimes placed on the market as untreated hops.

Flavoring extracts and soda-water sirups.—The second and third shelves of this case are devoted to an exhibit of flavoring extracts, soda-water sirups, etc. The labels are, for the most part, a sufficient explanation of the samples on these shelves, but especial attention may be called to the practice of substituting tonka beans for vanilla beans in the preparation of this extract. The use of artificial flavoring material or mixtures of cheaper substances in place of vanilla is also commonly practiced. Certainly the most reprehensible practice in

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[1] See Pl. I, frontispiece.

connection with the manufacture of flavoring extracts is the use of methyl alcohol, or wood spirits, as a solvent in place of ordinary alcohol. Cases of death resulting from the use of lemon extract containing wood spirits are of common occurrence, and although such results follow the use of extracts as a beverage instead of the use for which they are intended, it is still true that an article of such toxic properties should never be added to food or food adjuncts. In this connection it should be stated that the poisonous properties of wood spirits are not due solely to the methyl alcohol they contain, but to impurities that always occur in the commercial article.

Sweetening materials and saccharine foods.—On the fourth shelf of this case are exhibited samples illustrating the most prevalent forms of adulteration used in connection with sugar and sweetening materials. One sample each of granulated sugar and "A" sugar is shown. These substances are rarely adulterated. The prevalent notions of admixture of sand and clay are entirely without foundation.

Adulterations do occur in some cases, however, and the sugars adulterated with glucose and saccharin exhibited on this shelf are now sold to a limited extent in various parts of the country.

Saccharin is placed on the market in several degrees of purity, the highest of which is about five hundred times as sweet as sugar. It is an artificial preparation manufactured from coal tar and possessing an intensely sweet taste. Saccharin passes through the body unchanged. It is therefore of value for sweetening foods for patients who are not allowed to receive sugar, but it has no food value whatever.

Five samples of glucose and grape sugar, illustrating the principal grades on the market, are shown on the same shelf. The liquid or sirupy preparations are commercially known as glucose, while those that are prepared in the solid state, though obtained from the same source, are known as grape sugar or glucose sugar. This product is used extensively with all varieties of sweetened foods.

A large percentage of the various table sirups on the market and many strained honeys are sweetened partly or entirely with glucose. Several samples of these articles containing glucose are exhibited on the same shelf.

Glucose is used in the manufacture of jellies, jams, and marmalades. The claim is commonly made that its use in such products is due not so much to its cheapness as to the fact that preparations containing it have less tendency to crystallize or "candy" than those prepared entirely with cane sugar.

Cacao and cacao preparations.—On the fifth shelf of this case two cacao or cocoa pods are exhibited, from one of which a segment has been removed, showing the cacao seed or cocoa bean in place. Five samples of these seeds grown in different localities are also exhibited.

Chocolate is prepared by grinding the shelled cacao seed or cocoa bean, mixing the ground product to a pulp, and molding. It may be either sweetened or unsweetened. The same product is used in the preparation of cacao, or cocoa, as it is commonly called, after the extraction of a portion of the fat. Both cacao and chocolate are largely adulterated, cacao shells, wheat flour, sago flour, and other materials of like nature being used for this purpose. Two samples of adulterated cacao are shown on this shelf.

Coffee.—A large part of the space on shelves 5 and 6 is occupied by samples of coffee and coffee substitutes. A number of samples of standard varieties of coffee are shown, both in the green and roasted condition. A striking similarity will be noticed in many cases between high-priced and low-priced samples of green coffee, while with roasted coffees this similarity is so great that even experts are frequently unable to distinguish them by their physical appearance. As illustrations of this may be noted the Java Peaberry, which sold at wholesale at the time this exhibit was collected at 20 cents a pound, and the Mexican and Santos Peaberry, which were sold at 13½ and 12 cents, respectively.

Again, the Bourbon Santos, which is grown in the province of Santos, Brazil, from the seed of the Arabian Mocha, closely resembles, as might be expected, the Arabian Mocha coffee. Its flavor is very different, however, and it commands a lower price in the market. These illustrations are sufficient to illustrate the principle involved, though they might be multiplied at will.

A large part of the alleged high-grade coffee sold by the trade belongs certainly to a much cheaper class of coffee than that for which it is sold. At the same time good coffee can always be obtained from reliable grocers.

On shelf 6 of this case a large number of roasted coffees are shown which illustrate even more strongly than green coffees the similarity of the high and low grades. Several mixtures of cereals, pea hulls, etc., which are sold as coffee, are also exhibited on this shelf, as well as one sample of artificial coffee beans which is composed entirely of flour.

Flour.—Owing to the firm attitude taken by American millers, the adulteration of staple brands of flour is practically unknown; still the samples of flour exhibited on shelf 6 are of considerable interest. The milling industry was seriously threatened several years ago by the extensive adulteration of wheat flour with a finely ground indian corn preparation which was sold as "flourine." The influence of this fraud in the price of flour was so disastrous that an organized fight was inaugurated by the millers and resulted in the passage of a revenue act which taxed and required the proper branding of mixtures of this nature. The result of this law was most wholesome, and the practice of adulterating wheat flour with indian corn products was quickly and effectually checked.

The ground soapstone, of which a sample is exhibited on this shelf, was quite extensively advertised as a flour adulterant, but appears to have found but little or no sale for that purpose. It is interesting to note that the originator of this swindle is now serving a prison sentence for fraudulent use of the United States mails. One form of flour adulteration which is still extensively practised is the substitution of ordinary flour for gluten flour. It is unfortunate, but this substitution is commonly practiced. If gluten flour is of value in the diet of invalids, it is highly important that a patient should be able to obtain the article prescribed by his physician.

CASE 3.[1]

Spices.—Spices probably afford a more fruitful field for adulteration than any other class of foods or food adjuncts. Some of the leading spice grinders make a practice of furnishing spices at almost any price that is desired, and the amount of foreign matter, which ordinarily consists of such materials as ground cereals, cocoanut shells, olive stones, sandal wood, mustard hulls, clove stems, linseed meal, and similar substances, is regulated according to the price of the goods sold. At the same time there are many grinders who practice no form of adulteration, and who do not handle any substance whatever, for the sophistication of their wares. It is unfortunately true, however, that a large percentage of the ground spices on the market is adulterated. Mixtures are even sold which are prepared for the express purpose of adulterating spices. Their color and physical appearance are practically identical with the spices they are intended to replace, but they contain no spicy flavor whatever. A full set of these fillers (marked "P. D.") is exhibited on the first and second shelves of this case.

The adulteration of spices, however, is not confined to the ground article. Unground pepper often receives an addition of stems, sticks, and pepper shells, which are removed in a preparation of white pepper. Cloves are often mixed with broken clove stems and pimento. Several varieties of spices are sometimes distilled with steam for the preparation of volatile oil, and the exhausted residue sold as pure spices. Examples of these various forms of adulteration are shown on the first three shelves of this case.

Even in pure, unground spices there is a great difference in grade and consequently in price. It is manifestly impossible to form a correct estimate of the wares of two grocers by comparing the prices for which they sell.

Food preservatives.—Among the most objectionable forms of food adulteration may be mentioned the use of chemical food preservatives. The compounds usually used for this purpose are salicylic, benzoic, and boric acids, and their sodium compounds, formaldehyde

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[1] See Pl. I, frontispiece.

and sulphites. Several others, such as ammonium fluorid, pyroligneous acid, beta naphthol, and abrastol, are used to a limited extent. These substances may be divided into two classes, those which are undoubtedly injurious, such as formaldehyde, salicylic acid, and sulphites, and those whose toxic action is disputed, like borax and benzoic acid. The addition to foods of substances belonging to the first class should be prohibited. The others should be used only with food that is so marked as to inform the purchaser of their presence. Alleged new discoveries, which are claimed to be entirely wholesome, are now extensively sold for the preservation of food. Without exception, these products consist of chemicals (often mixtures of two or more) which are well known to the scientific world, and many of which are familiar to the general public. A number of commercial preservatives, and of the chemical substances of which they are composed, are exhibited on the fourth shelf of this case.

It is claimed by those interested in their use that the amount of preservatives added to foods is so small as to be unimportant. It is certainly true, however, that the amount added sometimes greatly exceeds that which is believed to be necessary by those who favor the use of chemical preservatives. On shelf 3 of the fourth case are exhibited a series of samples of preservative chemicals which were actually recovered from foods.

Canned vegetables.—Among the most important abuses which are practiced in the preparation of canned vegetables is the use of an excessive amount of water, and of mature vegetables which are soaked before canning and placed on the market as green vegetables. Many States require that cans containing soaked goods shall have the word "soaked" printed in conspicuous type on the label. The tendency of some firms to evade pure-food legislation was illustrated on the original labels of some of the samples exhibited on the shelves 4 and 5 of this case. These labels attempted to comply with the letter of the law above mentioned by publishing the following sentence: "These goods are carefully prepared from selected stock and soaked in artesian well water." The practice of preserving in leguminous vegetables a bright green color by the use of copper sulphate (blue vitriol) is illustrated by samples on the same shelves. In this connection it may be stated that some State laws require that vegetables containing copper salts shall be labeled with, or bear a paster stating, the amount of copper in each can.

Baking powder and baking powder chemicals.—Several illustrations of the frauds in this class of food adjuncts are given on the fifth shelf of this case. Whatever standards may be adopted for baking powders, the sale of an article whose composition is markedly different from that represented by the label must always be regarded as fraudulent. Insoluble matter, such as gypsum and talc, should not enter into the composition of substances of this nature.

Salad oils.—Olive, peanut, sunflower, and cotton-seed oils are all used extensively under their own names as foods, and no less than 15 oils are used as salad oil or to adulterate olive oil. The sale of a cheaper for a more expensive oil must be regarded as fraudulent

CASE 4.

One of the important questions in connection with the preparation of foods is the extent to which foreign coloring matters may be legitimately employed. In most European countries it is forbidden to color artificially any substance which has a distinct color of its own; for instance, wine and fruit products must be sold without the addition of any foreign coloring matter. At the same time all countries permit the addition of some harmless colors, often specified by name, to foods and especially confections which are themselves colorless, but are ordinarily artificially colored. In some cases colors whose use with foods is permitted are not only specified by name, but the method by which such colors may be manufactured is given. This is done to exclude the use of coloring matters in whose preparation poisonous substances, such as arsenic, are employed. The fact that some of our common articles of food are often artificially colored at the present time is shown by the dyed fabrics displayed in the top of the three cases.

Heavy metals.—The use of tin cans as hermetically sealed receptacles for food has been of incalculable benefit in cheapening almost every article of food and prolonging the season of consumption for those which otherwise could be had only a comparatively short time. At the same time it must not be forgotten that an appreciable amount of heavy metals is often dissolved by the more acid varieties of food. The amount that is so dissolved depends on the age of the sample, the grade of tin plate employed, and the method by which the can was manufactured. Tin plate containing a large amount of lead is much more readily attacked than plate which is nearly free from lead. The plate which is manufactured by the oil process is more resistant to acids than that made by the acid process. Cans in whose manufacture zinc chlorid is used, often retain that salt between the seams, to be given up to the contents of the can. It is fortunate that the method of soldering with oil and resin is now usually employed.

Fruit products.—On the fourth shelf of this case is given an interesting collection of jelly and jam samples. The forms of adulteration to which this class of foods is subject are well indicated on the labels. This exhibit includes pure fruit preparations and products thickened with starch, sweetened with glucose and saccharin, preserved with salicylic acid, benzoic acid, etc., and artificially colored. A favorite practice is the preparation of jam from the refuse pulp of jelly manufacture. A sample of raspberry seeds found in "currant jam" is shown on the shelf above. The prices paid for these samples are worthy of note. In this class of goods, as in others, adulteration is caused largely by the demand for cheap articles. A purchaser who pays no more for jelly than the glass which holds it and the sugar it is supposed to contain are worth should not expect a first-class article.

Little comment is necessary on the canned goods shown on shelf 5 of this case. The differences in value which attend the use of different sirups are not apparent to the eye. Even the quality of fruit employed can not always be determined by appearance alone. The branding of one variety with the name of another and labeling the goods of one locality as coming from another are always reprehensible. In this connection the recent court decisions forbidding certain Baltimore canners to label their goods as California products are of interest.

BEET-SUGAR INDUSTRY.

By E. E. Ewell.

The Department of Agriculture, through the Division of Chemistry, which July 1 was raised to the rank of a bureau, has been endeavoring to develop our domestic sugar industry for more than two decades. During the last ten years its efforts have been devoted principally to the development of the beet-sugar industry. Since 1897 this industry has grown rapidly and may now be considered to be on a permanent footing, as approximately $25,000,000 are invested in the manufacture of beet sugar in this country. This does not include the large amount of capital invested in the growing of sugar beets.

The development and present condition of the industry in the United States is shown by a collection of statistical tables and photographs (pls. 1 to 40, referred to below), mounted in "wing frames" and designated as No. 5 on the diagram. (See frontispiece.) An effort was made in preparing the collection of photographs to illustrate as fully as possible all phases of the sugar industry from the production of the seed from which the beets are grown to the marketing of the sugar.

The modern sugar beet of high sugar content has been developed and its present high quality has been maintained by careful selection of the mother beets, from which seed is produced. At the beginning of the century the sugar beet contained only 5 to 6 per cent of sugar. The beets delivered to American factories in 1899 contained an average of 14.5 per cent of sugar, while the average of those grown in California was 15.9. Many single beets have been produced which contained more than 20 per cent of sugar, and the product of some entire fields has been found to contain nearly that amount. Until recently the seeds used for sugar-beet growing in the United States have been imported from the seed farms of Europe. The production of high-grade beet seed has now commenced in this country, and a sample of seeds grown by the Utah Sugar Company, of Lehi, Utah, is exhibited in the case No. 6. (See Pl. I, frontispiece.) The production of sugar-beet seed has also been undertaken by the Spreckels Sugar Company, Spreckels, Cal., the Peninsular Sugar Refining Company, at Caro, Mich., and perhaps elsewhere.

Plates 5 to 13 of the exhibit illustrate the appearance of typical sugar beets and the methods used in this country for their cultivation, including the preparation of the land, the sowing of the seed, and other field operations, as well as the harvesting and delivering of the beets to the factory. Some sugar beets of great richness are shown in case No. 7. (See Pl. I, frontispiece.) They were taken from a lot of beets containing over 18 per cent of sugar.

GROWING AND MARKETING SUGAR BEETS.

In case No. 7 (see Pl. I, frontispiece) a map is exhibited which shows the areas in the United States probably suited to sugar-beet culture. This map was published with the reports of experiments with sugar beets made by the Division of Chemistry of the United States Department of Agriculture in 1897. Since that time twenty additional factories have been built and operated; eight more are in process of construction for the crop of 1901. All of these factories are located in or adjacent to the areas indicated on the map as probably suited to sugar-beet culture because of their favorable mean summer temperature. Subsequent experiments do not suggest, in general, that any material changes should be made in the areas indicated on this map as probably suited to sugar-beet culture. The Bureau of Chemistry is indebted to the Weather Bureau for valuable cooperation in the preparation of this map.

Unless the factory provides ample facilities for quickly weighing and unloading a large number of wagonloads of beets, the expense of delivering sugar beets to the factory is materially increased. Some of the methods employed for transferring sugar beets from wagons to cars or from wagons to the storage bins of the factory are shown on pls. 15 and 16 of the exhibit. The net method or some form of the tilting platform are very much used in various parts of the country. The net method is now very generally used on the Pacific coast. The net is placed in the bottom of the wagon and the beets loaded on top of it. When the wagon arrives at the factory or other unloading point, a rope is attached to the net, and by means of a horse or other power the beets are quickly transferred to the car or storage bin.

SUBSTANTIAL CONSTRUCTION OF AMERICAN FACTORIES.

The confidence of investors in the continued success of the industry is shown by the substantial character of the buildings which have been erected for the housing of the machinery used for the manufacture of beet sugar in this country. Pls. 17 to 20 of the exhibit give an excellent idea of some of the typical forms of construction which have been adopted for this purpose.

STORAGE OF THE BEETS.

The factory must provide storage for many thousand tons of sugar beets. The device generally used is a shed or open bin with a trough-shaped floor along the bottom of which there extends a canal made of metal or masonry, which reaches from the storage place to the factory. This canal or sluiceway is covered with boards before the bins are filled with beets. When it is desired to transfer the beets from a given shed to the factory, these boards are pulled up one at a time and the beets allowed to fall into the canal, where they are caught up by a constantly flowing current of water and carried into the factory.

WASHING, WEIGHING, AND SLICING THE BEETS.

A large part of the adhering soil is removed during the hydraulic transportation of the beets, but in order to make the washing operation perfect the beets are passed through a special washing machine on their way to the slicing apparatus. In the modern factory the washed beets are weighed by an automatic scale, from which the superintendent or factory proprietor can learn at any moment the quantity of beets entering the factory during a given period, and compare it with the yield of sugar obtained and the richness of the beets as shown by the chemist's report. After the beets have been weighed they fall into the slicer, where they are cut into small slices having a V-shaped cross section by means of corrugated knives radially placed on a revolving disk. The storage sheds and the washing, weighing, and slicing machines are shown on pls. 21 and 22 of the exhibit.

EXTRACTION OF THE SUGAR FROM THE BEETS.

The extraction of the sugar from the sugar beet by means of pressure has given place to the more advantageous and more modern "diffusion process." This operation is conducted in a series of from 12 to 14 closed metal tanks connected by an elaborate system of pipes and valves, known in the sugar factory as the "diffusion battery." Each tank or "cell" in the battery holds one or more tons of beets, according to the capacity of the factory. The operation of the "battery" is as follows:

A cell is filled with slices of beets and the top door closed. Hot water is then admitted at the bottom until all of the space not occupied by the slices is filled with water. While the water is flowing into the first cell a second cell is being filled with beet slices, and as soon as this second cell is filled the conveyor which brings the slices to the "battery" is adjusted to deliver them into a third cell, and so on, the current of slices being diverted to an empty cell as soon as one is filled. When the first cell is filled with liquid it is allowed to flow into cell No. 2, and through it into cells Nos. 3, 4, etc., as fast as they are filled with beets, and closed. The liquid flows from cell to cell through the system of piping referred to above, the current of water continuously entering cell No. 1. This is continued until all but two of the cells of the battery are filled. The manipulation is then varied by drawing liquid from the cell last filled with slices and liquid, into a measuring tank before the current of liquid is turned into the next cell of fresh slices. This portion of hot water has passed through ten or twelve portions of fresh beet slices, has approximately eight-tenths the density of the juice originally contained in the beets, and is called "diffusion juice." The sugar is extracted from the beets partially by a process of displacement of the juice by hot water, but largely by the process of diffusion, the sugar diffusing from the slices into the liquid which surrounds them. The beet slices contained in the cell which was first filled have now been washed with ten or twelve successive portions of water, and contain less than one-half of 1 per cent of sugar. This cell is therefore emptied in order to make room for more fresh slices. The process is continuous. Each time a cell is filled with fresh beet slices and juice, and a portion of diffusion juice drawn off, the cell at the opposite end of the line contains exhausted slices and is emptied.

The cells of a "diffusion battery" are sometimes arranged in a straight line and sometimes in a circle. The appearance and construction of different forms of batteries are shown on pls. 23 to 26 of the exhibit.

PURIFICATION OF THE JUICE.

The "diffusion juice" is submitted to an elaborate process of purification before it is in a condition suitable for evaporation for the recovery of the sugar contained in it. Lime and carbon dioxide (carbonic-acid gas) are the agents principally employed for this purpose. They are both obtained from a lime kiln, which is kept continuously in operation (pl. 27 of the exhibit). The kiln is charged with coke and limestone at the top and the burnt lime is withdrawn at the bottom. Carbon dioxide is formed in large quantities in the kiln, both by the combustion of the coke and by the decomposition of the limestone. It is withdrawn at the top of the kiln by means of pumps, and forced through the juice contained in the "carbonatation tanks" (see pls. 27 and 29 of the exhibit). The process of purification includes five filtrations and two successive treatments with lime and carbon dioxide. The juice coming from the battery is passed through coarse filters for the purpose of removing small fragments of beet pulp. It is then treated with a large excess of lime (2 to 3 per cent of the weight of the beets worked), and carbon dioxide is then forced through the hot juice until the lime which has not already been rendered insoluble by combination with organic acids and other impurities in the juice is precipitated as carbonate of lime. The "carbonated" juice is very turbid, and is pumped through filter presses (pls. 27–29 of the exhibit), which remove the insoluble matter suspended in it. This insoluble matter consists of carbonate of lime, lime compounds formed with the impurities contained in the juice, proteid bodies rendered insoluble by the heat, etc. The clear juice is again treated with lime and carbon dioxide, and again filtered. The clear juice coming from the second "carbonatation" is then bleached with sulphurous acid, applied in the form of the fumes of burning sulphur. The bleached juice, after being again filtered, is ready for the evaporator.

EVAPORATION OF THE JUICE TO SIRUP.

The juice, after having been purified by the method described, is evaporated to a sirup containing about 50 per cent of water and 50 per cent of solid matter. The solid matter is made up of 40 to 45 per cent of sugar and 5 to 10 per cent of organic and inorganic substances other than sugar, which, to a greater or less extent, prevent the crystallization of the sugar.

In the modern sugar factories the juice is evaporated in multiple-effect vacuum evaporators heated by steam. These evaporators consist of from two to four closed evaporating pans which are heated by steam which circulates through copper pipes arranged in the lower part of the first pan. They are called "multiple effect" because more than one effect of a given portion of steam is obtained. For example, exhausted steam from the pumps and engines or steam drawn directly from the boilers is used to heat the first pan. The steam generated by the boiling juice in this pan is collected, and used to heat the second pan. The vapor of the second pan is in turn used to heat the third pan. In the case of a quadruple-effect evaporator the vapor in the third pan is used to heat a fourth pan. The vapor from the last pan is conveyed to a condensing apparatus in which it meets a spray of cold water, which condenses the vapor to form water.

Air leaking into the apparatus and noncondensible vapor are removed from the condenser by means of a vacuum pump, which is kept constantly in action. The juice in the first pan boils at approximately the atmospheric pressure. The pressure in the following pans is successively reduced from pan to pan, the liquid in the last pan boiling in as nearly a complete vacuum as is practicable. Evaporators of this type are called "double," "triple," or "quadruple effects" accordingly as there are two, three, or four pans. The operation of the evaporators is continuous. The juice is pumped into the first pan while the finished sirup is pumped out of the last pan in a continuous stream. The collection of photographs already referred to contains sectional and exterior views of two types of evaporators (pls. 30 and 31).

It is the practice in most modern factories to filter the sirup after it comes from the evaporator, as more or less insoluble matter separates from the juice during the process of evaporation.

GRANULATION OF THE SIRUP.

The filtered sirup is granulated in a vacuum apparatus which the sugar maker calls a "strike-pan." The appearance of the granulating pan is shown on pl. 32 of the exhibit.

The operation of the vacuum pan is one of several processes conducted in the beet-sugar factory that requires a great amount of skill. The pan is heated by several tiers of copper coils so connected that steam can be admitted to any one of them at the will of the operator. Sirup is drawn into the pan and concentrated until the pan is from one-fourth to one-third filled with a liquid of such density that when a fresh charge of cool sirup enters a large number of small crystals of sugar is formed.

The boiling is then continued in such a manner that these crystals continue to grow in size until the entire pan is filled with a thick mass of crystals of sugar and molasses. The number of crystals formed at the beginning of the boiling determines the size of the crystals, or the "grain" of the finished product. When the operation is skillfully conducted no additional crystals, or "false grain," as it is called, are allowed to form after the original quantity of "grain" which the sugar boiler considers the proper amount has been formed. The coarse and fine granulated sugars found in the market are due to the manner is which the boiling is conducted and not to any subsequent crushing or grinding operation.

SEPARATION OF THE SUGAR FROM THE MOLASSES.

The finished product of the vacuum pan is known in the sugar house as "masse-cuite," and is separated into molasses and sugar by means of centrifugal machines. These machines consist essentially of a cylinder having walls of fine wire cloth and attached to a vertical shaft in such a way that they can be made to revolve at a speed of from 1,200 to 1,500 revolutions per minute. Small portions of the "masse-cuite" are placed in these machines, which are then rotated at the rapid rate named. The centrifugal force causes the molasses to pass through the mass of sugar and the screen, while the crystals are retained thereon. Any adhering molasses is removed from the crystals of sugar by means of a spray of water to which a small portion of ultramarine blue (a harmless coloring matter) is added to correct the yellow tint which the sugar would otherwise have. The construction and outer appearance of the centrifugal machines may be seen by inspecting the photographs on pl. 33 of the exhibit.

DRYING AND PACKING THE SUGAR.

The sugar as it comes from the centrifugal machine is moist and must first be passed through the "granulator" before it is ready for packing. One form of "granulator" is shown on pl. 33 of the exhibit. It usually consists of a revolving drum through which the sugar is made to pass in contact with a current of hot air. The sugar is packed for the market either in barrels or in burlap sacks lined with muslin. The packing room and a train load of sugar are shown on pl. 34 of the exhibit.

EXHIBIT OF FACTORY PRODUCTS.

The sugars and intermediate products made in a number of American beet-sugar factories are exhibited in case No. 6 (see Pl. I, frontispiece). The final product of most of the factories is a high-grade granulated sugar suitable for table use. In two or three cases, however, raw sugar is made which must first go to the refinery and be subjected to a refining process before it is suitable for consumption.

It is quite generally believed that granulated sugar made from sugar beets does not possess the sweetening power of the corresponding product made from sugar cane. When the granulated sugar from the two sources has in each case been skillfully made by modern processes, the product, for all practical purposes, is precisely the same, whether it comes from sugar beets or from sugar cane. It consists of more than 99.5 per cent of pure cane sugar mixed with less than one-half per cent of other materials which consist of small amounts of moisture, mineral matter, and other substances which do not essentially alter the character of the product. Chemists have never been able to detect any difference between the thoroughly purified sugars from the two sources, and this sugar, when separated in pure form, is called cane sugar, whether it comes from beets or from sugar cane, because it was originally found in the latter and manufactured therefrom for commercial purposes. Therefore, as the commercial products are rendered more and more pure by the use of good manufacturing processes, the difficulty of telling the source from which the sugar is obtained (beet root or sugar cane) becomes greater and greater. Poorly made granulated sugars obtained from beet roots possess to a greater or less extent a characteristic odor which can best be observed by placing the sugar in a bottle or other receptacle that can be tightly closed and noting the odor of the air surrounding the sugar in the bottle immediately after the cork has been removed and after the sugar has been closed up in the bottle for one or more days. When proper skill and the most improved processes are used for the manufacture of sugar from beets, this characteristic of the product becomes much less and, for all practical purposes, disappears. Therefore, statements that the sweetening power of sugar made from sugar beets is essentially different from that made from sugar cane are erroneous. It is of course true that while many of the raw sugars and other unrefined products from sugar cane are very palatable this is not the case with the unrefined products of the beet-sugar factory.

IMPORTANT BY-PRODUCTS.

Samples of the important by-products, beet pulp both in a dry and in a fresh condition, and the lime-cake fertilizer, can also be found in cases Nos. 6 and 7. (See Pl. I, frontispiece.) The lime-cake fertilizer is prepared by drying and grinding the filter-press cake, which consists of the insoluble matter removed from the carbonated juice by filtration. The sample exhibited has the following chemical composition:

Composition of the lime-cake fertilizer sent by American Beet Sugar Company, Chino, Cal.

	Per cent.
Phosphoric acid (P_2O_5)	0.35
Potash (K_2O)	2.30
Lime (C_aO)	41.65
Carbonic acid	23.20
Nitrogen	.17
Equivalent to ammonia (NH_3)	.21

The most important by-product of the beet-sugar industry, particularly from the standpoint of the farmer, is the exhausted beet pulp, which forms a most excellent stock food either in a moist or in a dried condition. The pulp as it comes from the battery contains approximately 95 per cent of water, but a considerable part of this is removed by passing the pulp through some form of continuous press (pl. 35 of the exhibit). The pressed pulp contains 85 to 90 per cent of water. A load of pressed pulp therefore contains about twice as much food material as does the same weight of the unpressed pulp. Recently some of the factories in this country have been equipped for rendering the pulp still more suitable for transportation by drying it in especially constructed drying plants until only about 10 per cent of moisture remains in it. Samples of both fresh and dried pulp are shown in cases Nos. 6 and 7. (See Pl. I, frontispiece). The American farmers have been slow to utilize the exhausted beet pulp for feeding purposes. Its use, however, is being extended every year, and doubtless within a short time none of it will be allowed to go to waste.

The sample of dried sugar-beet pulp exhibited was made at the factory of the Bay City Sugar Company of Bay City, Mich. Its chemical composition was as follows:

Composition of dried sugar-beet pulp.

	Per cent.
(1) Results of analyses made to determine food value:	
Moisture	9.56
Fat	.99
Protein (nitrogen × 6.25)	7.13
Fiber	18.30
Ash	3.73
Digestible carbohydrates, etc., by difference	60.29
(2) Results of analyses made to determine fertilizer value:	
Nitrogen	1.14
Equal to ammonia	1.38
Phosphoric acid (P_2O_5)	.34
Potash (K_2O)	.19

For the average composition of pressed and dried beet pulp in comparison with certain other feeding materials in common use, see the Yearbooks of the Department of Agriculture, 1898, pp. 213–220, and 1900, p. 752.

The factory at Leavitt, Nebr., may be mentioned as one of those at which special attention has been given to the utilization of the exhausted beet pulp for stock feeding. Several views taken on the farm of the Standard Cattle Company, Ames, Nebr., which uses pulp from the factory at Leavitt, are shown on pls. 35 and 36 of the exhibit.

The appliances used at the factory of the California and Hawaiian Sugar Refining Company's factory at Crockett, Cal., for the transportation of sugar-beet pulp from the factory to the silos are shown on the large photograph exhibited in case No. 7. (See Pl. I, frontispiece).

POWER AND LIGHTING.

Pls. 37 and 38 of exhibit show typical views in the boiler and engine rooms and the electric-lighting plants of American beet-sugar factories. The fuel employed is generally coal, with the exception of California, where crude petroleum is very largely used.

THE BEET-SUGAR MANUFACTURER'S DEBT TO SCIENCE.

The present condition of the beet-sugar industry is the result of the application of scientific methods in the field and in the factory. While other sciences have contributed largely analytical chemistry has been the most important factor in the development of the modern high grade sugar beet and in perfecting the methods of manufacture. Case 7 (see Pl. I, frontispiece) has been utilized for exhibiting some of the best methods and appliances for the analysis of the sugar beets and the sugar house products for the control of manufacturing processes. The usefulness of the analytical laboratory begins with the production of the sugar-beet seed. All of the larger seed farms in Europe, and those which are now being established in this country, are provided with laboratories equipped for the analysis of the "mother" beets in order that only those containing a high percentage of sugar and a very pure juice may be replanted for seed production. The methods employed for the analysis of beets which are to be selected for seed production must be rapid and inexpensive in order that a large number of beets, often hundreds or thousands, may be analyzed daily without too great an expenditure. The determination of sugar by means of a polariscope is now the means generally employed for this purpose. Various methods have been devised for removing a small portion of the beet and extracting the sugar therefrom, preparatory to determining its amount in the polariscope; a small portion of each beet can be taken without lessening its value for seed production.

EXHIBIT OF METHODS AND APPARATUS FOR THE ANALYSIS OF SUGAR BEETS.

One of the most rapid processes (shown in the case mentioned) consists in cutting out from each beet a small cylinder with an apparatus similar to an apple corer. From this cylinder a portion is cut with the Pellet parallel-bladed knife, the knives being so adjusted that the piece removed will weigh an alliquot part of the normal weight of sample arbitrarily adopted for the polariscope used. This sample portion is reduced to a pulp by the Hanriot machine and washed into a graduated flask. A small quantity of lead acetate solution is then added and the mixture diluted with water to a definite volume, thoroughly mixed by shaking and filtered. A tube, closed with glass disks at each end, is filled with the clear filtrate and placed in the polariscope; the percentage of sugar is then read directly upon the scale. This method sacrifices accuracy to some extent, but gains in rapidity by eliminating the use of a balance for determining the quantity of beet pulp to be used for each analysis.

There is also exhibited the Keil and Dolle boring rasp, which can be used either for sampling beets for seed selection or for sampling the beets at the factory receiving laboratory. The Pellet conical rasp, suitable only for the latter purpose, is also shown. Small apparatus for expressing juice from beet pulp for the analysis of beet juice for the purpose of seed selection also form a part of the exhibit.

Two polariscopes are shown: a small one for the analysis of sugar beets for seed selection, and a larger one of one of the latest improved models, with an incandescent electric lamp for illumination, used when greater accuracy is required. An important accessory of the polariscope is the Pellet continuous tube, which greatly increases the number of sugar solutions which can be examined in the polariscope in a given time. Both the methods and the instruments for the polariscopic determination of sugars have been greatly improved during recent years, until at the present time results of the highest accuracy can be obtained when the necessary precautions are observed. Recently the influence of temperature on sugar determinations by means of the polariscope has been carefully worked out by several investigators, and tables of factors, prepared by means of which corrections may readily be made for the slight errors necessarily introduced by the varying temperature of the laboratory.[1]

For the encouragement of farmers to produce the richest beets possible in a given region, it has long been the practice in Europe and in this country to vary the price paid the farmer according to the percentage of sugar in the beets. Formerly it was the practice in Europe

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[1] See article by Harvey W. Wiley, On the Influence of Temperature on the Specific Rotation of Sucrose and Method of Correcting Readings of Compensating Polariscopes therefor. Journal of the American Chemical Society, 1891, 21, 568-596.

to simply determine the density of the juice of the beet by means of the hydrometer, inasmuch as it is a fair indication of the percentage of sugar contained therein. With the improvement of analytical processes, both in accuracy and in rapidity, it has now become customary to make an actual determination of the percentage of sugar contained in each lot of beets delivered at the factory. Two types of methods are in use for this purpose:

(1) The determination of the sugar contained in the juice expressed from the beet and the calculation of the percentage of sugar contained in the beet by means of an arbitrary factor.

(2) The direct determination of the sugar in the beet by means of extraction with alcohol, hot water, or, more recently, with cold water.

The indirect method involves the use of an arbitrary factor which has frequently given rise to controversy. The percentage of juice contained in the beet varies with the conditions under which they were grown and with the time and manner of their storage after removal from the ground. It is therefore a difficult matter to decide upon the proper factor for the calculation of the percentage of sugar in the beet in each individual case. It is usually not practicable in the receiving laboratory of the factory, which is a very busy place and a very expensive adjunct of the factory, to do more than adopt an average factor and apply the same to all beets received.

The direct methods of analysis have, however, been recently so greatly improved in point of rapidity that it seems that factory proprietors may now consider their adoption for the analysis of beets in their receiving laboratories. For their successful application, however, it should be remembered that the working rooms and the laboratories should be provided with a great abundance of apparatus of the most improved pattern as well as ample room for conducting the various analytical operations. No economy will be found in limiting either space or equipment in the receiving laboratory. The exhibit of apparatus in the case named contains several devices which will be found useful for rapidly and accurately executing a large number of beet analyses.

In addition to a receiving laboratory where the beets are analyzed as they are delivered by the farmers, the beet-sugar factory has a laboratory for the analysis of the exhausted slices, juices, sirups, massecuites, and other products of the factory. These analyses are necessary to enable the proprietor or factory superintendent to determine whether all of the different manufacturing processes are being conducted in a proper manner.

The laboratory of an American sugar factory is shown on pl. 40 of the collection of photographs.

In this connection it is proper that acknowledgment should be made of the samples of sugar-house products, photographs, and other materials contributed by the manufacturers of beet sugar in various

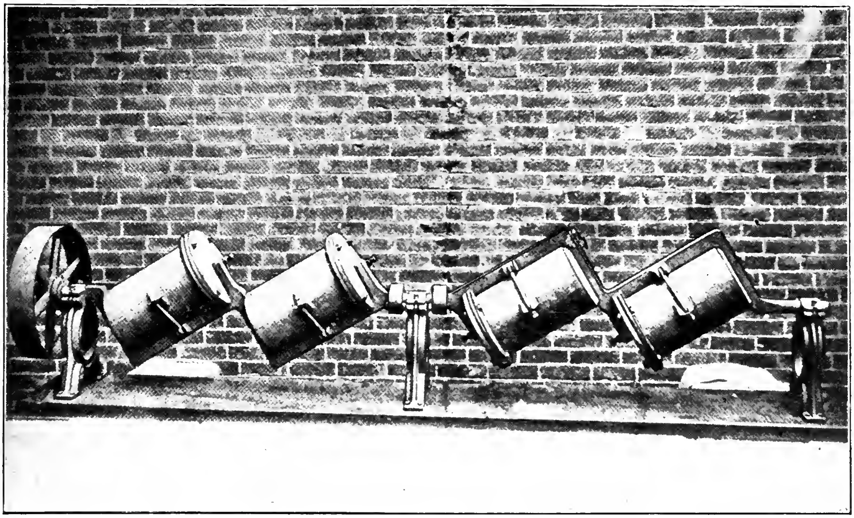


FIG. 1.—ABRASION MACHINE.

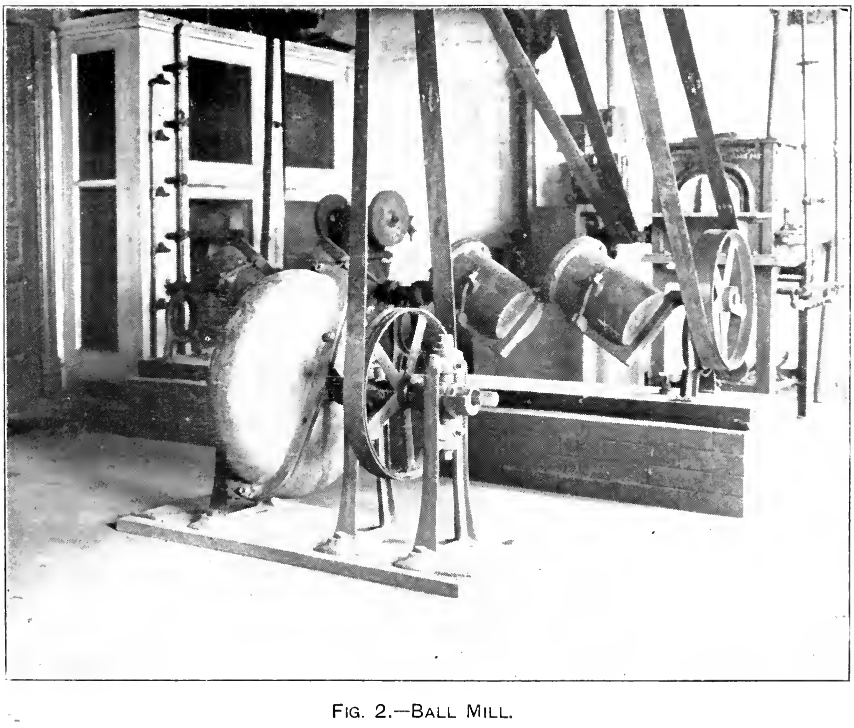


FIG. 2.—BALL MILL.

parts of the country. Without this cooperation on the part of the factory proprietors this exhibit would have been impossible.

EXHIBIT OF ROAD-MATERIAL LABORATORY.

By Logan Waller Page.

The Road-Material Laboratory was established in October last for testing road materials free of charge for any citizen of the United States. As most of the machinery necessary for this work had to be especially designed, the actual testing of road materials was not begun until December.

The short time which has intervened since then, together with the lack of available funds, has made it impossible to do more than install a part of the equipment necessary for the testing of rock and gravel. The present exhibit is consequently far from complete. In order to make an understanding of the exhibit as clear as possible, a brief description will be given of the entire process of testing rock and gravel at the present time.

When a request is received at the laboratory for making a test, a blank form containing a number of questions as to the exact location from which the material comes, by whom owned, and the amount available is sent, together with a tag envelope and instructions for selecting and shipping. In the case of rock, as soon as a sample is received at the laboratory, a hand specimen about 4 by 6 by 1 inches in dimensions is properly dressed and put aside for reference. Examples of such hand specimens can be seen in exhibit case No. 8. (See Pl. I, frontispiece).

ABRASION TEST.

The first test made on rock is the abrasion test, for determining the relative resistance to wear. This test is made by placing 5 kilograms (11 pounds) of rock of the usual size employed in road making (3 to 6 cm) in one of the cylinders of the abrasion machine. (See Pl. II, fig. 1.) These cylinders are 34 cm in depth and 20 cm in diameter, and are arranged on a shaft at an angle of 30° to the axis or rotation of the shaft. The cover of the cylinder is bolted on, and the cylinder is allowed to rotate for five hours, making 10,000 revolutions. Each revolution of the cylinder throws the fragments of rock from one end to the other twice, which causes them to grind and pound against one another and against the walls of the cylinder. The contents of the cylinder, after 10,000 revolutions, is brushed into a basin and the resulting fine detritus is sifted into several sizes (shown in the exhibit under the head of abrasion-test results) with an automatic sifter, a photograph of which is shown in the exhibit case. From the dust worn off two coefficients of wear and the percentage of wear are computed.

The Department coefficient of wear is obtained by subtracting 4,000 from the weight of the unabraded fragments of rock and dividing the difference by 10. This allows a possible range in results from zero to 100, i. e., if 1,000 grams of the material is abraded from the original 5 kilograms the result will be zero, and the material is considered unfit for road making. If no dust is worn from the original 5 kilograms the coefficient will be 100.

The French coefficient of wear is obtained by the following formula:

$$\text{Coefficient of wear} = 20 \times \frac{20}{w} = \frac{400}{w}$$

where "w" is the weight in grams of dust under 0.16 cm. (one-sixteenth of an inch) in size, obtained per kilogram (2.2 pounds) of rock used, 20 being the standard of excellence.

The percentage result includes all sizes of material worn from the original 5 kilograms. The results of 8 abrasion tests can be seen in the exhibit case.

This test was designed by M. Deval, and was first exhibited in Paris in 1878. It is, as far as the writer has been able to ascertain, the first machine especially constructed for testing road materials.

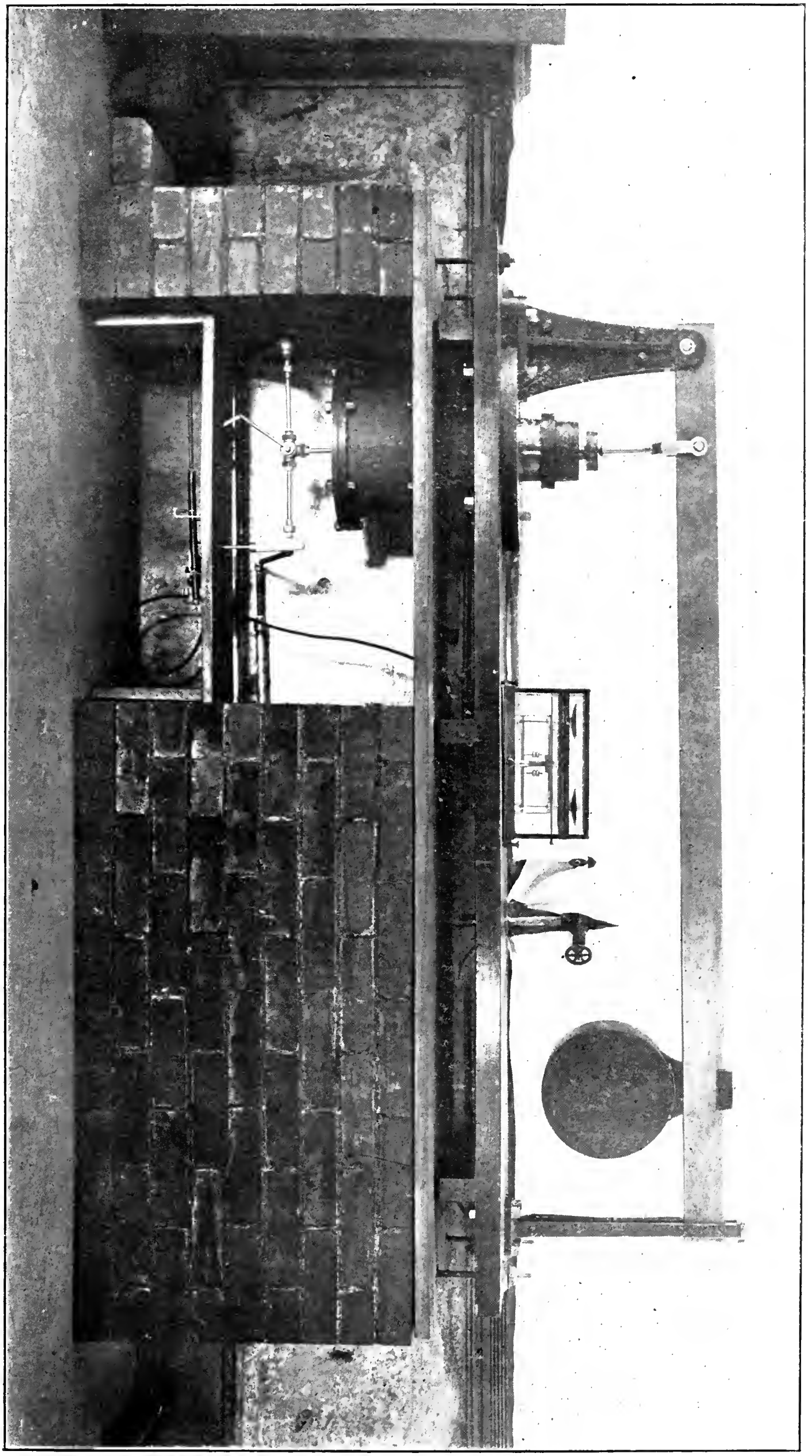
ABSORPTIVENESS AND DENSITY OF ROCK.

As soon as the abrasion test is completed one of the smoothly worn fragments, from 20 to 40 grams in weight, is used for determining the absorptiveness of the sample, which is done in the following manner: This smoothly worn stone is weighed in air after it has been brought to a constant weight in a hot-air bath. It is then immersed in water and immediately reweighed in water. After ninety-six hours of immersion it is again weighed in water.[1] The absorption is obtained by the following formula:

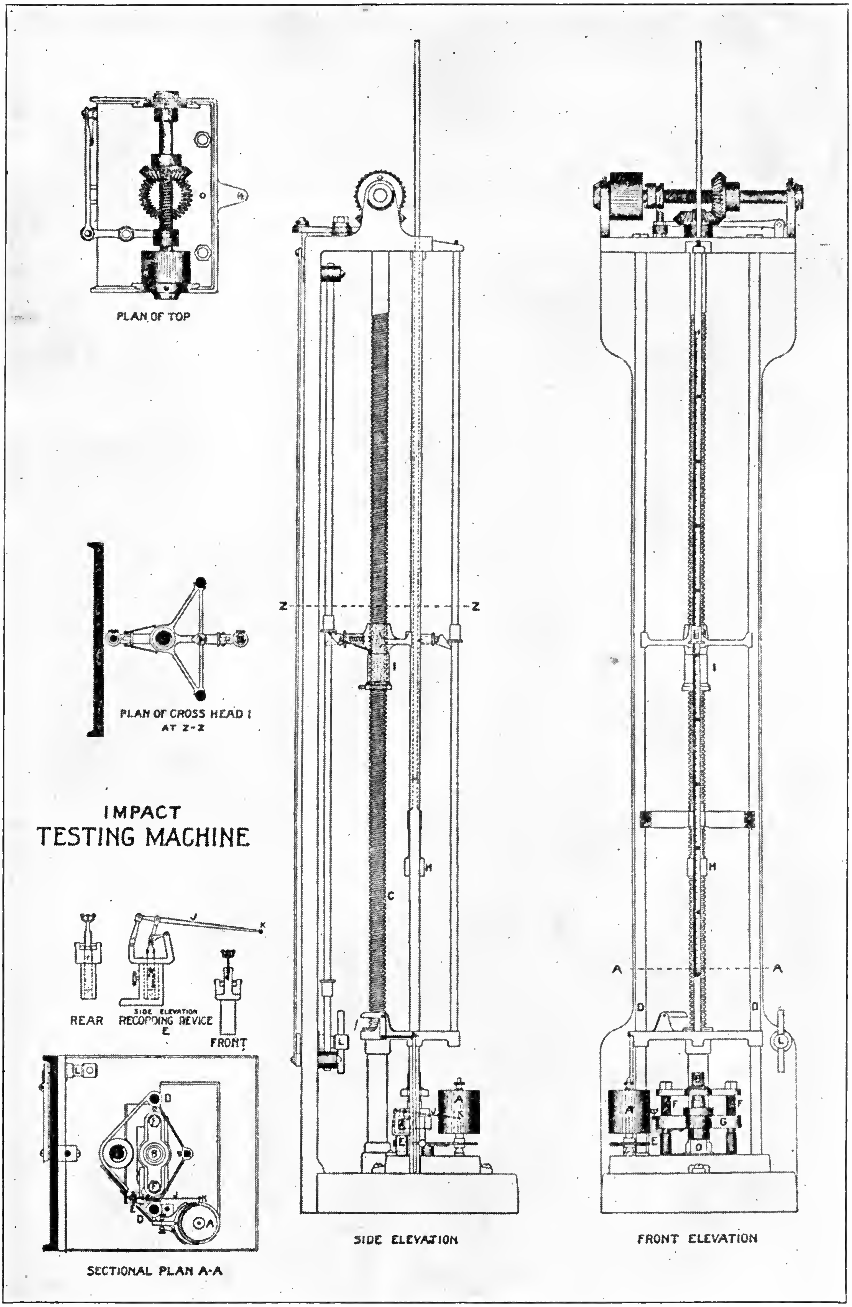
Number of pounds of water absorbed by a cubic foot of rock $= \frac{C-B}{A-B} \times 62.5$, in which "A" is equal to the weight in air, "B" the weight immediately after immersion in water, "C" the weight after absorption for ninety-six hours, and 62.5 the weight of a cubic foot of water.

This method has no particular advantages over others except that it requires less manipulation and time and the result is a little more practical. It is not intended to give the porosity of rock, but merely to obtain from a small specimen the number of pounds of water absorbed by a cubic foot of rock in ninety-six hours. It can be readily seen that the specific gravity and weight of a cubic foot of the rock can be determined from the above data. Two such trials are always made for each sample, and three or more when necessary.

[1] It was found by experiment with a number of stones that absorption practically ceases after sixty-two hours, so ninety-six hours was given as a safe allowance.



BRIQUETTE MACHINE.



IMPACT MACHINE.

During the coming year it is intended to determine the density of rock by careful measurement with a micrometer screw, and the porosity by means of a vacuum pump and hot water, which will be much more accurate than the methods at present employed.

CEMENTATION TEST.

The next test in order is the cementation test, which is intended to determine the important cementation or cohesive property of rock, which, when possessed in a high degree, gives an impervious shell to the surface of a road.

This property is determined by taking 500 grams of the sample broken to pass through a screen of 6 mm mesh, but not through a 0.5 mm mesh. The material thus broken is placed in a ball mill (Pl. II, fig. 2) and reduced to a powder that will pass through a 0.25 ($\frac{1}{100}$ inch) mm mesh. This dust is made into briquettes of circular section, 25 mm (0.98 inch) in diameter and 25 mm in height, by mixing the dust with distilled water (about 4 cc) on a glass plate and placing it in a steel die of the proper dimensions. This die has a closely fitting steel plug which is inserted over the dust, and the dust is subjected to a pressure of 100 kilograms per square centimeter (1,422 pounds per square inch) with a machine especially in designed for the purpose, which gives perfectly uniform conditions in making each briquette. (See Pl. III, also photograph in exhibit case.) The weight of the dust varies with the density and compressibility of the rock, but generally it requires about 23 grams (0.8 of an ounce) of dust to make a briquette of the above dimensions. These briquettes are kept in a hot-air bath until their weight becomes constant, and are then placed in a desiccator and allowed to cool, after which they are broken by impact.

The machine especially designed for this test (see Pl. IV) consists of a 1 kilogram (2.2 pound) hammer (H), arranged like the hammer of a pile driver on two vertical guide rods (D). The hammer is raised by a screw (C) and dropped automatically from any desired height. It falls on the flat end plunger (B) of 1 kilogram weight, which is pressed upon the briquette (O) by two light spiral springs held on the guide rods (F). The plunger (B) is bolted to the crosshead (G), which is held by two vertical rods (F). A small lever (J), carrying a brass pencil (K) at its free end, is connected with the side of the crosshead by a link motion, arranged so that it gives a vertical movement to the pencil six times as great as the movement of the crosshead. The pencil is pressed against the drum (A), and its movement is recorded on a slip of silicated paper fastened thereto. The drum is moved automatically through a small angle at each stroke of the hammer. In this way a record is obtained of the movement of the hammer after each blow. The standard fall of the hammer for a test is 1 cm. (0.39 inch). This blow is repeated until the bond of cementation of the material is destroyed. The final blow is easily ascertained, for when the hammer falls on the plunger, if the material beneath it withstands the blow, the plunger rebounds; if not, the plunger stays at the point to which it is driven, which is recorded on the slip of paper. The automatic record thus obtained from each briquette is filed for future reference. The number of blows required to break the bond of cementation, as described above, is taken as representing the cementing value of the rock, and is so used in comparing this property in road materials. Five briquettes are tested from each sample and their average taken for the result. Briquettes can be seen in the exhibit case before and after they have been subjected to this test; also records of results.

RECEMENTATION TEST.

The fragments of the five briquettes that are broken are again passed through a 0.25 mm. screen, made into briquettes, and broken again to determine the recementation value. This property is in a way more important than the cementing value, for the dust on a road surface is continually being recemented. With most materials about 50 per cent of the cementing value is lost on recementation, but with a few it increases.

OTHER TESTS.

Besides the tests enumerated above, the character of each sample is studied, and each rock is properly classified according to its mineralogical composition.

During the present fiscal year a number of new tests will be taken up. Among the most important is a test for determining the toughness of rock, which will be made in the following manner:

A machine similar in all respects to the present machine used for breaking the rock-dust briquettes will be used, except that it will have a spherical end plunger instead of the present flat one, and cubes of rock will be substituted for the briquette. The test will consist in a drop of the hammer of 1 cm. for the first blow, and an increased drop of 1 cm. for each succeeding blow, until the cube is destroyed. The entire energy of each blow is thus concentrated at the center of the upper surface of the cube, splitting the cube from this point after the elastic limit is reached. The number of blows required to destroy a cube will be used to indicate the toughness of a rock. It can be seen that this treatment approximates very closely the blows of horses' feet and the wheels of vehicles to which road materials are subjected.

TESTS ON GRAVEL.

The only test made on gravel at the present time is a determination of its cementing value, which is made by grinding 500 grams of a sample in the ball mill referred to above, making it into briquettes, and testing them in the same way in which the rock samples are tested.

Apparatus is now in preparation for making mechanical analyses of gravel, which will doubtless prove of much value. These analyses will consist in separating the natural sizes of the gravel by precipitation in water. The present plan is to separate it into the following sizes: Between 2 and 1 mm., 1.5 mm.; 0.5 to 0.25 mm.; 0.25 to 0.1 mm.; 0.1 to 0.05 mm.; 0.05 to 0.01 mm.; 0.01 to 0.005 mm.; 0.005 to 0.0001 mm.

The testing of paving brick will also be taken up during the present fiscal year.

Those desiring road materials tested must apply to Road-Material Laboratory, Bureau of Chemistry, Department of Agriculture, Washington, D. C.

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