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AMERICAN SOCIETY OF CIVIL ENGINEERS

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TRANSACTIONS

Paper No. 1171

FEDERAL INVESTIGATIONS OF MINE ACCIDENTS, STRUCTURAL MATERIALS, AND FUELS.[1]

By Herbert M. Wilson, M. Am. Soc. C. E.

With Discussion by Messrs. Kenneth Allen, Henry Kreisinger, Walter O. Snelling, A. Bartoccini, H. G. Stott, B. W. Dunn, and Herbert M. Wilson.

Introduction.

The mine disaster, which occurred at Cherry, Ill., on November 13th, 1909, when 527 men were in the mine, resulting in the entombment of 330 men, of whom 310 were killed, has again focused public attention on the frequent recurrence of such disasters and their appalling consequences. Interest in the possible prevention of such disasters, and the possible means of combating subsequent mine fires and rescuing the imprisoned miners, has been heightened as it was not even by the series of three equally extensive disasters which occurred in 1907, for the reason that, after the Cherry disaster, 20 men were rescued alive after an entombment of one week, when practically all hope of rescuing any of the miners had been abandoned.

This accident, occurring, as it does, a little more than 1½ years after the enactment of legislation by Congress instructing the Director of the United States Geological Survey to investigate the causes and possible means of preventing the loss of life in coal-mining operations, makes this an opportune time to review what has been done by the Geological Survey during this time, toward carrying out the intent of this Act. 191

It may be stated with confidence, that had such a disaster occurred a year or more ago, all the entombed men must have perished, as it would have been impossible to enter the mine without the protection afforded by artificial respiratory apparatus. Moreover, but for the presence of the skilled corps of Government engineers, experienced by more than a year’s training in similar operations in more than twenty disasters, the mine would have been sealed until the fire had burned out, and neither the dead, nor those who were found alive, would have been recovered for many weeks. In the interval great suffering and loss would have been inflicted on the miners, because of enforced idleness, and on the mine owners because of continued inability to re-open and resume operations.

Character of the Work.—The United States Geological Survey has been engaged continuously since 1904 in conducting investigations relating to structural materials, such as stone, clay, cement, etc., and in making tests and analyses of the coals, lignites, and other mineral fuel substances, belonging to, and for the use of, the Government.

Incidentally, the Survey has been considering means to increase efficiency in the use of these resources as fuels and structural materials, in the hope that the investigations will lead to their best utilization.

These inquiries attracted attention to the waste of human life incident to the mining of fuel and its preparation for the market, with the result that, in May, 1908, provision was made by Congress for investigations into the causes of mine explosions with a view to their prevention.

Statistics collected by the Geological Survey show that the average death rate in the coal mines of the United States from accidents of all kinds, including gas and dust explosions, falls of roof, powder explosions, etc., is three times that of France, Belgium, or Germany. On the other hand, in no country in the world are natural conditions so favorable for the safe extraction of coal as in the United States. In Belgium, foremost in the study of mining conditions, a constant reduction in the death rate has been secured, and from a rate once nearly as great as that of the United States, namely, 3.28 per thousand, in the period 1851-60,
it had been reduced to about 2 per thousand in the period 1881-90; and in the last decade this 192
has been further reduced to nearly 1 per thousand. It seems certain, from the investigations already made by the Geological Survey, that better means of safeguarding the lives of miners will be found, and that the death rate from mine accidents will soon show a marked reduction.

Other statistics collected by the Geological Survey show that, to the close of 1907, nearly 7,000,000,000 tons of coal had been mined in the United States, and it is estimated that for every ton mined nearly a ton has been wasted, 3,500,000,000 tons being left in the ground or thrown on the dump as of a grade too low for commercial use. To the close of 1907 the production represents an exhaustion of somewhat more than 10,000,000,000 tons of coal. It has been estimated that if the production continues to increase, from the present annual output of approximately 415,000,000 tons, at the rate which has prevailed during the last fifty years, the greater part of the more accessible coal supply will be exhausted before the middle of the next century.

The Forest Service estimates that, at the present rate of consumption, renewals of growth not being taken into account, the timber supply will be exhausted within the next quarter of a century. It is desirable, therefore, that all information possible be gained regarding the most suitable substitutes for wood for building and engineering construction, such as iron, stone, clay products, concrete, etc., and that the minimum proportion in which these materials should be used for a given purpose, be ascertained. Exhaustion, by use in engineering and building construction, applies not only to the iron ore, clay, and cement-making materials, but, in larger ratio, to the fuel essential to rendering these substances available for materials of construction. Incidentally, investigations into the waste of structural materials have developed the fact that the destructive losses, due to fires in combustible buildings, amount to more than $200,000,000 per annum. A sum even greater than this is annually expended on fire protection. Inquiries looking to the reduction of fire losses are being conducted in order to ascertain the most suitable fire-resisting materials for building construction.

Early in 1904, during the Louisiana Purchase Exposition, Congress made provision for tests, demonstrations, and investigations concerning the fuels and structural materials of the United
States. These investigations were organized subsequently as the Technologic Branch of the 193
United States Geological Survey, under Mr. Joseph A. Holmes, Expert in Charge, and the President of the United States invited a group of civilian engineers and Chiefs of Engineering Bureaus of the Government to act as a National Advisory Board concerning the method of conducting this work, with a view to making it of more immediate benefit to the Government and to the people of the United States. This Society is formally represented on this Board by C. C. Schneider, Past-President, Am. Soc. C. E., and George S. Webster, M. Am. Soc. C. E. Among representatives of other engineering societies, or of Government Bureaus, the membership of the National Advisory Board includes other members of this Society, as follows: General William Crozier, Frank T. Chambers, Professor W. K. Hatt, Richard L. Humphrey, Robert W. Hunt, H. G. Kelley, Robert W. Lesley, John B. Lober, Hunter McDonald, and Frederick H. Newell.

In view, therefore, of the important part taken both officially and unofficially by members of this Society in the planning and organization of this work, it seems proper to present a statement of the scope, methods, and progress of these investigations. Whereas the Act governing this work limits the testing and investigation of fuels and of structural materials to those belonging to the United States, the activities of the Federal Government in the use of these materials so far exceeds that of any other single concern in the United States, that the results cannot but be of great value to all engineers and to all those engaged in engineering works.

MINE ACCIDENTS INVESTIGATIONS.

Organization, and Character of the Work.—The mine rescue investigations, carried on at the Federal testing station, at Pittsburg, Pa., include five lines of attack:

1.—Investigations in the mines to determine the conditions leading up to mine disasters, the presence and the relative explosibility of mine gas and coal dust, and mine fires and means of preventing and combating them.

2.—Tests to determine the relative safety, or otherwise, of the various explosives used in coal mining, when ignited in the presence of explosible mixtures of natural gas and air, or coal dust, or of both.

3.—Tests to determine the conditions under which electric equipment is safe in coal-mining operations.

4.—Tests to determine the safety of various types of mine lights in the presence of inflammable 194
gas, and their accuracy in detecting small percentages of mine gas.

5.—Tests of the various artificial breathing apparatus, and the training of miners and of skilled mining engineers in rescue methods.

The first four of these lines of investigation have to do with preventive measures, and are those on which ultimately the greatest dependence must be placed. The fifth is one in which the result seems at first to be the most apparent. It has to do, not with prevention, but with the cure of conditions which should not arise, or, at least, should be greatly ameliorated.

During the last 19 years, 28,514 men have been killed in the coal-mining industries.[2] In 1907 alone, 3,125 men lost their lives in coal mines, and, in addition, nearly 800 were killed in the metal mines and quarries of the country. Including the injured, 8,441 men suffered casualties in the mines in that year. In every mining camp containing 1,000 men, 4.86 were taken by violent death in that year. In the mining of coal in Great Britain, 1.31 men were killed in every 1,000 employed in the same year; in France, 1.1; in Belgium, 0.94, or less than 1 man in every 1,000 employed. It is thus seen that from three to four times as many men are being killed in the United States as in any European coal-producing country. This safer condition in Europe has resulted from the use of safer explosives, or the better use of the explosives available; from the reduction in the use of open lights; from the establishment of mine rescue stations and the training with artificial breathing apparatus; and from the adoption of regulations for safeguarding the lives of the workmen.

The mining engineering field force of the Geological Survey, at the head of which is Mr. George S. Rice, an experienced mining and consulting engineer, has already made great progress in the study of underground mining conditions and methods. Nearly all the more dangerous coal mines in the United States have been examined; samples of gas, coal, and dust have been taken and analyzed at the chemical laboratories at Pittsburg; extended tests have been made as to the explosibility of various mixtures of gas and air; as to the explosibility of
dust from various typical coals; as to the chemical composition and physical characteristics of 195
this dust; the degree of fineness necessary to the most explosive conditions; and the methods of dampening the dust by water, by humidifying, by steam, or of deadening its explosibility by the addition of calcium chloride, stone dust, etc. A bulletin outlining the results thus far obtained in the study of the coal-dust problem is now in course of publication.[3]

After reviewing the history of observations and experiments with coal dust carried on in Europe, and later, the experiments at the French, German, Belgian, and English explosives-testing stations, this bulletin takes up the coal-dust question in the United States. Further chapters concern the tests as to the explosibility of coal dust, made by the Geological Survey, at Pittsburg; investigations, both at the Pittsburg laboratory and in mines, as to the humidity of mine air. There is also a chapter on the chemical investigations into the ignition of coal dust by Dr. J. C. W. Frazer, of the Geological Survey. The application of some of these data to actual mine conditions in Europe, in the last year, is treated by Mr. Axel Larsen; the use of exhaust steam in a mine of the Consolidation Coal Company, in West Virginia, is discussed by Mr. Frank Haas, Consulting Engineer; and the use of sprays in Oklahoma coal mines is the subject of a chapter by Mr. Carl Scholz, Vice-President of the Rock Island Coal Mining Company.

An earlier bulletin setting forth the literature and certain mine investigations of explosive gases and dust,[4] has already been issued. After treating of methods of collecting and analyzing the gases found in mines, of investigations as to the rate of liberation of gas from coal, and of studies on coal dust, this bulletin discusses such factors as the restraining influence of shale dust and dampness on coal-dust explosions. It then takes up practical considerations as to the danger of explosions, including the relative inflammability of old and fresh coal dust. The problems involved are undergoing further investigation and elaboration, in the light of information already gathered.

Permissible Explosives.—The most important progress in these tests and investigations has been made in those relating to the various explosives used in getting coal from mines. Immediately upon the enactment of the first legislation, in the spring of 1908, arrangements
were perfected whereby the lower portion of the old Arsenal grounds belonging to the War 196
Department and adjacent to the Pennsylvania Railroad, on the Alleghany River, at 40th and Butler Streets, Pittsburg, Pa., were transferred to the Interior Department for use in these

investigations. Meantime, in anticipation of the appropriation, Mr. Clarence Hall, an engineer experienced in the manufacture and use of explosives, was sent to Europe to study the methods of testing explosives practiced at the Government stations in Great Britain, Germany, Belgium, and France. Mr. Joseph A. Holmes also visited Europe for the purpose of studying methods of ameliorating conditions in the mines. Three foreign mining experts, the chiefs of investigating bureaus in Belgium, Germany, and England, spent three months studying conditions in the United States at the invitation of the Secretary of the Interior, to whom they submitted a valuable report.[5]

Under the supervision of the writer, Chief Engineer of these investigations, detailed plans and specifications had been prepared in advance for the necessary apparatus and the transformation of the buildings at Pittsburg to the purposes of this work. It was possible, therefore, to undertake immediately the changes in existing buildings, the erection of new buildings, the installation of railway tracks, laboratories, and the plumbing, heating, and lighting plant, etc. This work was carried on with unusual expedition, under the direction of the Assistant Chief Engineer, Mr. James C. Roberts, and was completed within a few months, by which time most of the apparatus was delivered and installed.

One building (No. 17) is devoted to the smaller physical tests of explosives. It was rendered fire resistant by heavily covering the floors, ceiling, and walls with cement on metal lath, and otherwise protecting the openings. In it are installed apparatus for determining calorific value of explosives, pressure produced on ignition, susceptibility to ignition when dropped, rate of detonation, length and duration of flame, and kindred factors. Elsewhere on the grounds is a gallery of boiler-steel plate, 100 ft. long and more than 6 ft. in diameter, solidly attached to a mass of concrete at one end, in which is embedded a cannon from which to discharge the explosive under test, and open at the other end, and otherwise so constructed as to simulate a 197
small section of a mine gallery (Fig. 2, Plate VI). The heavy mortar pendulum, for the pendulum test for determining the force produced by an explosive, is near by, as is also an armored pit in which large quantities of explosive may be detonated, with a view to studying the effects of magazine explosions, and for testing as to the rate at which ignition of an explosive travels from one end to the other of a cartridge, and the sensitiveness of one cartridge to explosion by discharge of another near by.

In another building (No. 21), is a well-equipped chemical laboratory for chemical analyses and investigations of explosives, structural materials, and fuels.

Several months were required to calibrate the various apparatus, and to make analyses of the available natural gas to determine the correct method of proportioning it with air, so as to produce exact mixtures of 2, 4, 6, or 8% of methane with air. Tests of existing explosives were made in air and in inflammable mixtures of air and gas, with a view to fixing on some standard explosive as a basis of comparison. Ultimately, 40% nitro-glycerine dynamite was adopted as the standard. Investigative tests having been made, and the various factors concerning all the explosives on the market having been determined, a circular was sent to all manufacturers of explosives in the United States, on January 9th, 1909, and was also published in the various technical journals, through the associated press, and otherwise.

On May 15th, 1909, all the explosives which had been offered for test, as permissible, having been tested, the first list of permissible explosives was issued, as given in the following circular:

“EXPLOSIVES CIRCULAR NO. 1.

“DEPARTMENT OF THE INTERIOR.

“UNITED STATES GEOLOGICAL SURVEY.

“MAY 15, 1909.

“LIST OF PERMISSIBLE EXPLOSIVES.

“Tested prior to May 15, 1909.

“As a part of the investigation of mine explosions authorized by Congress in May, 1908, it was decided by the Secretary of the Interior that a careful examination should be made of the various explosives used in mining operations, with a view to determining the extent to which the 198
use of such explosives might be responsible for the occurrence of these disasters.

“The preliminary investigation showed the necessity of subjecting to rigid tests all explosives intended for use in mines where either gas or dry inflammable dust is present in quantity or under conditions which are indicative of danger.

“With this in view, a letter was sent by the Director of the United States Geological Survey on January 9, 1909, to the manufacturers of explosives in the United States, setting forth the conditions under which these explosives would be examined and the nature of the tests to which they would be subjected.

“Inasmuch as the conditions and tests described in this letter were subsequently followed in testing the explosives given in the list below, they are here reproduced, as follows:

“(1) The manufacturer is to furnish 100 pounds of each explosive which he desires to have tested; he is to be responsible for the care, handling, and delivery of this material at the testing station on the United States arsenal grounds, Fortieth and Butler streets, Pittsburg, Pa., at the time the explosive is to be tested; and he is to have a representative present during the tests, who will be responsible for the handling of the packages containing the explosives until they are opened for testing.

“(2) No one is to be present at or to participate in these tests except the necessary government officers at the testing station, their assistants, and the representative of the manufacturer of the explosives to be tested.

“(3) The tests will be made in the order of the receipt of the applications for them, provided the necessary quantity of the explosive is delivered at the plant by the time assigned, of which due notice will be given by the Geological Survey.

“(4) Preference will be given to the testing of explosives that are now being manufactured and that are in that sense already on the market. No test will be made of any new explosive which is not now being manufactured and marketed, until all explosives now on the market that may be offered for testing have been tested.

“(5) A list of the explosives which pass certain requirements satisfactorily will be furnished to the state mine inspectors, and will be made public in such further manner as may be considered desirable.

“TEST REQUIREMENTS FOR EXPLOSIVES.

“The tests will be made by the engineers of the United States Explosives Testing Station at Pittsburg, Pa., in gas and dust gallery No. 1. The charge of explosive to be fired in tests 1, 2, and 3 shall be equal in disruptive power to one-half pound (227 grams) of 40 per cent. nitroglycerin dynamite in its original wrapper, of the following formula:

Nitroglycerin	40
Nitrate of sodium	44
Wood pulp	15
Calcium carbonate	1
	100

“Each charge shall be fired with an electric fuse of sufficient power to completely detonate or 199
explode the charge, as recommended by the manufacturer. The explosive must be in such condition that the chemical and physical tests do not show any unfavorable results. The explosives in which the charge used is less than 100 grams (0.22 pound) will be weighed in tinfoil without the original wrapper.

“The dust used in tests 2, 3, and 4 will be of the same degree of fineness and taken from one mine.[6]

“Test 1.—Ten shots with the charge as described above, in its original wrapper, shall be fired, each with 1 pound of clay tamping, at a gallery temperature of 77° F., into a mixture of gas and air containing 8 per cent. of methane and ethane. An explosive will pass this test if all ten shots fail to ignite the mixture.

“Test 2.—Ten shots with charge as previously noted, in its original wrapper, shall be fired, each with 1 pound of clay tamping at a gallery temperature of 77° F., into a mixture of gas and air containing 4 per cent. of methane and ethane and 20 pounds of bituminous coal dust, 18 pounds of which is to be placed on shelves laterally arranged along the first 20 feet of the gallery, and 2 pounds to be placed near the inlet of the mixing system in such a manner that all or part of it will be suspended in the first division of the gallery. An explosive will pass this test if all ten shots fail to ignite the mixture.

“Test 3.—Ten shots with charge as previously noted, in its original wrapper, shall be fired, each with 1 pound of clay tamping at a gallery temperature of 77° F., into 40 pounds of bituminous coal dust, 20 pounds of which is to be distributed uniformly on a horse placed in front of the cannon and 20 pounds placed on side shelves in sections 4, 5, and 6. An explosive will pass this test if all ten shots fail to ignite the mixture.

“Test 4.—A limit charge will be determined within 25 grams by firing charges in their original wrappers, untamped, at a gallery temperature of 77° F., into a mixture of gas and air containing 4 per cent. of methane and ethane and 20 pounds of bituminous coal dust, to be arranged in the same manner as in test 2. This limit charge is to be repeated five times under the same conditions before being established.

“Note.—At least 2 pounds of clay tamping will be used with slow-burning explosives.

“Washington, D. C., *January 9, 1909*.

“In response to the above communication applications were received from 12 manufacturers for the testing of 29 explosives. Of these explosives, the 17 given in the following list have passed all the test requirements set forth, and will be termed permissible explosives.

“Permissible explosives tested prior to May 15, 1909.

Brand.	Manufacturer.
Ætna coal powder A	Ætna Powder Co., Chicago, Ill.
Ætna coal powder B	Do.
Carbonite No. 1	E. I. Dupont de Nemours Powder Co., Wilmington, Del.
Carbonite No. 2	E. I. Du Pont de Nemours Powder Co., Wilmington, Del. 200
Carbonite No. 3	Do.
Carbonite No. 1 L. F.	Do.
Carbonite No. 2 L. F.	Do.
Coal special No. 1	Keystone Powder Co., Emporium, Pa.
Coal special No. 2	Do.
Coalite No. 1	Potts Powder Co., New York City.
Coalite No. 2 D	Do.
Collier dynamite No. 2	Sinnamahoning Powder Co., Emporium, Pa.
Collier dynamite No. 4	Do.
Collier dynamite No. 5	Do.
Masurite M. L. F.	Masurite Explosive Co., Sharon, Pa.

Meteor dynamite	E. I. Du Pont de Nemours Powder Co., Wilmington, Del.
Monobel	Do.

"Subject to the conditions named below, a permissible explosive is defined as an explosive which has passed gas and dust gallery tests Nos. 1, 2, and 3 as described above, and of which in test No. 4 1½ pounds (680 grams) of the explosive has been fired into the mixture there described without causing an ignition.

"*Provided:*

"1. That the explosive is in all respects similar to the sample submitted by the manufacturer for test.

"2. That double-strength detonators are used of not less strength than 1 gram charge consisting by weight of 90 parts of mercury fulminate and 10 parts of potassium chlorate (or its equivalent), except for the explosive 'Masurite M. L. F.' for which the detonator shall be of not less strength than 1½ grams charge.

"3. That the explosive, if in a frozen condition, shall be thoroughly thawed in a safe and suitable manner before use.

"4. That the amount used in practice does not exceed 1½ pounds (680 grams) properly tamped.

"The above partial list includes the permissible explosives that have passed these tests prior to May 15, 1909. The announcement of the passing of like tests by other explosives will be made public immediately after the completion of the tests for such explosives.

"A description of the method followed in making these and the many additional tests to which each explosive is subjected, together with the full data obtained in each case, will be published by the Survey at an early date.

201

"NOTES AND SUGGESTIONS.

"It may be wise to point out in this connection certain differences between the permissible explosives as a class and the black powders now so generally used in coal mining, as follows:

"(*a*) With equal quantities of each, the flame of the black powder is more than three times as long and has a duration three thousand to more than four thousand times that of one of the permissible explosives, also the rate of explosion is slower.

"(*b*) The permissible explosives are one and one-fourth to one and three-fourths times as strong and are said, if properly used, to do twice the work of black powder in bringing down coal; hence only half the quantity need be used.

"(*c*) With 1 pound of a permissible explosive or 2 pounds of black powder, the quantity of noxious gases given off from a shot averages approximately the same, the quantity from the black powder being less than from some of the permissible explosives and slightly greater than from others. The time elapsing after firing before the miner returns to the working face or fires another shot should not be less for permissible explosives than for black powder.

"The use of permissible explosives should be considered as supplemental to and not as a substitute for other safety precautions in mines where gas or inflammable coal dust is present under conditions indicative of danger. As stated above, they should be used with strong detonators; and the charge used in practice should not exceed 1½ pounds, and in many cases need not exceed 1 pound.

"Inasmuch as no explosive manufactured for use in mining is flameless, and as no such explosive is entirely safe under all the variable mining conditions, the use of the terms 'flameless' and 'safety' as applied to explosives is likely to be misunderstood, may endanger human life, and should be discouraged.

"Joseph A. Holmes,
"*Expert in Charge Technologic Branch*.

"Approved, May 18, 1909:
"Geo. Otis Smith,
"*Director*."

In the meantime, many of the explosives submitted, which heretofore had been on the market as safety explosives, were found to be unsafe for use in gaseous or dusty mines, and the manufacturers were permitted to withdraw them. Their weaknesses being known, as a result of these tests, the manufacturers were enabled to produce similar, but safer, explosives. Consequently, applications for further tests continued to pour in, as they still do, and on October 1st, 1909, a second list of permissible explosives was issued, as follows:

"EXPLOSIVES CIRCULAR NO. 2. 202

"DEPARTMENT OF THE INTERIOR.

"United States Geological Survey.

October 1, 1909.

"LIST OF PERMISSIBLE EXPLOSIVES.

"Tested prior to October 1, 1909.

"The following list of permissible explosives tested by the United States Geological Survey at Pittsburg, Pa., is hereby published for the benefit of operators, mine owners, mine inspectors, miners, and others interested.

"The conditions and test requirements described in Explosives Circular No. 1, issued under date of May 15, 1909, have been followed in all subsequent tests.

"Subject to the provisions named below, a permissible explosive is defined as an explosive which is in such condition that the chemical and physical tests do not show any unfavorable results; which has passed gas and dust gallery tests Nos. 1 and 3, as described in circular No. 1; and of which, in test No. 4, 1½ pounds (680 grams) has been fired into the mixture there described without causing ignition.

“*Permissible explosives tested prior to October 1, 1909.*

“[Those reported in Explosives Circular No. 1 are marked *.]

Brand.	Manufacturer.
* Ætna coal powder A	Ætna Powder Co., Chicago, Ill.
Ætna coal powder AA	Do.
* Ætna coal powder B	Do.
Ætna coal powder C	Do.
Bituminite No. 1	Jefferson Powder Co., Birmingham, Ala.
Black Diamond No. 3	Illinois Powder Manufacturing Co., St. Louis, Mo.
Black Diamond No. 4	Do.
* Carbonite No. 1	E. I. Du Pont de Nemours Powder Co., Wilmington, Del.
* Carbonite No. 2	Do.
* Carbonite No. 3	Do.
* Carbonite No. 1-L. F.	Do.
* Carbonite No. 2-L. F.	Do.
* Coalite No. 1	Potts Powder Co., New York City.
* Coalite No. 2-D.	Do.
* Coal special No. 1	Keystone Powder Co., Emporium, Pa.
* Coal special No. 2	Do.
* Collier dynamite No. 2.	Sinnamahoning Powder Manufacturing Co., Emporium, Pa. 203
* Collier dynamite No. 4.	Do.
* Collier dynamite No. 5.	Do.
Giant A low-flame dynamite.	Giant Powder Co. (Con.), Giant, Cal.
Giant B low-flame dynamite.	Do.
Giant C low-flame dynamite.	Do.
* Masurite M. L. F.	Masurite Explosives Co., Sharon, Pa.
* Meteor dynamite.	E. I. Du Pont de Nemours Powder Co., Wilmington, Del.
Mine-ite A.	Burton Powder Co., Pittsburg, Pa.
Mine-ite B.	Do.
* Monobel.	E. I. Du Pont de Nemours Powder Co., Wilmington, Del.
Tunnelite No. 5.	G. R. McAbee Powder and Oil Co., Pittsburg, Pa.
Tunnelite No. 6.	Do.
Tunnelite No. 7.	Do.
Tunnelite No. 8.	Do.

“*Provided:*

“1. That the explosive is in all respects similar to sample submitted by the manufacturer for test.

“2. That No. 6 detonators, preferably No. 6 electric detonators (double strength), are used of not less strength than 1 gram charge, consisting by weight of 90 parts of mercury fulminate and 10 parts of potassium chlorate (or its equivalent), except for the explosive ‘Masurite M. L. F.,’ for which the detonator shall be of not less strength than 1½ grams charge.

“3. That the explosive, if frozen, shall be thoroughly thawed in a safe and suitable manner before use.

“4. That the amount used in practice does not exceed 1½ pounds (680 grams), properly tamped.

“The above partial list includes all the permissible explosives that have passed these tests prior to October 1, 1909. The announcement of the passing of like tests by other explosives will be made public immediately after the completion of the tests.

“With a view to the wise use of these explosives it may be well in this connection to point out again certain differences between the permissible explosives as a class and the black powders now so generally used in coal mining, as follows:

“(*a*) With equal quantities of each, the flame of the black powder is more than three times as
long and has a duration three thousand to more than four thousand times that of one of the 204
permissible explosives; the rate of explosion also is slower.

“(*b*) The permissible explosives are one and one-fourth to one and three-fourths times as strong and are said, if properly used, to do twice the work of black powder in bringing down coal; hence only half the quantity need be used.

“(*c*) With 1 pound of a permissible explosive or 2 pounds of black powder, the quantity of noxious gases given off from a shot averages approximately the same, the quantity from the black powder being less than from some of the permissible explosives and slightly greater than from others. The time elapsing after firing before the miner returns to the working face or fires another shot should not be less for permissible explosives than for black powder.

“The use of permissible explosives should be considered as supplemental to and not as a substitute for other safety precautions in mines where gas or inflammable coal dust is present under conditions indicating danger. As stated above, they should be used with strong detonators, and the charge used in practice should not exceed 1½ pounds and in many cases need not exceed 1 pound.

“Joseph A. Holmes,
“*Expert in Charge Technologic Branch*.

“Approved, October 11, 1909.
“H. C. Rizer,
“*Acting Director*.”

The second list contains 31 explosives which the Government is prepared to brand as permissible, and therefore comparatively safe, for use in gaseous and dusty mines. An equally large number of so-called safety powders failed to pass these tests. Immediately on the passing of the tests, as to the permissibility of any explosive, the facts are reported to the manufacturer and to the various State mine inspectors. When published, the permissible lists were issued to all explosives manufacturers, all mine operators in the United States, and State inspectors. The effect has been the enactment, by three of the largest coal-producing States, of legislation or regulations prohibiting the use of any but permissible explosives in gaseous or dusty mines, and other States must soon follow. To prevent fraud, endeavor is being made to restrict the use of the brand "Permissible Explosive, U. S. Testing Station, Pittsburg, Pa.," to only such boxes or packages as contain listed permissible explosives.

As these tests clearly demonstrate, both in the records thereof and visually to such as follow
them, that certain explosives, especially those which are slow-burning like black powder, or 205
produce high temperature in connection with comparative slow burning, will ignite mixtures of gas and air, or mixtures of coal dust and air, and cause explosions. The results point out clearly to all concerned, the danger of using such explosives. The remedy is also made available by the announcement of the names of a large number of explosives now on the market at reasonable cost, which will not cause explosions under these conditions. It is believed that when permissible explosives are generally adopted in coal mines, this source of danger will have been greatly minimized.

Explosives Investigations.—Questions have arisen on the part of miners or of mine operators as to the greater cost in using permissible explosives due to their expense, which is slightly in excess of that of other explosives; as to their greater shattering effect in breaking down the coal, and in giving a smaller percentage of lump and a larger percentage of slack; and as to the possible danger of breathing the gases produced.

Observations made in mines by Mr. J. J. Rutledge, an experienced coal miner and careful mining engineer connected with the Geological Survey, as to the amount of coal obtained by the use of permissible and other explosives, tend to indicate that the permissible explosives are not more, but perhaps less expensive than others, in view of the fact that, because of their greater relative power, a smaller quantity is required to do the work than is the case, say, with black powder. On the other hand, for safety and for certainty of detonation, stronger detonators are recommended for use with permissible explosives, preferably electric detonators. These may cost a few cents more per blast than the squib or fuse, but there is no danger that they will ignite the gas, and the difference in cost is, in some measure, offset by the greater certainty of action and the fact that they produce a much more powerful explosion, thus again permitting the use of still smaller quantities of the explosive and, consequently, reducing the cost. These investigations are still in progress.

Concerning the shattering of the coal: This is being remedied in some of the permissible explosives by the introduction of dopes, moisture, or other means of slowing down the disruptive effect, so as to produce the heaving and breaking effect obtained with the slower-
burning powders instead of the shattering effect produced by dynamite. There is every reason 206
to believe that as the permissible explosives are perfected, and as experience develops the proper methods of using them, this difficulty will be overcome in large measure. This matter is also being investigated by the Survey mining engineers and others, by the actual use of such explosives in coal-mining operations.

Of the gases given off by explosives, those resulting from black powder are accompanied by considerable odor and smoke, and, consequently, the miners go back more slowly after the shots, allowing time for the gases to be dissipated by the ventilation. With the permissible explosive, the miner, seeing no smoke and observing little odor, is apt to be incautious, and to think that he may run back immediately. As more is learned of the use of these explosives, this source of danger, which is, however, inconsiderable, will be diminished. Table 1 gives the percentages of the gaseous products of combustions from equal weights of black powder and two of the permissible explosives. Of the latter, one represents the maximum amount of injurious gases, and the other the minimum amount, between which limits the permissible explosives approximately vary.

Such noxious gases as may be produced by the discharge of the explosive are diluted by a much larger volume of air, and are practically harmless, as proven by actual analysis of samples taken at the face immediately after a discharge.

TABLE 1.

	Black powder.	Permissible Explosives.	
		Maximum.	Minimum.
CO_2	22.8	14.50	21.4
CO	10.3	27.74	1.3
N	10.3	45.09	74.4

In addition to investigations as to explosives for use in coal mining, the Explosives Section of the Geological Survey analyzes and tests all such materials, fuses, caps, etc., purchased by the Isthmian Canal Commission, as well as many other kinds used by the Government. It is thus acquiring a large fund of useful information, which will be published from time to time, relative
to the kinds of explosives and the manner of using them best suited to any blasting operations, 207
either above or under water, in hard rock, earth, or coal. There has been issued from the press,

recently, a primer of explosives,[7] by Mr. Clarence Hall, the engineer in charge of these tests, and Professor C. E. Munroe, Consulting Explosives Chemist, which contains a large amount of valuable fundamental information, so simply expressed as to be easily understandable by coal miners, and yet sufficiently detailed to be a valuable guide to all persons who have to handle or use explosives.

In the first chapters are described the various combustible substances, and the chemical reactions leading to their explosibility. The low and high explosives are differentiated, and the sensitiveness of fulminate of mercury and other detonators is clearly pointed out. The various explosives, such as gunpowder, black blasting powder, potassium chlorate powders, nitro-glycerine powders, etc., are described, and their peculiarities and suitability for different purposes are set forth. The character and method of using the different explosives, both in opening up work and in enclosed work in coal mines, follow, with information as to the proper method of handling, transporting, storing, and thawing the same. Then follow chapters on squibs, fuses, and detonators; on methods of shooting coal off the solid; location of bore-holes; undercutting; and the relative advantages of small and large charges, with descriptions of proper methods of loading and firing the same. The subjects of explosives for blasting in rock, firing machines, blasting machines, and tests thereof, conclude the report.

The work of the chemical laboratory in which explosives are analyzed, and in which mine gases and the gases produced by combustion of explosives and explosions of coal-gas or coal dust are studied, has been of the most fundamental and important character. The Government is procuring a confidential record of the chemical composition and mode of manufacture of all explosives, fuses, etc., which are on the market. This information cannot but add greatly to the knowledge as to the chemistry of explosives for use in mines, and will furnish the basis on which remedial measures may be devised.

A bulletin (shortly to go to press) which gives the details of the physical tests of the permissible
explosives thus far tested, will set forth elaborately the character of the testing apparatus, and 208
the method of use and of computing results.[8]

This bulletin contains a chapter, by Mr. Rutledge, setting forth in detail the results of his observations as to the best methods of using permissible explosives in getting coal from various mines in which they are used. This information will be most valuable in guiding mining engineers who desire to adopt the use of permissible explosives, as to the best methods of handling them.

Electricity in Mines.—In connection with the use of electricity in mines, an informal series of tests has been made on all enclosed electric fuses, as to whether or not they will ignite an explosive mixture of air and gas when blown out. The results of this work, which is under the direction of Mr. H. H. Clark, Electrical Engineer for Mines, have been furnished the manufacturers for their guidance in perfecting safer fuses, a series of tests of which has been announced. A series of tests as to the ability of the insulation of electric wiring to withstand the attacks of acid mine waters is in progress, which will lead, it is hoped, to the development of more permanent and cheaper insulation for use in mine wiring. A series of competitive tests of enclosed motors for use in mines has been announced, and is in progress, the object being to determine whether or not sparking from such motors will cause an explosion in the presence of inflammable gas.

In the grounds outside of Building No. 10 is a large steel gallery, much shorter than Gallery No. 1, in fact, but 30 ft. in length, and much greater in diameter, namely, 10 ft. (Fig. 3, Plate X), in which electric motors, electric cutting machines, and similar apparatus, are being tested in the presence of explosive mixtures of gas and dust and with large amperage and high voltage, such as may be used in the largest electrical equipment in mines.

The investigation as to the ability of insulation to withstand the effects of acid mine waters has been very difficult and complicated. At first it was believed possible that mine waters from nearby Pennsylvania mines and of known percentages of acidity could be procured and kept in an immersion tank at approximately any given percentage of strength. This was found to be impracticable, as these waters seem to undergo rapid change the moment they are exposed to
the air or are transported, in addition to the changes wrought by evaporation in the tank. It 209
has been necessary, therefore, to analyze and study carefully these waters with a view to reproducing them artificially for the purpose of these tests. Concerning the insulation, delicate questions have arisen as to a standard of durability which shall be commensurate with reasonable cost. These preliminary points are being solved in conference with the manufacturers, and it is expected that the results will soon permit of starting the actual tests.

Safety-Lamp Investigations.—Many so-called safety lamps are on the market, and preliminary tests of them have been made in the lamp gallery, in Building No. 17 (Fig. 2, Plate X). After nearly a year of endeavor to calibrate this gallery, and to co-ordinate its results with those produced in similar galleries in Europe, this preliminary inquiry has been completed, and the manufacturers and agents of all safety lamps have been invited to be present at tests of their products at the Pittsburg laboratory.

A circular dated November 19th, 1909, contains an outline of these tests, which are to be conducted under the direction of Mr. J. W. Paul, an experienced coal-mining engineer and ex-Chief of the Department of State Mine Inspection of West Virginia. The lamps will be subjected to the following tests:

(*a*).—Each lamp will be placed in a mixture of air and explosive natural gas containing 6, 8, and

10% of gas, moving at a velocity of from 200 to 2,500 ft. per min., to determine the velocity of the air current which will ignite the mixture surrounding the lamp. The current will be made to move against the lamp in a horizontal, vertical ascending, and vertical descending direction, and at an angle of 45°, ascending and descending.

(*b*).—After completing the tests herein described, the lamps will be subjected to the tests described under (*a*), with the air and gas mixture under pressure up to 6 in. of water column.

(*c*).—Under the conditions outlined in (*a*), coal dust will be introduced into the current of air and gas to determine its effect, if any, in inducing the ignition of the gas mixture.

(*d*).—Each lamp will be placed in a mixture of air and varying percentages of explosive natural gas to determine the action of the gas on the flame of the lamp.

(*e*).—Each lamp will be placed in a mixture of air and varying percentages of carbonic acid gas to determine the action of the gas on the flame.

(*f*).—Lamps equipped with internal igniters will be placed in explosive mixtures of air and gas 210
in a quiet state and in a moving current, and the effect of the igniter on the surrounding mixture will be observed.

(*g*).—The oils (illuminants) used in the lamps will be tested as to viscosity, gravity, flashing point, congealing point, and composition.

(*h*).—Safety-lamp globes will be tested by placing each globe in position in the lamp and allowing the flame to impinge against the globe for 3 min. after the lamp has been burning with a full flame for 10 min., to determine whether the globe will break.

(*i*).—Each safety-lamp globe will be mounted in a lighted lamp with up-feed, and placed for 5 min. in an explosive mixture of air and gas moving at the rate of 1,000 ft. per min., to determine whether the heat will break the glass and, if it is broken, to note the character of the fracture.

(*j*).—Safety-lamp globes will be broken by impact, by allowing each globe to fall and strike, horizontally, on a block of seasoned white oak, the distance of fall being recorded.

(*k*).—Each safety lamp globe will be mounted in a safety lamp and, when the lamp is in a horizontal position, a steel pick weighing 100 grammes will be permitted to fall a sufficient distance to break the globe by striking its center, the distance of the fall to be recorded.

(*l*).—To determine the candle power of safety lamps, a photometer equipped with a standardized lamp will be used. The candle-power will be determined along a line at right angles to the axis of the flame; also along lines at angles to the axis of the flame both above and below the horizontal. The candle-power will be read after the lamp has been burning 20 min.

(*m*).—The time a safety lamp will continue to burn with a full charge of illuminant will be determined.

(*n*).—Wicks in lamps must be of sufficient length to be at all times in contact with the bottom of the vessel in which the illuminant is contained, and, before it is used, the wick shall be dried to remove moisture.

Mine-Rescue Methods.—Mr. Paul, who has had perhaps as wide an experience as any mining man in the investigation of and in rescue work at mine disasters, is also in charge of the mine-rescue apparatus and training for the Geological Survey. These operations consist chiefly of a 211
thorough test of the various artificial breathing apparatus, or so-called oxygen helmets. Most of these are of European make and find favor in Great Britain, Belgium, France, or Germany, largely according as they are of domestic design and manufacture. As yet nothing has been produced in the United States which fulfills all the requirements of a thoroughly efficient and safe breathing apparatus for use in mine disasters.

At the Pittsburg testing station there are a number of all kinds of apparatus. The tests of these are to determine ease of use, of repair, durability, safety under all conditions, period during which the supply of artificial air or oxygen can be relied on, and other essential data.

In addition to the central testing station, sub-stations for training miners, and as headquarters for field investigation as to the causes of mine disasters and for rescue work in the more dangerous coal fields, have been established; at Urbana, Ill., in charge of Mr. R. Y. Williams, Mining Engineer; at Knoxville, Tenn., in charge of Mr. J. J. Rutledge, Mining Engineer; at McAlester, Okla., in charge of Mr. L. M. Jones, Assistant Mining Engineer; and at Seattle, Wash., in charge of Mr. Hugh Wolflin, Assistant Mining Engineer. Others may soon be established in Colorado and elsewhere, in charge of skilled mining engineers who have been trained in this work at Pittsburg, and who will be assisted by trained miners. It is not to be expected that under any but extraordinary circumstances, such as those which occurred at Cherry, Ill., the few Government engineers, located at widely scattered points throughout the United States, can hope to save the lives of miners after a disaster occurs. As a rule, all who are alive in the mine on such an occasion, are killed within a few hours. This is almost invariably the case after a dust explosion, and is likely to be true after a gas explosion, although a fire such as that at Cherry, Ill., offers the greatest opportunity for subsequent successful rescue operations. The most to be hoped for from the Government engineers is that they shall train miners and be available to assist and advise State inspectors and mine owners, should their services be called for.

It should be borne in mind that the Federal Government has no police duties in the States, and 212
that, therefore, its employees may not direct operations or have other responsible charge in the enforcement of State laws. There is little reason to doubt that these Federal mining engineers, both because of their preliminary education as mining engineers and their subsequent training in charge of mine operations, and more recently in mine-accidents investigations and rescue work, are eminently fitted to furnish advice and assistance on such occasions. The mere fact that, within a year, some of these men have been present at, and assisted in, rescue work or in opening up after disasters at nearly twenty of such catastrophes, whereas the average mining engineer or superintendent may be connected with but one in a lifetime, should make their advice and assistance of supreme value on such occasions. They cannot be held in any way responsible for tardiness, however, nor be unduly credited with effective measures taken after a mine disaster, because of their lack of responsible authority or charge, except in occasional instances where such may be given them by the mine owners or the State officials, from a reliance on their superior equipment for such work.

Successful rescue operations may only be looked for when the time, now believed to be not far distant, has been reached when the mine operators throughout the various fields will have their own rescue stations, as is the practice in Europe, and have available, at certain strategic mines, the necessary artificial breathing apparatus, and have in their employ skilled miners who have been trained in rescue work at the Government stations. Then, on the occurrence of a disaster, the engineer in charge of the Government station may advise by wire all those who have proper equipment or training to assemble, and it may be possible to gather, within an hour or two of a disaster, a sufficiently large corps of helmet-men to enable them to recover such persons as have not been killed before the fire—which usually is started by the explosion—has gained sufficient headway to prevent entrance into the mine. Without such apparatus, it is essential that the fans be started, and the mine cleared of gas. The usual effect of this is to give life to any incipient fire. With the apparatus, the more dense the gas, the safer the helmet-men are from a secondary explosion or from the rapid ignition of a fire, because of the absence of the oxygen necessary to combustion.

The miners who were saved at Cherry, Ill., on November 20th, 1909, owe their lives primarily 213
to the work of the Government engineers. The sub-station of the Survey at Urbana, Ill., was promptly notified of the disaster on the afternoon of November 13th. Arrangements were immediately made, whereby Mr. R. Y. Williams, Mining Engineer in Charge, and his Assistant, Mr. J. M. Webb, with their apparatus, were rushed by special train to the scene, arriving early the following day (Sunday).

Chief Mining Engineer, George S. Rice, Chief of Rescue Division, J. W. Paul, and Assistant Engineer, F. F. Morris, learned of the disaster through the daily press, at their homes in Pittsburg, on Sunday. They left immediately with four sets of rescue apparatus, reaching Cherry on Monday morning. Meantime, Messrs. Williams and Webb, equipped with oxygen helmets, had made two trips into the shaft, but were driven out by the heat. Both shafts were shortly resealed with a view to combating the fire, which had now made considerable headway.

The direction of the operations at Cherry, was, by right of jurisdiction, in charge of the State Mine Inspectors of Illinois, at whose solicitation the Government engineers were brought into conference as to the proper means to follow in an effort to get into the mine. The disaster was not due to an explosion of coal or gas, but was the result of a fire ignited in hay, in the stable within the mine. The flame had come through the top of the air-shaft, and had disabled the ventilating fans. A rescue corps of twelve men, unprotected by artificial breathing apparatus, had entered the mine, and all had been killed. When the shafts were resealed on Monday evening, the 15th, a small hole was left for the insertion of a water-pipe or hose. During the afternoon and evening, a sprinkler was rigged up, and, by Tuesday morning, was in successful operation, the temperature in the shaft at that time being 109° Fahr. After the temperature had been reduced to about 100°, the Federal engineers volunteered to descend into the shaft and make an exploration. The rescue party, consisting of Messrs. Rice, Paul, and Williams, equipped with artificial breathing apparatus, made an exploration near the bottom of the air-shaft and located the first body. After they had returned to the surface, three of the Illinois State Inspectors, who had previously received training by the Government engineers in the use
of the rescue apparatus, including Inspectors Moses and Taylor, descended, made tests of the 214
air, and found that with the fan running slowly, it was possible to work in the shaft. The rescue corps then took hose down the main shaft, having first attached it to a fire engine belonging to the Chicago Fire Department. Water was directed on the fire at the bottom of the shaft, greatly diminishing its force, and it was soon subdued sufficiently to permit the firemen to enter the mine without the protection of breathing apparatus.

Unfortunately, these operations could be pursued only under the most disadvantageous circumstances and surrounded by the greatest possible precautions, due to the frequent heavy falls of roof—a result of the heating by the mine fire—and the presence of large quantities of black-damp. All movements of unprotected rescuers had to be preceded by exploration by the trained rescue corps, who analyzed the gases, as the fire still continued to burn, and watched closely for falls, possible explosions, or a revival of the fire. While the heavy work of shoring up, and removing bodies, was being carried on by the unprotected rescue force, the helmet-men explored the more distant parts of the mine, and on Saturday afternoon, November 20th, one week after the disaster, a room was discovered in which a number of miners, with great presence of mind, had walled themselves in in order to keep out the smoke and heat. From this room 20 living men were taken, of whom 12 were recovered in a helpless condition, by the helmet-men.

This is not the first time this Government mining corps has performed valiant services. Directly and indirectly the members have saved from fifteen to twenty lives in the short time they have been organized. At the Marianna, Pa., disaster, the corps found one man still alive among 150 bodies, and he was brought to the surface. He recovered entirely after a month in the hospital.

At the Leiter mine, at Zeigler, Ill., two employees, who had been trained in the use of the oxygen helmets by members of the Government's corps, went down into the mine, following an explosion, and brought one man to the surface, where they resuscitated him.

Equally good service, either in actual rescue operations, or in explorations after mine disasters, or in fire-fighting, has been rendered by this force at the Darr, Star Junction, Hazel, Clarinda, Sewickley, Berwind-White No. 37, and Wehrum, Pa., mine disasters; at Monongah and Lick Branch, W. Va.; at Deering, Sunnyside, and Shelburn, Ind., Jobs, Ohio, and at Roslyn, Wash.

Explosives Laboratory.—The rooms grouped at the south end of Building No. 21, at Pittsburg, 215
are occupied as a laboratory for the chemical examination and analysis of explosives, and are in charge of Mr. W. O. Snelling.

Samples of all explosives used in the testing gallery, ballistic pendulum, pressure gauge, and other testing apparatus, are here subjected to chemical analysis in order to determine the component materials and their exact percentages. Tests are also made to determine the stability of the explosive, or its liability to decompose at various temperatures, and other properties which are of importance in showing the factors which will control the safety of the explosive during transportation and storage.

In the investigation of all explosives, the first procedure is a qualitative examination to determine what constituents are present. Owing to the large number of organic and inorganic compounds which enter into the composition of explosive mixtures, this examination must be thorough. Several hundred chemical bodies have been used in explosives at different times, and some of these materials can be separated from others with which they are mixed only by the most careful and exact methods of chemical analysis.

Following the qualitative examination, a method is selected for the separation and weighing of each of the constituents previously found to be present. These methods, of course, vary widely, according to the particular materials to be separated, it being usually necessary to devise a special method of analysis for each explosive, unless it is found, by the qualitative analysis, to be similar to some ordinary explosive, in which case the ordinary method of analysis of that explosive can be carried out. Most safety powders require special treatment, while most grades of dynamite and all ordinary forms of black blasting powder are readily analyzed by the usual methods.

The examination of black blasting powder has been greatly facilitated and, at the same time, made considerably more accurate, by means of a densimeter devised at this laboratory. In this apparatus a Torricellian vacuum is used as a means of displacing the air surrounding the grains of powder, and through very simple manipulation the true density of black powder is determined with a high degree of accuracy. In Building No. 17 there is an apparatus for separating or grading the sizes of black powder (Fig. 1, Plate X).

By means of two factors, the moisture coefficient and the hygroscopic coefficient, which have 216
been worked out at this laboratory, a number of important observations can be made on black powder, in determining the relative efficiency of the graphite coating to resist moisture, and also as a means of judging the thoroughness with which the components of the powder are mixed. The moisture coefficient relates to the amount of moisture which is taken up by the grains of the powder in a definite time under standard conditions of saturation; and the hygroscopic coefficient relates to the affinity of the constituents of the powder for moisture under the same standard conditions.

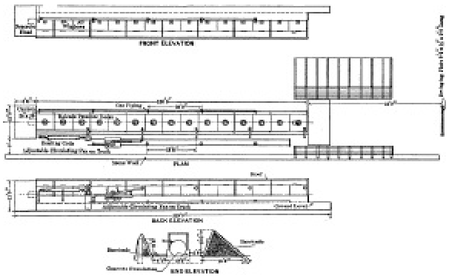
Besides the examination of explosives used at the testing station, those for the Reclamation Service, the Isthmian Canal Commission, and other divisions of the Government, are also inspected and analyzed at the explosives laboratory. At the present time, the Isthmian Canal Commission is probably the largest user of explosives in the world, and samples used in its work are inspected, tested, and analyzed at this laboratory, and at the branch laboratories at Gibbstown and Pompton Lakes, N. J., and at Xenia, Ohio.

Aside from the usual analysis of explosives for the Isthmian Canal Commission, special tests are made to determine the liability of the explosive to exude nitro-glycerine, and to deteriorate in unfavorable weather conditions. These tests are necessary, because of the warm and moist climate of the Isthmus of Panama.

Gas and Dust Gallery No. 1.—Gallery No. 1 is cylindrical in form, 100 ft. long, and has a minimum internal diameter of 6⅓ ft. It consists of fifteen similar sections, each 6⅔ ft. long and built up in in-and-out courses. The first three sections, those nearest the concrete head, are of ½-in. boiler-plate steel, the remaining twelve sections are of ⅜-in. boiler-plate steel, and have a tensile strength of, at least, 55,000 lb. per sq. in. Each section has one release pressure door, centrally placed on top, equipped with a rubber bumper to prevent its destruction when opened quickly. In use, this door may be either closed and unfastened, closed and fastened by stud-bolts, or left open. Each section is also equipped with one ¾-in. plate-glass window, 6 by 6 in., centrally placed in the side of the gallery (Fig. 1, and Figs. 1 and 2, Plate VI). The sections are held together by a lap-joint. At each lap-joint there is, on the interior of the gallery, a 2½-

in. circular, angle iron, on the face of which a paper diaphragm may be placed and held in position by semicircular washers, studs, and wedges. These paper diaphragms are used to assist in confining a gas-and-air mixture. 218

FIG. 1. [217]



EXPLOSIVES TESTING GALLERY No. 1

Natural gas from the mains of the City of Pittsburg is used to represent that found in the mines by actual analysis. A typical analysis of this gas is as follows:

VOLUMETRIC ANALYSIS OF TYPICAL NATURAL GAS.

Hydrogen gases	0
Carbon dioxide	0.1
Oxygen	0
Heavy hydrocarbons	0
Carbon monoxide	0
Methane	81.8
Ethane	16.8
Nitrogen	1.3

The volume of gas used is measured by an accurate test meter reading to one-twentieth of a cubic foot. The required amount is admitted near the bottom, to one or more of the 20-ft. divisions of the gallery, from a 2-in. pipe, 14 ft. long. The pipe has perforations arranged so that an equal flow of gas is maintained from each unit length.

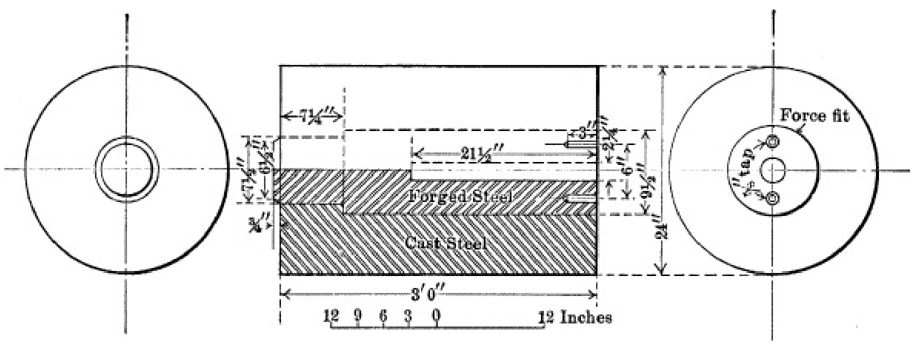
Each 20-ft. division of the gallery is further equipped with an exterior circulating system, as shown by Fig. 1, thus providing an efficient method of mixing the gas with the air. For the first division this circulating system is stationary, a portion of the piping being equipped with heating coils for maintaining a constant temperature.

The other divisions have a common circulating system mounted on a truck which may be used on any of these divisions. Valves are provided for isolating the fan so that a possible explosion will not injure it.

In the center section of each division is an indicator cock which is used to provide means of recording pressures above and below atmospheric, or of sampling the air-and-gas mixture. The first division of the gallery is equipped with shelves laterally placed, for the support of coal dust.

The cannon in which the explosive is fired is placed in the concrete head, the axial line of the bore-hole being coincident with that of the gallery. This cannon (Fig. 2) is similar to that used in the ballistic pendulum. The charge is fired electrically from the observation room. To minimize the risk of loading the cannon, the charger carries in his pocket the plug of a stage 219
switch (the only plug of its kind on the ground), so that it is impossible to complete the circuit until the charger has left the gallery. That portion of the first division of the gallery which is not embedded in concrete, has a 3-in. covering made up of blocks of magnesia, asbestos fiber, asbestos, cement, a thin layer of 8-oz. duck, and strips of water-proof roofing paper, the whole being covered with a thick coat of graphite paint. The object of this covering is to assist in maintaining a constant temperature.

FIG. 2.



The entire gallery rests on a concrete foundation 10 ft. wide, which has a maximum height of

4½ ft. and a minimum height of 2 ft.

The concrete head in which the cannon is placed completely closes that end of the gallery. A narrow drain extends under the entire length of the gallery, and a tapped hole at the bottom of each section provides an efficient means of drainage.

The buildings near the gallery are protected by two barricades near the open end, each 10 ft. high and 30 ft. long. A back-stop, consisting of a swinging steel plate, 6 ft. high and 9 ft. long, 50 ft. from the end of the gallery, prevents any of the stemming from doing damage.

Tests are witnessed from an observation room, a protected position about 60 ft. from the gallery. The walls of the room are 18 in. thick, and the line of vision passes through a ½-in. plate glass, 6 in. wide and 37 ft. long, and is further confined by two external guards, each 37 ft. long and 3 ft. wide.

In this gallery a series of experiments has been undertaken to determine the amount of moisture necessary with different coal dusts, in order to reduce the likelihood of a coal-dust explosion from a blown-out shot of one of the dangerous types of explosives.

Coal dust taken from the roads of one of the coal mines in the Pittsburg district required at 220
least 12% of water to prevent an ignition. It has also been proven that the finer the dust the more water is required, and when it was 100-mesh fine, 30% of water was required to prevent its ignition by the flame of a blown-out shot in direct contact. The methods now used in sprinkling have been proven entirely insufficient for thoroughly moistening the dust, and hence are unreliable in preventing a general dust explosion.

At this station successful experiments have been carried out by using humidifiers to moisten the atmosphere after the temperature of the air outside the gallery has been raised to mine temperature and drawn through the humidifiers. It has been found that if a relative humidity of 90%, at a temperature of 60° Fahr., is maintained for 48 hours, simulating summer conditions in a mine, the absorption of moisture by the dust and the blanketing effect of the humid air prevent the general ignition of the dust.

These humidity tests have been run in Gas and Dust Gallery No. 1 with special equipment consisting of a Koerting exhauster having a capacity of 240,000 cu. ft. per hour, which draws the air out of the gallery through the first doorway, or that next the concrete head in which the cannon is embedded.

The other end of the gallery is closed by means of brattice cloth and paper diaphragms, the entire gallery being made practically air-tight. The air enters the fifteenth doorway through a box, passing over steam radiators to increase its temperature, and then through the humidifier heads.

Explosives Testing Apparatus.

There is no exposed woodwork in Building No. 17, which is 40 by 60 ft., two stories high, and substantially constructed of heavy stone masonry, with a slate roof. The structure within is entirely fire-proof. Iron columns and girders, and wooden girders heavily encased in cement, support the floors which are either of cement slab construction or of wooden flooring protected by expanded metal and cement mortar, both above and beneath. At one end, on the ground floor, is the exposing and recording apparatus for flame tests of explosives, also pressure gauges, and a calorimeter, and, at the other end, is a gallery for testing safety lamps.

The larger portion of the second floor is occupied by a gas-tight training room for rescue work, 221
and an audience chamber, from which persons interested in such work may observe the methods of procedure. A storage room for rescue apparatus and different models of safety lamps is also on this floor.

The disruptive force of explosives is determined in three ways, namely, by the ballistic pendulum, by the Bichel pressure gauge, and by Trauzl lead blocks.

Ballistic Pendulum.—The disruptive force of explosives, as tested by the ballistic pendulum, is measured by the amount of oscillation. The standard unit of comparison is a charge of ½ lb. of 40% nitro-glycerine dynamite. The apparatus consists essentially of a 12-in. mortar (Fig. 3, Plate VI), weighing 31,600 lb., and suspended as a pendulum from a beam having knife-edges. A steel cannon is mounted on a truck set on a track laid in line with the direction of the swing of the mortar. At the time of firing the cannon may be placed 1/16-in. from the muzzle of the mortar. The beam, from which the mortar is suspended, rests on concrete walls, 51 by 120 in. at the base and 139 in. high. On top of each wall is a 1-in. base-plate, 7 by 48 in., anchored to the wall by ⅝-in. bolts, 28 in. long. The knife-edges rest on bearing-plates placed on these base-plates. The bearing-plates are provided with small grooves for the purpose of keeping the knife-edges in oil and protected from the weather. The knife-edges are each 6 in. long, 2 11/16 in. deep from point to back, 2 in. wide at the back, and taper 50° with the horizontal, starting on a line 1½ in. from the back. The point is rounded to conform to a radius of ¼ in. The back of each is 2 in. longer than the edge, making a total length of 10 in., and is 1 in. deep and 12 in. wide. This shoulder gives bolting surface to the beam from which the mortar is hung. The beam is of solid steel, has a 4 by 8-in. section, and is 87 in. long. Heavy steel castings are bolted to it to take the threads of the machine-steel rods which form the saddles on which the mortar is suspended. The radius of the swing, measured from the point of the knife-edges to the center of the trunnions, is 89¾ in.

Plate VI. [opp. 196]

Fig. 1.—Explosion from Coal Dust in Gas and Dust Gallery No. 1.

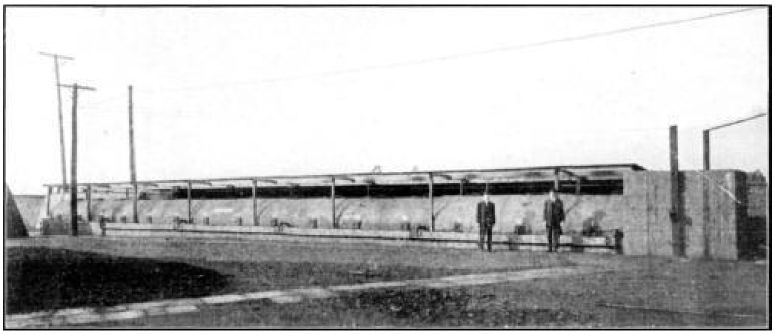


Fig. 2.—Mine Gallery No. 1.

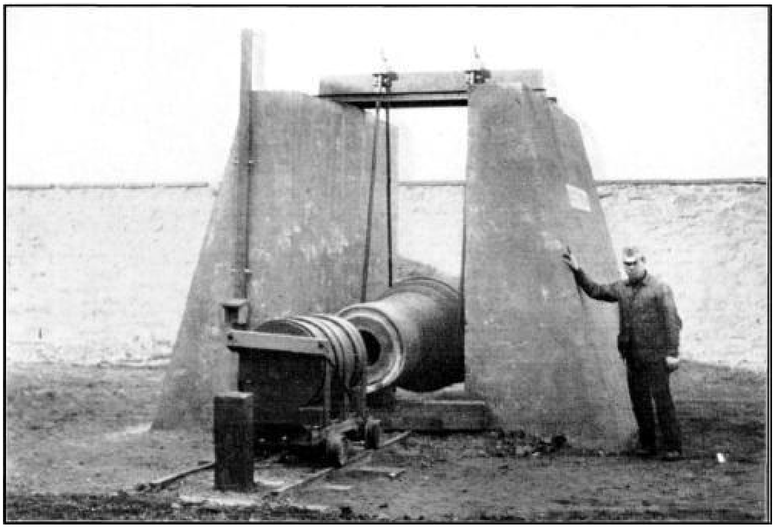


Fig. 3.—Ballistic Pendulum.

The cannon consists of two parts, a jacket and a liner. The jacket is 36 in. long, has an external diameter of 24 in., and internal diameters of 9½ and 7½ in. It is made of the best cast steel or of forged steel.

The liner is 36½ in. long, with a 1-in. shoulder, 7¾ in. from the back, changing the diameter 222
from 9½ to 7½ in. The bore is smooth, being 2¼ in. in diameter and 21½ in. long. The cannon rests on a 4-wheel truck, to which it is well braced by straps and rods. A track of 30-in. gauge extends about 9 ft. from the muzzle of the mortar to the bumper for the cannon.

The shot is fired by an electric firing battery, from the first floor of Building No. 17, about 10 yd. away. To insure the safety of the operator and the charger, the man who loads the cannon carries a safety plug without which the charge cannot be exploded. The wires for connecting to the fuse after charging are placed conveniently, and the safety plug is then inserted in a box at the end of the west wall. The completion of the firing battery by the switch at the firing place is indicated by the flashing of a red light, after which all that is necessary to set off the charge is to press a button on the battery. An automatic recording device at the back of the mortar records the length of swing which, by a vernier, may be read to 1/200 in.

Bichel Pressure Gauges.—Pressure gauges are constructed for the purpose of determining the unit disruptive force of explosives detonating at different rates of velocity, by measuring pressures developed in an enclosed space from which the generated gases cannot escape. The apparatus consists of a stout steel cylinder, which may be made absolutely air-tight; an air-pump and proper connections for exhausting the air in the cylinder to a pressure equivalent to 10 mm. of mercury; an insulated plug for providing the means of igniting the charge; a valve by which the gaseous products of combustion may be removed for subsequent analysis; and an indicator drum (Fig. 1, Plate VII) with proper connections for driving it at a determinable speed.

PLATE VII. [opp. 220]

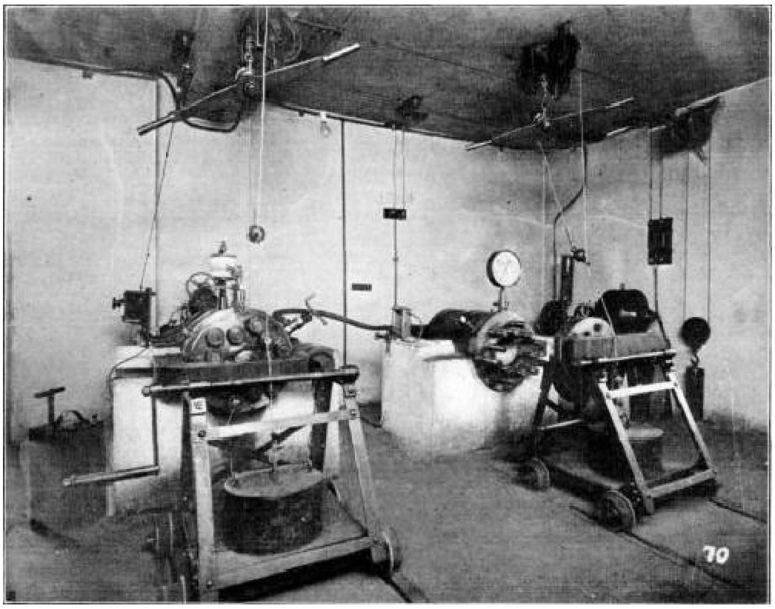


FIG. 1.—BICHEL PRESSURE GAUGES.

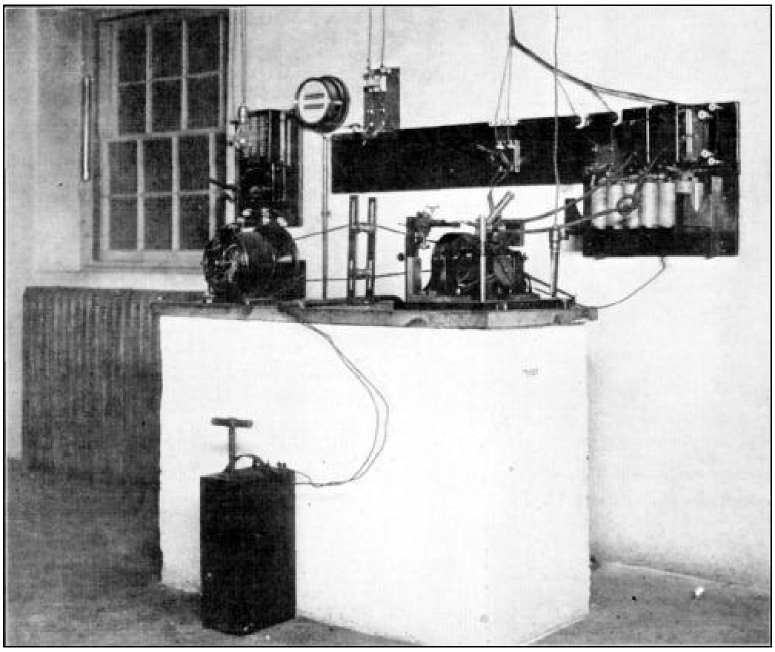


FIG. 2.—RATE OF DETONATION RECORDER.

This apparatus is in the southeast corner of Building No. 17. The cylinder is 31½ in. long, 19¾ in. in diameter, and is anchored to a solid concrete footing at a convenient height for handling. The explosion chamber is 19 in. long and 7⅞ in. in diameter, with a capacity of exactly 15 liters. The cover of the cylinder is a heavy piece of steel held in place by stout screw-bolts and a heavy steel clamp.

The charge is placed on a small wire tripod, and connections are made with a fuse to an electric firing battery for igniting the charges. The cover is drawn tight, with the twelve heavy bolts against lead washers. The air in the cylinder is exhausted to 10 mm., mercury column, in order to approach more closely the conditions of a stemmed charge exploding in a bore-hole 223 inaccessible to air; the indicator drum is placed in position and set in motion; and, finally, the shot is fired. The record shown on the indicator card is a rapidly ascending curve for quick explosives and a shallower, slowly rising curve for explosives of slow detonation. When the gases cool, the curve merges into a straight line, which indicates the pressures of the cooled gases on the sides of the chamber.

Since the ratio of the volume of the cylinder to the volume of the charge may be computed, the pressure of the confined charge may also be found, and this pressure often exceeds 100,000 lb. per sq. in. The cooling effect of the inner surface on the gaseous products of combustion, a vital point in computations of the disruptive force of explosives by this method, is determined by comparing the pressures obtained in the original cylinder with those in a second cylinder of larger capacity, into which has been inserted one or more steel cylinders to increase the superficial area while keeping the volume equal to that of the first cylinders. By comparing results, a curve may be plotted, which will determine the actual pressures developed, with the surface-cooling effect eliminated.

Trauzl Lead Blocks.—The lead-block test is the method adopted by the Fifth International Congress of Applied Chemistry as the standard for measuring the disruptive force of explosives. The unit by this test is defined to be the force required to enlarge the bore-hole in the block to an amount equivalent to that produced by 10 grammes of standard 40% nitro-glycerine dynamite stemmed with 50 grammes of dry sand under standard conditions as produced with the tamping device. The results of this test, when compared with those of the Bichel gauge, indicate that, for explosives of high detonation, the lead block is quite accurate, but for slow explosives, such as gunpowder, the expansion of the gases is not fast enough to make comparative results of value. The reason for this is that the gases escape through the bore of the block rather than take effect in expanding the bore-hole.

The lead blocks are cylindrical, 200 mm. in diameter, and 200 mm. high. Each has a central cavity, 25 mm. in diameter and 125 mm. deep (Fig. 1, Plate IX), in which the charge is placed. The blocks are made of desilverized lead of the best quality, and, as nearly as possible, under identical conditions. The charge is placed in the cavity and prepared for detonation with an
electrical exploder and stemming. After the explosion the bore-hole is pear-shaped, the size of 224
the cavity depending, not only on the disruptive power of the explosive, but also on its rate of detonation, as already indicated. The size of the bore-hole is measured by filling the cavity with water from a burette. The difference in the capacity of the cavity before and after detonation indicates the enlarging power of the explosive.

Calorimeter.—The explosion calorimeter is designed to measure the amount of heat given off by the detonation of explosive charges of 100 grammes. The apparatus consists of the calorimeter bomb (Fig. 1, Plate VIII), the inner receiver or immersion vessel, a wooden tub, a registering thermometer, and a rocking frame. This piece of apparatus stands on the east side of Building No. 17.

The bottle-shaped bomb is made of ½-in. wrought steel, and has a capacity of 30 liters. On opposite sides near the top are bored apertures, one for the exhaust valve for obtaining a partial vacuum (about 20 mm., mercury column) after the bomb has been charged, the other for inserting the plug through which passes the fuse wire for igniting the charge. The bomb is closed with a cap, by which the chamber may be made absolutely air-tight. It is 30 in. high with the cap on, weighs 158 lb., and is handled to and from the immersion vessel by a small crane.

The inner receiver is made of 1/16-in. sheet copper, 30⅞ in. deep, and with an inner diameter of 17⅞ in. It is nickel-plated, and strengthened on the outside with bands of copper wire, and its capacity is about 70 liters. The outer tub is made of 1-in. lumber strengthened with four brass hoops on the outside. It is 33 in. deep, and its inner diameter is 21 in.

The stirring device, operated vertically by an electric motor, consists of a small wooden beam connected to a system of three rings having a horizontal bearing surface. When the apparatus is put together, the inner receiver rests on a small standard on top of the base of the outer tank, and the rings of the stirring device are run between the bomb and the inner receiver. The bomb itself rests on a small standard placed on the bottom of the inner receiver. The apparatus is provided with a snugly fitting board cover. The bomb is charged from the top, the explosive being suspended in its center. The air is exhausted to the desired degree of rarification. The caps are then screwed on, and the apparatus is set together as described.

The apparatus is assembled on scales and weighed before the water is poured in and after the 225
receiver is filled. From the weight of the water thus obtained and the rise of temperature, the calorific value may be computed. The charge is exploded by electricity, while the water is being stirred. The rise in the temperature of the water is read by a magnifying glass, from a thermometer which measures temperature differences of 0.01 degree. From the readings obtained, the maximum temperature of explosion may be determined, according to certain formulas for calorimetric experiments. Proper corrections are made for the effects, on the temperature readings, of the formation of the products of combustion, and for the heat-absorbing power of the apparatus.

Impact Machine.—In Building No. 17, at the south side, is an impact machine designed to gauge the sensitiveness of explosives to shock. For this purpose, a drop-hammer, constructed to meet the following requirements, is used: A substantial, unyielding foundation; minimum friction in the guide-grooves; and no escape or scattering of the explosive when struck by the falling weight. This machine is modeled after one used in Germany, but is much improved in details of construction.

The apparatus, Fig. 1, Plate XI, consists essentially of the following parts: An endless chain working in a vertical path and provided with lugs; a steel anvil on which the charge of explosive is held by a steel stamp; a demagnetizing collar moving freely in vertical guides and provided with jaws placed so that the lugs of the chain may engage them; a steel weight sliding loosely in vertical guides and drawn by the demagnetizing collar to determinable heights when the machine is in operation; a second demagnetizing collar, which may be set at known heights, and provided with a release for the jaws of the first collar; and a recording device geared to a vertically-driven threaded rod which raises or lowers, sets the second demagnetizing collar, and thus determines the height of fall of the weight. By this apparatus the weight may be lifted to different known heights, and dropped on the steel stamp which transmits the shock to the explosive. The fall necessary to explode the sample is thus determined.

The hammers are of varying weight, the one generally used weighing 2,000 grammes. As the sensitiveness of an explosive is influenced by temperature changes, water at 25° cent. is allowed to flow through the anvil in order to keep its temperature uniform.

Flame Test.—An apparatus, Fig. 2, Plate VIII, designed to measure the length and duration of flames given off by explosives, is placed at the northeast corner of Building No. 17. It consists essentially of a cannon, a photographing device, and a drum geared for high speed, to which a sensitized film may be attached. 226

PLATE VIII. [opp. 222]

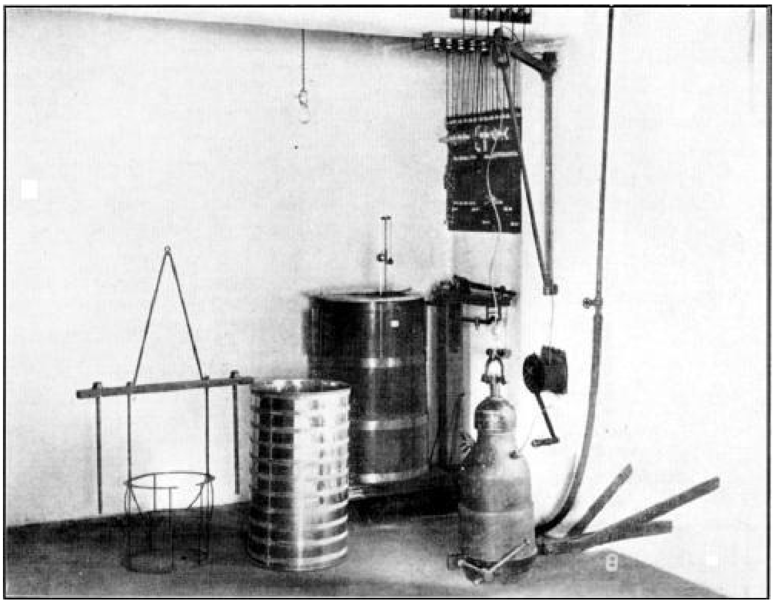


FIG. 1.—EXPLOSIVES CALORIMETER.

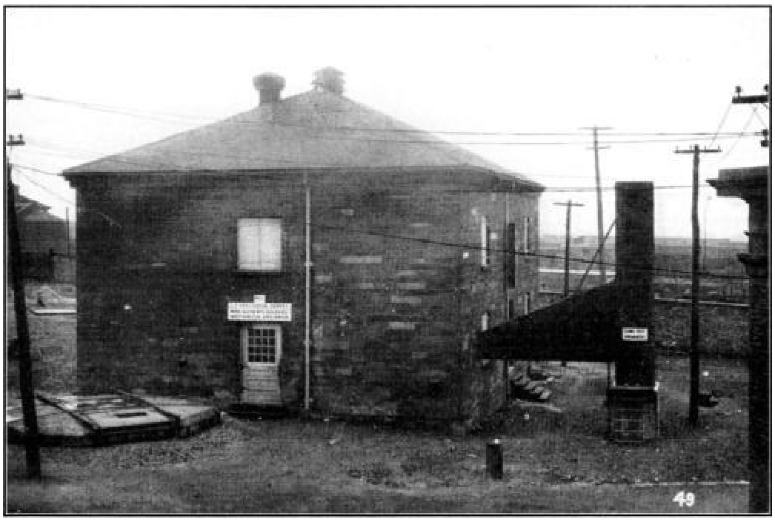


FIG. 2.—BUILDING NO. 17, AND FLAME-TEST APPARATUS.

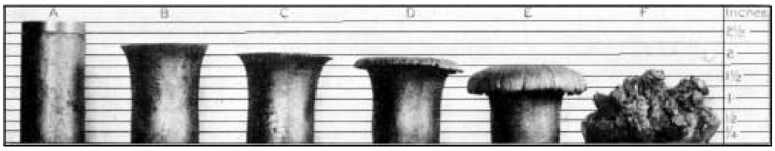


FIG. 3.—SMALL LEAD BLOCK TEST.

About 13 ft. outside the wall of Building No. 17, set in a concrete footing, is a cannon pointing vertically into an encasing cylinder or stack, 20 ft. high and 43 in. in diameter. This cannon is a duplicate of the one used for the ballistic pendulum, details of which have already been given. The stack or cylinder is of ¼-in. boiler plate, in twenty-four sections, and is absolutely tight against light at the base and on the sides. It is connected with a dark room in Building No. 17 by a light-tight conduit of rectangular section, 12 in. wide, horizontal on the bottom, and sloping on the top from a height of 8¼ ft. at the stack to 21 in. at the inside of the wall of the building.

The conduit is carefully insulated from the light at all joints, and is riveted to the stack. A vertical slit, 2 in. wide and 8 ft. long, coincident with the center line of the conduit, is cut in the stack. A vertical plane drawn through the center line of the bore-hole of the cannon and that of the slit, if produced, intersects the center line of a quartz lens, and coincides with the center of a stenopaic slit and the axis of the revolving drum carrying the film. The photographing apparatus consists of a shutter, a quartz lens, and a stenopaic slit, 76 by 1.7 mm., between the lens and the sensitized film on the rotary drum. The quartz lens is used because it will focus the ultra-violet rays, which are those attending extreme heat.

The drum is 50 cm. in circumference and 10 cm. deep. It is driven by a 220-volt motor connected to a tachometer which reads both meters per second and revolutions per minute. A maximum peripheral speed of 20 m. per sec. may be obtained.

When the cannon is charged, the operator retires to the dark room in which the recording apparatus is located, starts the drum, obtains the desired speed, and fires the shot by means of a battery. When developed, the film shows a blur of certain dimensions, produced by the flame from the charge. From the two dimensions—height and lateral displacement—the length and duration of the flame of the explosive are determined.

The results of flame tests of a permissible explosive and a test of black blasting powder, all shot without stemming, are shown on Fig. 2, Plate IX. In this test, the speed of the drum 227
carrying the black powder negative was reduced to one sixty-fourth of that for the permissible explosives, in order that the photograph might come within the limits of the negative. In other words, the duration of the black powder flame, as shown, should be multiplied by 64 for comparison with that of the permissible explosive, which is from 3,500 to 4,000 times quicker.

PLATE IX. [opp. 224]

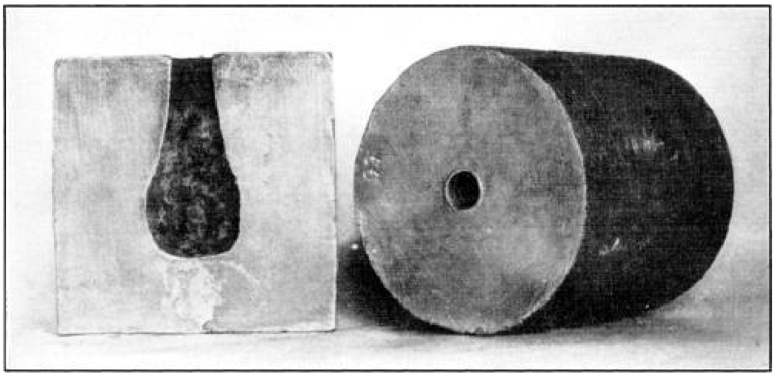


FIG. 1.—TRAUZL LEAD BLOCKS.

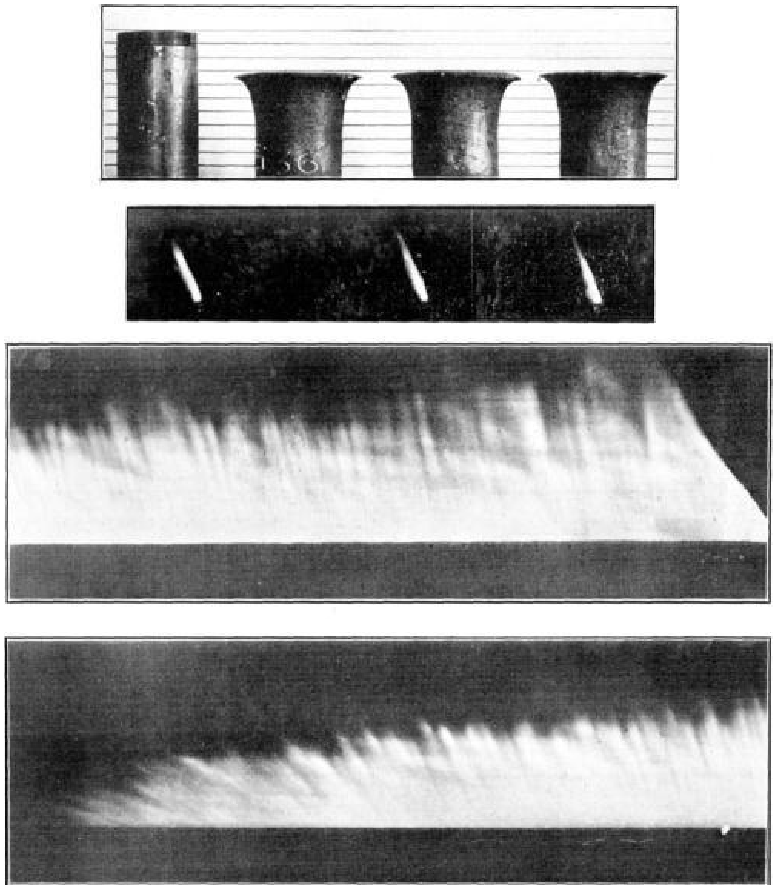


FIG. 2.—POWDER FLAMES.

Apparatus for Measuring Rate of Detonation.—The rate at which detonation travels through a given length of an explosive can be measured by an apparatus installed in and near Building No. 17. Its most essential feature is a recording device, with an electrical connection, by which very small time intervals can be measured with great exactness.

The explosive is placed in a sheet-iron tube about 1½ in. in diameter and 4 ft. long, and suspended by cords in a pit, 11 ft. deep and 16 ft. in diameter. This pit was once used as the well of a gas tank, Fig. 2, Plate VIII. In adapting the pit to its new use, the tank was cut in two; the top half, inverted, was placed in the pit on a bed of saw-dust, and the space between the tank and the masonry walls of the pit was filled with saw-dust. The cover of the pit consists of heavy timbers framed together and overlaid by a 12-in. layer of concrete reinforced by six **I**-beams. Four straps extend over the top and down to eight “deadmen” planted about 8 ft. below the surface of the ground.

The recording device, known as the Mettegang recorder, Fig. 2, Plate VII, comprises two sparking induction coils and a rapidly revolving metallic drum driven by a small motor, the periphery of the drum having a thin coating of lampblack. A vibration tachometer which will indicate any speed between 50 and 150 rev. per sec., is directly connected to the drum, so that any chance of error by slipping is eliminated. The wires leading to the primary coils of the sparking coils pass through the explosive a meter or more apart. Wires lead from the secondary coils to two platinum points placed a fraction of a millimeter from the periphery of the drum. A separate circuit is provided for the firing lines.

In making a test, the separate cartridges, with the paper trimmed from the ends, are placed, end to end, in the sheet-iron tube; the drum is given the desired peripheral speed, and the charge is exploded. The usual length between the points in the tube is 1 m., and the time required for the detonation of a charge of that length is shown by the distance between the 228
beginning of two rows of dots on the drum made by the sparks from the secondary coil circuits, the dots starting the instant the primary circuits are broken by the detonation. At one end of the drum are gear teeth, 1 mm. apart on centers, which can be made to engage a worm revolving a pointer in front of a dial graduated to hundredths; by means of this and a filar eyepiece, the distance between the start of the two rows of spark dots on the drum can be measured accurately to 0.01 mm. As the drum is 500 mm. in circumference, and its normal speed is 86 rev. per sec., it is theoretically possible to measure time to one four-millionth of a second, though with a cartridge 1 m. long, such refinement has not been found necessary.

The use of small lead blocks affords another means of determining the rate of detonation or quickness of an explosive. Each block (a cylinder, 2½ in. long and 1½ in. in diameter) is enclosed in a piece of paper so that a shell is formed above the block, in which to place the charge. A small steel disk of the same diameter as the block is first placed in the shell on top of the block, then the charge with a detonator is inserted. The charge is customarily 100 grammes. On detonation of the charge, a deformation of the lead takes place, the amount of which is due to the quickness of the explosive used (Fig. 3, Plate VIII).

Sample Record of Tests.

The procedure followed in the examination of an explosive is shown by the following outline:

1.—*Physical Examination.*

(*a*).—Record of appearance and marks on original package.

(*b*).—Dimensions of cartridge.

(*c*).—Weight of cartridge, color and specific gravity of powder.

2.—*Chemical Analysis.*

(*a*).—Record of moisture, nitro-glycerine, sodium or potassium nitrate, and other chemical constituents, as set forth by the analysis; percentage of ash, hygroscopic coefficient—the amount of water taken up in 24 hours in a saturated atmosphere, at 15° cent., by 5 grammes, as compared with the weight of the explosive.

(*b*).—Analysis of products of combustion from 100 grammes, including gaseous products, solids, and water.

(*c*).—Composition of gaseous products of combustion, including carbon monoxide and 229
carbon dioxide, hydrogen, nitrogen, etc.

(*d*).—Composition of solid products of combustion, subdivided into soluble and insoluble.

3.—A Typical Analysis of Natural Gas.

Used in tests, as follows:

Carbon dioxide	0.0	per cent.
Heavy hydrocarbons	0.2	” ”
Oxygen	0.1	” ”
Carbon monoxide	0.0	” ”
Methane	82.4	” ”
Ethane	15.3	” ”
Nitrogen	2.0	” ”
	100.00	per cent.

4.—Typical Analysis of Bituminous Coal Dust, 100-Mesh Fine, Used in Tests.

Moisture	1.90
Volatile matter	35.05
Fixed carbon	58.92
Ash	4.13
	100.00
Sulphur	1.04

5.—An Average Analysis of Detonators.

Used on Trauzl lead blocks, pressure gauge, calorimeter, and small lead blocks:

$M - 1 \frac{l}{m}$. Triple-strength exploder.

Charge	1.5729 grammes.		
		Mercury fulminate.	Chlorate of potash.
Specification		89.73	10.27

Used on all other tests:

$M - 260 \frac{l}{m}$. Double-strength exploder.

Charge	0.9805 grammes.		
		Mercury fulminate.	Chlorate of potash.
Specification		91.31	8.69

6.—Ballistic-Pendulum Tests. 230

This record includes powder used, weight of charge, swing of mortar, and unit disruptive charge, the latter being the charge required to produce a swing of the mortar equal to that produced by ½ lb. (227 grammes) of 40% dynamite, or 3.01 in.

7.—Record of Tests.

Tests Nos. 1 to 5 in Gallery No. 1, as set forth in preceding circular.

8.—Trauzl Lead-Block Test.

Powder and test numbers, expansion of bore-hole in cubic centimeters, and average expansion compared with that produced by a like quantity (10 grammes) of 40% dynamite, the latter giving an average expansion of 294 cu. cm.

9.—Pressure Gauge.

Powder and test number, weight of charge, charging density, height of curve, pressure developed, and pressure developed after cooling, compared with pressure developed after elimination of surface influences by a like quantity (100 grammes) of 40% dynamite, the average being 8,439 kg. per sq. cm.

10.—Rate of Detonation.

Powder and test number, size of cartridge, and rate of detonation in meters per second, for comparison with rate of detonation of 40% dynamite, which, under the same conditions, averages 4,690 m. per sec.

11.—Impact Machine.

Explosive and test numbers, distance of fall (2,000-gramme weight) necessary to cause explosion, for comparison with length of fall, 11 cm., necessary to cause explosion of 40% dynamite.

12.—Distance of Explosive Wave Transmitted by 1.25 by 8-in. Cartridge.

Explosive and test numbers, weight of cartridge, distance separating cartridges in tests, resulting explosion or non-explosion, for comparison with two cartridges of 40% dynamite, hung, under identical conditions, 13 in. apart, end to end, in which case detonation of the first cartridge will explode the second.

13.—Flame Test.

Explosive and test numbers, charge 100 grammes with 1 lb. of clay stemming, average length of flame and average duration of flame, for comparison with photographs produced by 40% dynamite under like conditions.

14.—Small Lead Blocks. 231

Powder and test numbers, weight of charge, and compression produced in blocks.

15.—Calories Developed.

Number of large calories developed per kilogramme of explosive, for comparison with 1,000 grammes of 40% dynamite, which develop, on an average, 1,229 large calories.

Blasting Powder Separator.

The grains of black blasting powder are graded by a separator, similar to those used in powder mills, but of reduced size. It consists of an inclined wooden box, with slots on the sides to carry a series of screens, and a vertical conduit at the end for carrying off the grains as they are screened into separate small bins (Fig. 1, Plate X). At the upper end of the screens is a small 12 by 16-in. hopper, with a sliding brass apron to regulate the feed. The screens are shaken laterally by an eccentric rod operated by hand. The top of the hopper is about 6½ ft. above the floor. The box is 6 ft. 10 in. long, from tip to tip, and inclines at an angle of 9 degrees.

PLATE X.

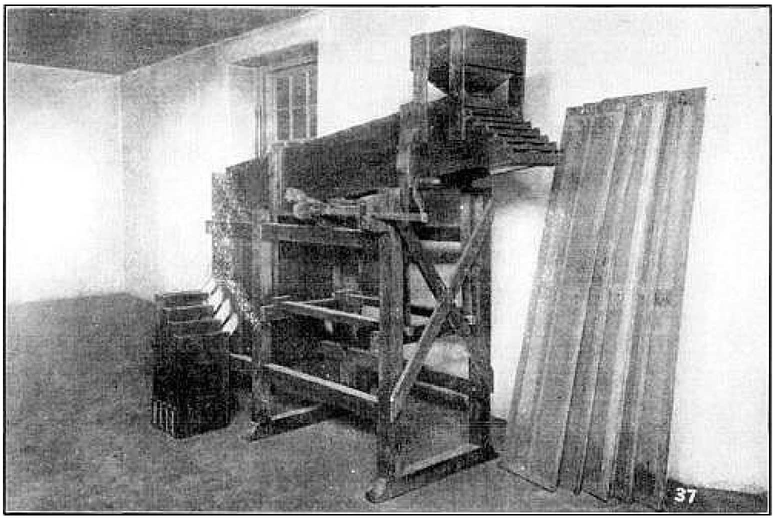


FIG. 1.—SEPARATOR FOR GRADING BLACK POWDER.

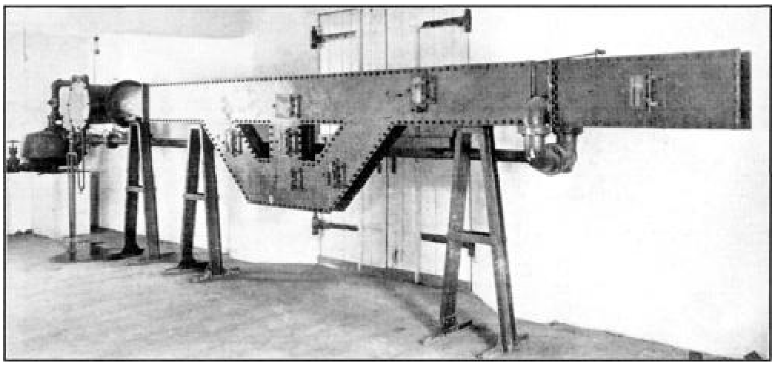


FIG. 2.—SAFETY LAMP TESTING GALLERY.

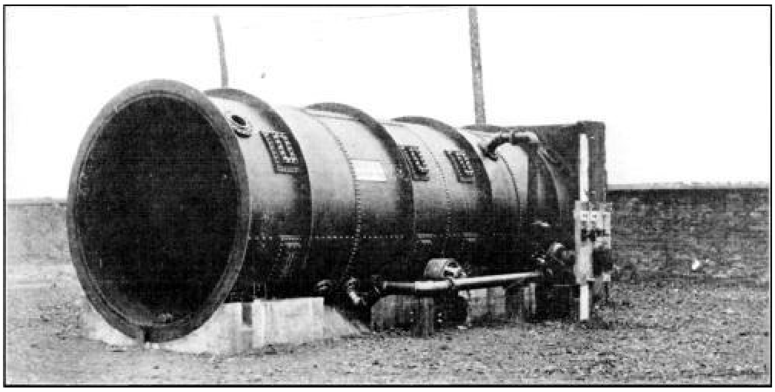


FIG. 3.—MINE GALLERY NO. 2.

After separation the grains fall through a vertical conduit, and thence to the bins through zinc chutes, 1 by 2 in. in section. Care is taken to have no steel or iron exposed to the powder.

The screens are held by light wooden frames which slip into the inclined box from the upper end. In this way, any or all of the screens may be used at once, thus separating all grades, or making only such separations as are desired. The screens with the largest meshes are diagonally-perforated zinc plates. Table 2 gives the number of holes per square foot in zinc plates perforated with circular holes of the diameters stated.

TABLE 2.—NUMBER OF HOLES PER SQUARE FOOT IN ZINC PLATES WITH CIRCULAR PERFORATIONS.

Diameter, in inches	Number of holes.
1/2	353
4/10	518
1/3	782
1/4	1,392
1/6	1,680
1/8	3,456
1/10	6,636
1/16	12,800

The finer meshes are obtained by using linen screens with holes of two sizes, namely, 1/20 in. square and 1/28 in. square.

Until a few years ago, black blasting powder was manufactured in the sizes given in Table 3. 232

TABLE 3.—Gradation of Black Blasting Powder.

Grade.	Mesh.
CC	2-2½
C	2½-3
F	3-5
FF	5-8
FFF	8-16
FFFF	16-28

In late years there has been considerable demand for special sizes and mixed grains for individual mines, especially in Illinois. As no material change has been made in the brands, the letters now used are not indicative of the size of the grains, which they are supposed to represent. Of 29 samples of black blasting powder recently received from the Illinois Powder Commission, only 10 were found to contain 95% of the size of grains they were supposed to represent; 4 contained 90%; 7 varied from 80 to 90%; several others were mixtures of small and large grains, and were branded FF black blasting powder; and one sample contained only 8.5% of the size of grains it was supposed to represent. The remaining samples showed many variations, even when sold under the same name. The practice of thus mixing grades is exceedingly dangerous, because a miner, after becoming accustomed to one brand of FF powder of uniform separation, may receive another make of similar brand but of mixed grains, and, consequently, he cannot gauge the quantity of powder to be used. The result is often an over-load or a blown-out shot. The smaller grains will burn first, and the larger ones may be thrown out before combustion is complete, and thus ignite any fire-damp present.

Plate XI. [opp. 232]

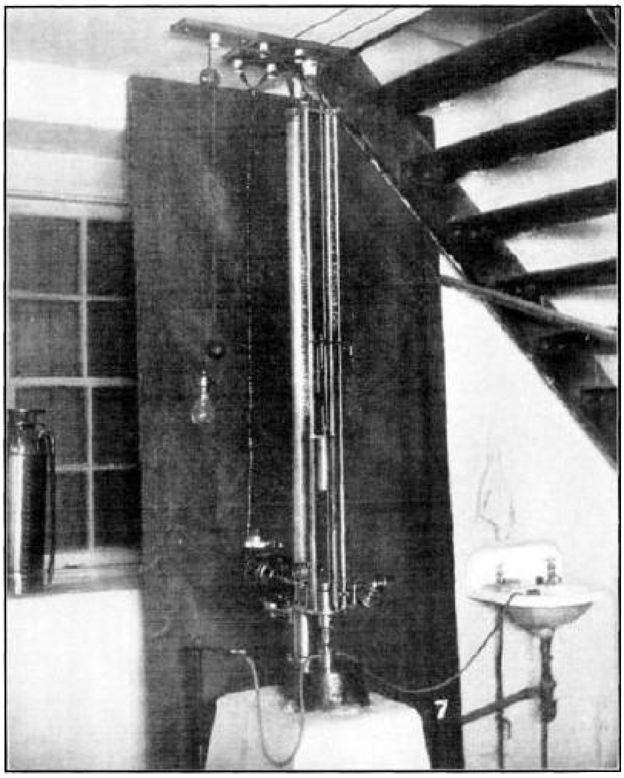


Fig. 1.—Impact Machine.

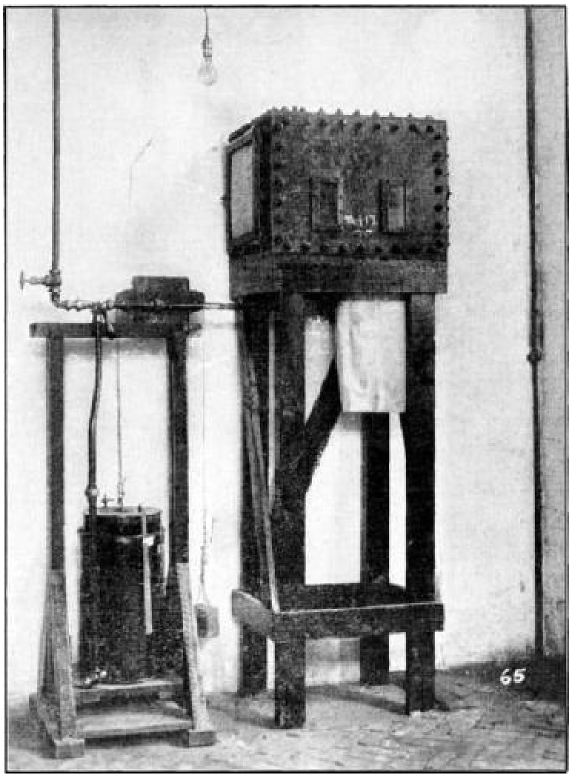


FIG. 2.—LAMP TESTING BOX.

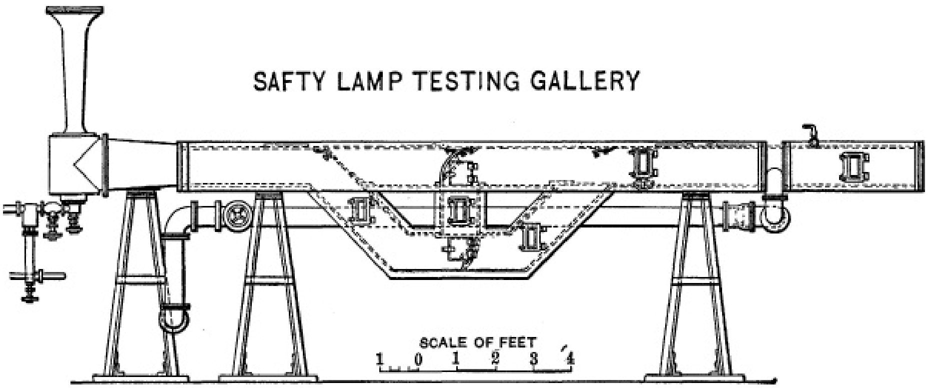
Lamp Testing Gallery.

At the Pittsburg testing station, there is a gallery for testing safety lamps in the presence of various percentages of inflammable gas. In this gallery the safety of the lamps in these gaseous mixtures may be tested, and it is also possible for mine inspectors and fire bosses to bring their safety lamps to this station, and test their measurements of percentage of gas, by noting the length and the appearance of the flame in the presence of mixtures containing known percentages of methane and air.

The gas-tight gallery used for testing the lamps, consists of a rectangular conduit (Fig. 2, 233
Plate X), having sheet-steel sides, 6 mm. thick and 433 mm. wide, the top and bottom being of channel iron. The gallery rests on two steel trestles, and to one end is attached a No. 5 Koerting exhauster, capable of aspirating 50 cu. m. per min., under a pressure of 500 mm. of water, with the necessary valve, steam separator, etc. The mouth of the exhauster passes through the wall of the building and discharges into the open air.

Besides the main horizontal conduit, there are two secondary conduits connected by a short horizontal length, and the whole is put together so that the safety lamp under test may be placed in a current of air, or of air and gas, which strikes it horizontally, vertically upward or downward, or at an angle of 45° (Fig. 3). The path of the current is determined by detachable sheet-steel doors.

FIG. 3.



There are five double observing windows of plate glass, which open on hinges. The size of each window is 7½ by 3 in.; the inner glass is ¼ in. thick and the outer one, ½ in. thick. These glasses are separated by a space of ¼ in. The upper conduit has four safety doors along the top, each of the inclined conduits has one safety door, and the walls and windows are provided with rubber gaskets or asbestos packing, to make them gas-tight. The cross-sectional area of the conduit is 434 sq. cm.

The air inlet consists of 36 perforations, 22 mm. in diameter, in a bronze plate or diaphragm. The object of this diaphragm is to produce pressure in the conduit before the mixing boxes, and permit the measuring of the velocity of the current. The air-current, after passing through 234 the holes, enters the mixer, a cast-steel box traversed by 36 copper tubes, each perforated by 12 openings, 3 mm. in diameter, arranged in a spiral along its length and equally spaced. The total cross-sectional area of the tubes is 137 sq. cm.

The explosive gas enters the interior of the box around the tubes through large pipes, each 90 mm. in diameter, passes thence through the 432 openings in the copper tubes, and mixes thoroughly with the air flowing through these tubes. The current through the apparatus is induced by the exhauster, and its course is determined by the position of the doors.

The gallery can be controlled so as to provide rapidly and easily a current of known velocity and known percentage of methane. In the explosive current of gas and air, safety lamps of any size or design can be tested under conditions simulating those found occasionally in mines, air-currents containing methane in dangerous proportions striking the lamps at different angles, and the relative safety of the various types of lamps under such conditions can be determined. In this gallery it is also possible to test lighting devices either in a quiet atmosphere or in a moving current, and, by subjecting the lamps to air containing known percentages of methane, it is possible to acquaint the user with the appearance of the flame caps.

Breathing Apparatus.

With this apparatus, the wearer may explore a gaseous mine, approach fires for the purpose of fighting them, or make investigations after an explosion. Its object is to provide air or oxygen to be breathed by the wearer in coal mines, when the mine air is so full of poisonous gases as to render life in its presence impossible.

A variety of forms of rescue helmets and apparatus are on the market, almost all of European manufacture, which are being subjected to comparative trials as to their durability and safety, the ease or inconvenience involved in their use, etc. All consist essentially of helmets which fit air-tight about the head, or of air-tight nose clamps and mouthpieces (Fig. 1, Plate XII).

These several forms of breathing apparatus are of three types:

1.—The liquid-air type, in which air, in a liquid state, evaporates and provides a constant supply of fresh air.

2.—The chemical oxygen-producing type, which artificially makes or supplies oxygen for breathing at about the rate required; and,

3.—The compressed-oxygen type. 235

Apparatus of the first type, weighing 20 lb., supplies enough air to last about 3 hours, and the products of breathing pass through a check-valve directly into space. Apparatus of the second type supplies oxygen obtained from oxygen-producing chemicals, and also provides means of absorbing the carbonic acid gas produced in respiration. They contain also the requisite tubes, valves, connections, etc., for the transmission of the fresh air and the respired air so as to produce sufficient oxygen while in use; to absorb and purify the products of expiration; and to convey the fresh air to the mouth without contamination by the atmosphere in which the apparatus is used. Three oxygen-generating cartridges are provided, each supplying oxygen enough for 1 hour, making the total capacity 3 hours. Changes of cylinders can be made in a few seconds while breathing is suspended. This apparatus weighs from 20 to 25 lb., according to the number of oxygen generators carried. The cartridges for generating oxygen, provided with this apparatus, are of no value after having been used for about an hour.

The third type of apparatus is equipped with strong cylinders charged with oxygen under high pressure; two potash regenerative cans for absorbing the carbon dioxide gas exhaled; a facial helmet; the necessary valves, tubes, etc., for the control of the oxygen; and a finimeter which registers the contents of the cylinders in atmospheres and minutes of duration. The two cartridges used for absorbing the carbonic acid gas are of no value after having been in use for two hours.

If inhalation is through the mouth alone, a mouthpiece is attached to the end of the breathing tube by which the air or oxygen is supplied, the nose is closed by a clip, and the eyes are protected by goggles. To inhale through both nose and mouth, the miner wears a helmet or headgear which can be made to fit tightly around the face. The helmet has two tubes attached, one for inspiration and the other for expiration. In the oxygen-cylinder apparatus these tubes lead to and from rubber sacks used for pure-air and bad-air reserves.

Mine-Rescue Training.

It has been found in actual service that when a miner, equipped with breathing apparatus for the first time, enters a mine in which an explosion has occurred, he is soon overcome by excitement or nervousness induced by the artificial conditions of breathing imposed by the 236
apparatus, the darkness and heat, and the consciousness that he is surrounded with poisonous gases. It has also been found that a brief period of training in the use of such apparatus, under conditions simulating those encountered in a mine after a disaster, gives the miner confidence and enables him to use the apparatus successfully under the strain of the vigorous exertion incident to rescue work.

The rescue corps consists of five or six miners under the direction of a mining engineer who is experienced in rescue operations and familiar with the conditions existing after mine disasters. The miners work in pairs, so that one may assist the other in case of accident, or of injury to the breathing apparatus, and so that each may watch the condition of the oxygen supply, as shown by the gauges in the other’s outfit.

The training is given in the gas-tight room of Building No. 17, or in similar rooms at sub-stations (Fig. 2, Plate XII). This room is made absolutely dark, and is filled with formaldehyde gas, SO_2, CO_2, or CO, produced by burning sulphur or charcoal on braziers. At each period of training, the miners enter and walk a distance of about 1 mile, the average distance usually traveled from the mine mouth to the working face or point of explosion. They then remove a number of timbers; lift a quantity of brick or hard lump-coal into wheel-barrows; climb through artificial tunnels, up and down inclines, and over surfaces strewn with coal or stone; operate a machine with a device attached to it, which automatically records the foot-pounds of work done; and perform other vigorous exercise, during a period of 2 hours. This routine is repeated daily during 1 week, after which the rescue corps is considered sufficiently trained for active service.

Plate XII. [opp. 234]

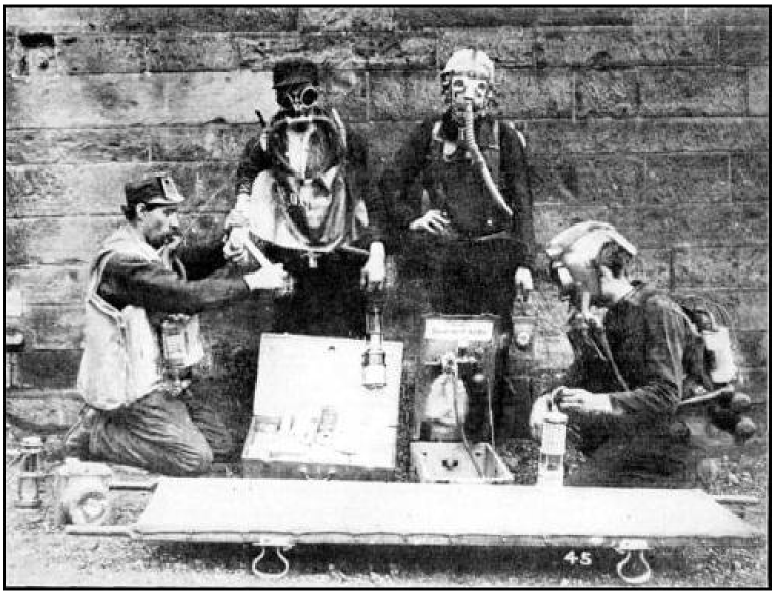


Fig. 1.—Breathing and Rescue Apparatus.

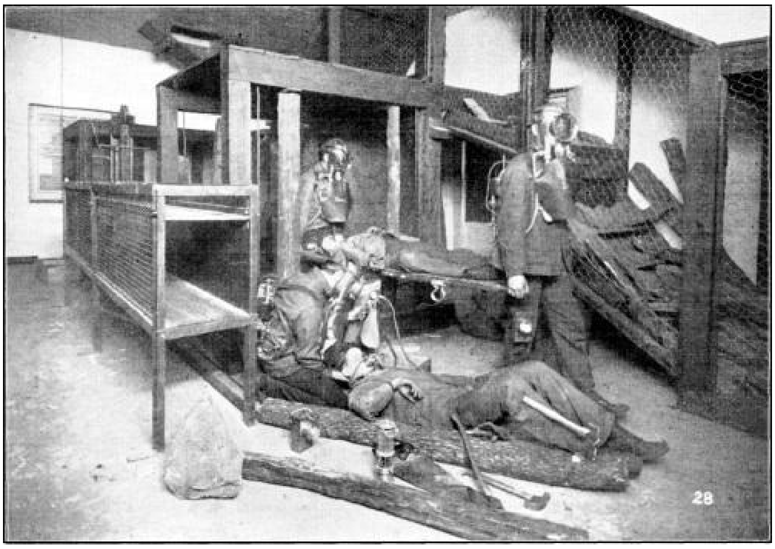


Fig. 2.—Rescue Training Room.

The apparatus used for recording the foot-pounds of work done by the person operating the work machine within the gas-tight rescue room, comprises a small dial with electrical connections, which records the number of strokes made by the machine, and a pencil point which rests on a paper diaphragm, fastened to a horizontal brass disk. This disk is driven by clockwork, and makes one complete revolution per hour. When the machine is in operation, the pencil point works back and forth, making a broad line on the paper; when the operator of the machine rests, the pencil point traces a single line. The apparatus thus records the number of 237
strokes given by the operator during a given time. From the weight lifted, the height of lift, and the number of strokes in the given time, the foot-pounds of work are readily calculated.

Electric Testing Apparatus.

On the ground floor of Building No. 10, two rooms are occupied as laboratories for investigating the electrical equipment used in mining operations. The purpose of these investigations is to ascertain the conditions under which electricity of various voltages may be used with safety—in mine haulage, hoisting, pumping, or lighting—in the presence of dangerous mixtures of explosive gases or of dust. It is also proposed to test various kinds of insulation and insulators in this laboratory, and to determine the durability of such insulation in the presence of such corrosive gases and water as are found in mines.

A water-proof wooden tank, measuring 15 by 5 by 5 ft., is installed, in which insulation and insulating materials are tested under either pure or polluted water. Various electric lighting devices and equipment can be connected from a switch-board in Building No. 17 with Gas-and-Dust Gallery No. 2, for testing the effect of such lighting apparatus in the presence of explosive mixtures of gas and dust, as set forth on page 220.

In the electrical laboratory, Building No. 10, is a booster set developing 60 kw., and an appropriate switch-board for taking direct current at 220 volts from the turbo-generator and converting it into current varying from 0 to 750 volts. There are also transformers for developing 60-cycle, alternating current at voltages of from 110 to 2,200. The switch-board is designed to handle these various voltages and to communicate them to the apparatus under test in Building No. 10, Gallery No. 2, or elsewhere.

Tests are in progress of insulating materials for use in mines, and of electric fuses, lights, etc., in Gallery No. 2 (Fig. 3, Plate X), and in the lamp-testing box (Fig. 2, Plate XI). It is proposed, at the earliest possible date, to make comparative tests of the safety of various mine locomotives and mine-hoisting equipment through the medium of this laboratory, and it is believed that the results will furnish valuable information as a guide to the safety, reliability, and durability of these appliances when electrically operated.

Electric Lamp and Fuse Testing Box.—An apparatus for testing safety lamps and electric lights 238
and fuses, consists of ¼-in. iron plates, bolted together with 1½ in. angle-irons to form a box with inside dimensions of 18 by 18 by 24 in. The box is placed on a stand at such a height that the observation windows are on a level with the observer's eye (Fig. 2, Plate XI), and it is connected, by a gas-pipe, with a supply of natural gas which can be measured by a gas-holder or meter alongside the box.

By the use of this apparatus the effect of explosive gas on flames, of electric sparks on explosive mixtures of gas and air, and of breaking electric lamps in an explosive mixture of gas and air, may be studied. The safety lamps are introduced into the box from beneath, through a hole 6 in. square, covered with a hinged iron lid, admission to which is had through a flexible rubber sleeve, 20 in. long.

The behavior of the standard safety lamp and of the safety lamps undergoing test may be compared in this box as to height of flame for different percentages of methane in the air, the effect of such flames in igniting gas, etc.

In each end of the box is an opening 1 ft. square, over which may be placed a paper diaphragm held by skeleton doors, the purpose of which is to confine the gas in such a manner that, should an explosion occur, no damage would be done. In the front of the box are two plate-glass observing windows, 2⅝ by 5½ in. In the side of the box, between the two windows, is a ⅜-in. hole, which can be closed by a tap-screw, through which samples for chemical analysis are drawn.

The gasometer consists of two iron cans, the lower one being open at the top and filled with water and the upper one open at the bottom and suspended by a counterweight. The latter has attached to its upper surface a scale which moves with it, thereby measuring the amount of gas in the holder. A two-way cock permits the admission of gas into the gasometer and thence into the testing box.

Gas-and-Dust Gallery No. 2.—This gallery is constructed of sheet steel and is similar to Gallery No. 1, the length, however, being only 30 ft. and the diameter 10 ft. It rests on a concrete foundation (Fig. 3, Plate X). Diaphragms can be placed across either extremity, or at various sections, to confine the mixtures of gas and air in which the tests are made. The admission of gas is controlled by pipes and valves, and the gas and air can be stirred or mixed by a fan, as described for Gallery No. 1, and as shown by Fig. 1.

Gallery No. 2 is used for investigating the effect of flames of various lamps, of electric 239
currents, motors, and coal-cutting machines, in the presence of known mixtures of explosive gas and air. It is also used for testing the length of flame of safety lamps in still air carrying various proportions of methane, and, for this purpose, is more convenient than the lamp gallery. In tests with explosive mixtures, after the device to be tested has been introduced and preparations are completed, operations are controlled from a safe distance by a switch-board in a building near-by.

Among other investigations conducted in this gallery are those of the effect of sparks on known gas mixtures. These sparks are such as those struck from a pick on flint, but in this case they are produced by rubbing a rapidly revolving emery wheel against a steel file. The effect of a spark produced by a short circuit of known voltage, the flame from an arc lamp, etc., may also be studied in this gallery.

Structural Materials Investigations.

The structural materials investigations are being conducted for the purpose of determining the nature and extent of the materials available for use in the building and construction work of the Government, and how these materials may be used most efficiently.

These investigations include:

(1).—Inquiries into the distribution and local availability, near each of the building centers in the United States, of such materials as are needed by the Government.

(2).—How these materials may be used most efficiently.

(3).—Their fire-resisting qualities and strength at different temperatures.

(4).—The best and most economic methods of protecting steel by fire-resistant covering.

(5).—The most efficient methods of proportioning and mixing the aggregate, locally available, for different purposes.

(6).—The character and value of protective coatings, or of various mixes, to prevent deterioration by sea water, alkali, and other destructive agencies.

(7).—The kinds and forms of reinforcement for concrete necessary to secure the greatest strength in beams, columns, floor slabs, etc.

(8).—Investigation of the clays and of the products of clays needed in Government works, as to
their strength, durability, suitability as fire-resisting materials, and the methods of analyzing 240
and testing clay products.

(9).—Tests of building stones, and investigations as to their availability near the various building centers throughout the United States.

The operations of the Structural Materials Division include investigations into cement-making materials, constituent materials of concrete, building stones, clays, clay products, iron, steel, and miscellaneous materials of construction, for the use of the Government. The organization comprises a number of sections, including those for the chemical and physical examination of Departmental purchases; field sampling and laboratory examination of constituent materials of concrete collected by skilled field inspectors in the neighborhood of the larger commercial and building centers; similar field sampling of building stones and of clays and clay products, offered for use in Government buildings or engineering construction; and the forwarding of such samples to the testing laboratories at St. Louis or Pittsburg for investigation and test. The investigative tests include experiments regarding destructive agencies, such as electrolysis, alkaline earths and waters, salt water, fire, and weathering; also experiments with protective and water-proofing agencies, including the various washes or patented mixtures on the market, and the methods of washing, and mixing mortars and concrete, which are likely to result in rendering such materials less pervious to water.

Investigations are also being conducted to determine the nature and extent of materials available for use in the building-construction work of the Government, and how these materials may be used most efficiently and safely. While the act authorizing this work does not permit investigations or tests for private parties, it is believed that these tests for the Government cannot fail to be of great general value. The aggregate expenditure by the Federal Government in building and engineering construction is about $40,000,000 annually. This work is being executed under so many different conditions, at points so widely separated geographically, and requires so great a variety of materials, that the problems to be solved for the Government can hardly fail to cover a large share of the needs of the Engineering Profession, State and municipal governments, and the general public.

Character of the Work.—The tests and analyses, of the materials of construction purchased by the various bureaus and departments for the use of the Government, are to determine the
character, quality, suitability, and availability of the materials submitted, and to ascertain data 241
leading to more accurate working values as a basis for better working specifications, so as to enable Government officials to use such materials with more economy and increased efficiency.

Investigative tests of materials entering into Government construction, relative to the larger problems involved in the use of materials purchased by the Government, include exhaustive study of the suitability for use, in concrete construction on the Isthmian Canal, of the sand and stone, and of the cementing value of pozzuolanic material, found on the Isthmus; the strength, elasticity, and chemical properties of structural steel for canal lock-gates; of wire rope and cables for use in hoisting and haulage; and the most suitable sand and stone available for concrete and reinforced concrete for under-water construction, such as the retaining walls being built by the Quartermaster’s Department of the Army, in San Francisco Harbor.

These tests also include investigations into the disintegrating effect of alkaline soil and water on the concrete and reinforced concrete structures of the Reclamation Service, with a view to preventing such disintegration; investigations into the proper proportions and dimensions of concrete and reinforced concrete structural columns, beams, and piers, and of walls of brick and of building stone, and of the various types of metal used for reinforcement by the Supervising Architect in the construction of public buildings; investigations into the sand, gravel, and broken stone available for local use in concrete construction, such as columns, piers, arches, floor slabs, etc., as a guide to the more economical design of public structures, and to determine the proper method of mixing the materials to render the concrete most impervious to water and resistant to weather and other destructive agencies.

Other lines of research may be stated briefly as follows:

The extent to which concrete made from cement and local materials can be most safely and efficiently used for different purposes under different conditions;

The best methods for mixing and utilizing the various constituent materials locally available for use in Government construction;

The materials suitable for the manufacture of cement on the public lands, or where the Government has planned extensive building or engineering construction work, where no cement plants now exist;

The kinds and forms of reinforcement for concrete, and the best methods of applying them in 242
order to secure the greatest strength in compression, tension, shear, etc., in reinforced concrete beams, columns, floor slabs, etc.;

The influence of acids, oils, salts, and other foreign materials, long-continued strain, or electric currents, on the permanence of the steel in reinforced concrete;

The value of protective coatings as preventives of deterioration of structural materials by destructive agencies; and

The establishment of working stresses for various structural materials needed by the Government in its buildings.

Investigations are being made into the effects of fire and the rate of conductivity of heat on concrete and reinforced concrete, brick, tile, building stone, etc., as a guide to the use of the most suitable materials for fire-proof building construction and the proper dimensioning of fire-resistive coverings.

Investigations and tests are being made, with a view to the preparation of working specifications for use in Government construction, of bricks, tile, sand-lime brick, paving brick, sewer pipe, roofing slates, flooring tiles, cable conduits, electric insulators, architectural terra cotta, fire-brick, and all shapes of refractories and other clay products, regarding which no satisfactory data for the preparation of specifications of working values now exist.

Investigations of the clay deposits throughout the United States are in progress, to determine proper methods of converting them into building brick, tile, etc., at the most reasonable cost, and the suitability of the resulting material for erection in structural forms and to meet building requirements.

Investigations are being made in the field, of building stones locally available, and physical and chemical tests of these building stones to determine their bearing or crushing strength; the most suitable mortars for use with them; their resistance to weathering; their fire-resistive and fire-proof qualities, etc., regarding which practically no adequate information is available as a guide to Government engineering and building design.

Results Accomplished.—During one period of six months alone, more than 2,500 samples, taken from Government purchases of structural materials, were examined, of which more than 300 failed to meet the specified requirements, representing many thousands of dollars worth
of inferior material rejected, which otherwise would have been paid for by the Government. 243
These tests were the means of detecting the inferior quality of large quantities of materials delivered on contracts, and the moral effect on bidders has proven as important a factor in the maintenance of a high quality of purchases, as in the saving of money.

The examination of sands, gravels, and crushed stones, as constituent materials for concrete and reinforced concrete construction, has developed data showing that certain materials, locally available near large building centers and previously regarded as inferior in quality, were, in fact, superior to other and more expensive materials which it had been proposed to use.

These investigations have represented an actual saving in the cost of construction on the work of the Isthmian Canal Commission, of the Supervising Architect, and of certain States and cities which have benefited by the information disseminated regarding these constituent materials.

Investigations of clay products, only recently inaugurated, have already resulted in the ascertainment of important facts relative to the colloid matter of clay and its measurement, and the bearing thereof on the plasticity and working values of various clays. The study of the preliminary treatment of clays difficult to handle dry, has furnished useful information regarding the drying of such clays, and concerning the fire resistance of bricks made of soft, stiff, or dried clay of various densities.

The field collection and investigation of building-stone samples have developed some important facts which had not been considered previously, relative to the effect of quarrying, in relation to the strike and dip of the bedding planes of building stone, and the strength and durability of the same material when erected in building construction. These investigations have also developed certain fundamental facts relative to the effects of blasting (as compared with channeling or cutting) on the strength and durability of quarried building stone.

Mineral Chemistry Laboratories.—Investigations and analyses of the materials of engineering and building construction are carried on at Pittsburg in four of the larger rooms of Building No. 21. In this laboratory, are conducted research investigations into the effect of alkaline waters and soils on the constituent materials of concrete available in arid regions, as related to the life and permanency of the concrete and reinforced concrete construction of the
Reclamation Service. These investigations include a study of individual salts found in particular 244
alkalis, and a study of the results of allowing solutions of various alkalis to percolate through cylinders of cement mortar and concrete. Other research analyses have to do with the investigation of destructive and preservative agencies for concrete, reinforced concrete, and similar materials, and with the chemistry of the effects of salt water on concrete, etc. The routine chemical analyses of the constituent materials of concrete and cement-making

materials, are made in this laboratory, as are also a large number of miscellaneous chemical analyses and investigations of reinforcement metal, the composition of building stones, and allied work.

A heat laboratory, in charge of Dr. J. K. Clement, occupies three rooms on the ground floor of Building No. 21, and is concerned chiefly with the measurement of temperatures in gas producers, in the furnaces of steam boilers, kilns, etc. The work includes determinations of the thermal conductivity of fire clays, concrete, and other building materials, and of their fire-resisting properties; measurements of the thermal expansion and specific heats of fire-bricks, porcelain, and glazes; and investigations of the effect of temperature variations on the various chemical processes which take place in the fuel bed of the gas producer, boiler furnace, etc.

The heat laboratory is equipped for the calibration of the thermometers and pyrometers, and electrical and other physical apparatus used by the various sections of the Technologic Branch.

For convenience in analyzing materials received from the various purchasing officers attached to the Government bureaus, this work is housed in a laboratory on the fourth floor of the Geological Survey Building in Washington.

Large quantities and many varieties of building materials for use in public buildings under contract with the Supervising Architect's office, are submitted to the laboratory by contractors to determine whether or not they meet the specified requirements. Further examinations are made of samples submitted by superintendents of construction, representing material actually furnished by contractors. It is frequently found that the sample of material submitted by the contractor is of far better quality than that sent by the superintendent to represent deliveries. The needed constant check on deliveries is thus provided.

In addition to this work for the office of the Supervising Architect, similar work on purchases 245
and supplies is carried on for the Isthmian Canal Commission, the Quartermaster-General's Department of the Army, the Life Saving Service, the Reclamation Service, and other branches of the Government. About 300 samples are examined each month, requiring an average of 12 determinations per sample, or about 3,600 determinations per month.

The chemical laboratory for testing Government purchases of structural materials is equipped with the necessary apparatus for making the requisite physical and chemical tests. For the physical tests of cement, there are a tensile test machine, briquette moulds, a pat tank for boiling tests to determine soundness, water tanks for the storage of briquettes, a moist oven, apparatus to determine specific gravity, fineness of grinding, etc.

The chemical laboratory at Washington is equipped with the necessary analytical balances, steam ovens, baths, blast lamps, stills, etc., required in the routine chemical analysis of cement, plaster, clay, bricks and terra cotta, mineral paints and pigments, roofing material, tern plate and asphaltic compounds, water-proofing materials, iron and steel alloys, etc.

At present, materials which require investigative tests as a basis for the preparation of suitable specifications, tests not connected with the immediate determination as to whether or not the purchases are in accordance with the specifications, are referred to the chemical laboratories attached to the Structural Materials Division, at Pittsburg.

The inspection and tests of cement purchased in large quantities, such as the larger purchases on behalf of public-building construction under the Supervising Architect, or the great 4,500,000-bbl. contract of the Isthmian Canal Commission, are made in the cement-testing laboratory of the Survey, in the Lehigh Portland cement district, at Northampton, Pa.

Testing Machines.—The various structural forms into which concrete and reinforced concrete may be assembled for use in public-building construction, are undergoing investigative tests as to their compressive and tensile strength, resistance to shearing, modulus of elasticity, coefficient of expansion, fire-resistive qualities, etc. Similar tests are being conducted on building stone, clay products, and the structural forms in which steel and iron are used for building construction.

The compressive, tensile, and other large testing machines, for all kinds of structural materials 246
reaching the testing stations, are under the general supervision of Richard L. Humphrey, M. Am. Soc. C. E. The immediate direction of the physical tests on the larger testing machines is in charge of Mr. H. H. Kaplan.

Most of this testing apparatus, prior to 1909, was housed in buildings loaned by the City of St. Louis, in Forest Park, St. Louis, Mo., and the arrangement of these buildings, details of equipment, organization, and methods of conducting the tests, are fully set forth in Bulletin No. 329 of the U. S. Geological Survey. In brief, this equipment included motor-driven, universal, four-screw testing machines, as follows: One 600,000-lb., vertical automatic, four-screw machine; one 200,000-lb., automatic, four-screw machine; and one 200,000-lb. and one 100,000-lb. machine of the same type, but with three screws. There are a number of smaller machines of 50,000, 40,000, 10,000, and 2,000 lb., respectively.

These machines are equipped so that all are available for making tensile and compressive tests (Fig. 1, Plate XIII). The 600,000-lb. machine is capable of testing columns up to 30-ft. lengths, and of making transverse tests of beams up to 25-ft. span, and tension tests for specimens up to 24 ft. in length. The smaller machines are capable of making tension and compressive tests up to 4 ft. in length and transverse beam tests up to 12 ft. span. In addition, there are ample subsidiary apparatus, including concrete mixers with capacities of ½ and 1 cu. yd., five hollow concrete block machines, automatic sifting machines, briquette moulds, storage tanks, etc.

PLATE XIII.

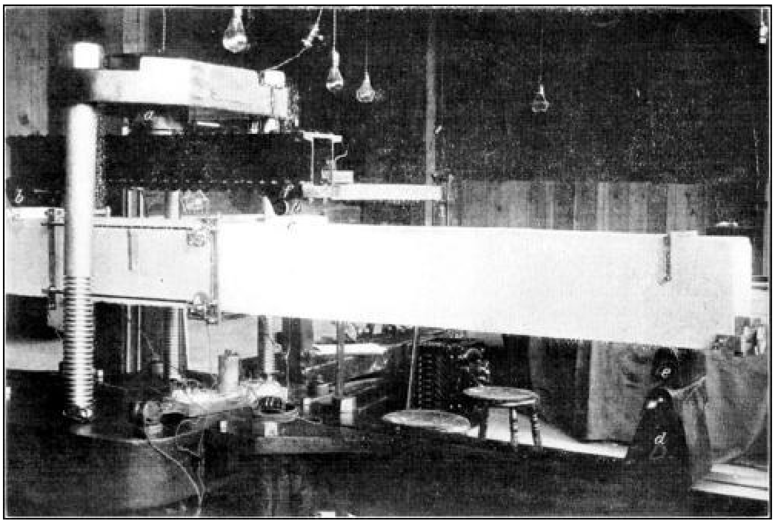


FIG. 1.—TESTING BEAM IN 200,000-LB. MACHINE.

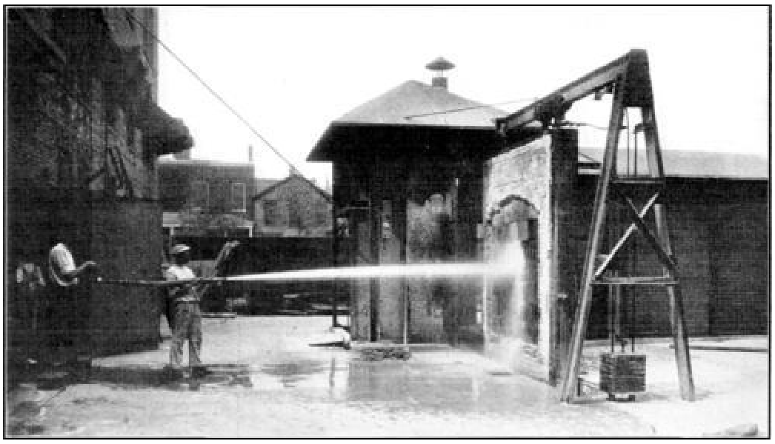
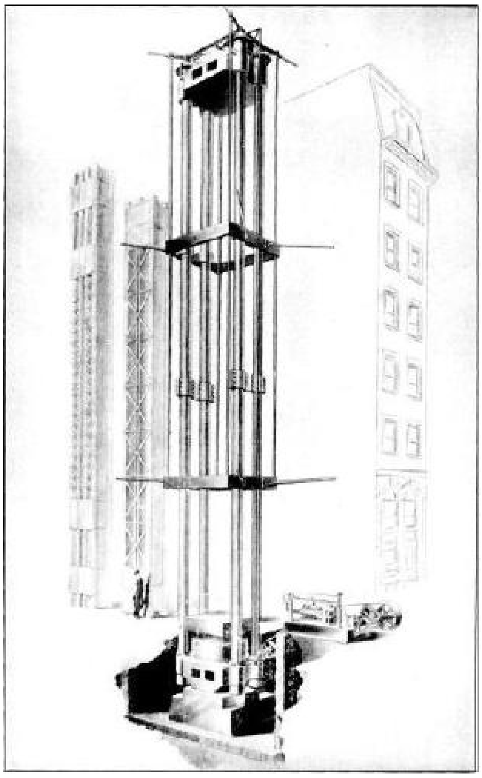


FIG. 2.—FIRE TEST OF PANEL.

At the Atlantic City sub-station, there is also a 200,000-lb., universal, four-screw testing machine, with miscellaneous equipment for testing cement and moulding concrete, etc.; and at the Northampton sub-station, there is a complete equipment of apparatus for cement testing, capable of handling 10,000 bbl. per day.

At the Pittsburg testing station, a 10,000,000-lb., vertical, compression testing machine (Plate XIV), made by Tinius Olsen and Company, is being erected for making a complete series of comparative tests of various building stones of 2, 4, and 12-in. cube, of stone prisms, 12 in. base and 24 in. high, of concrete and reinforced concrete columns up to 65 ft. in height, and of brick piers and structural-steel columns up to the the limits of the capacity and height of the machine.

PLATE XIV.

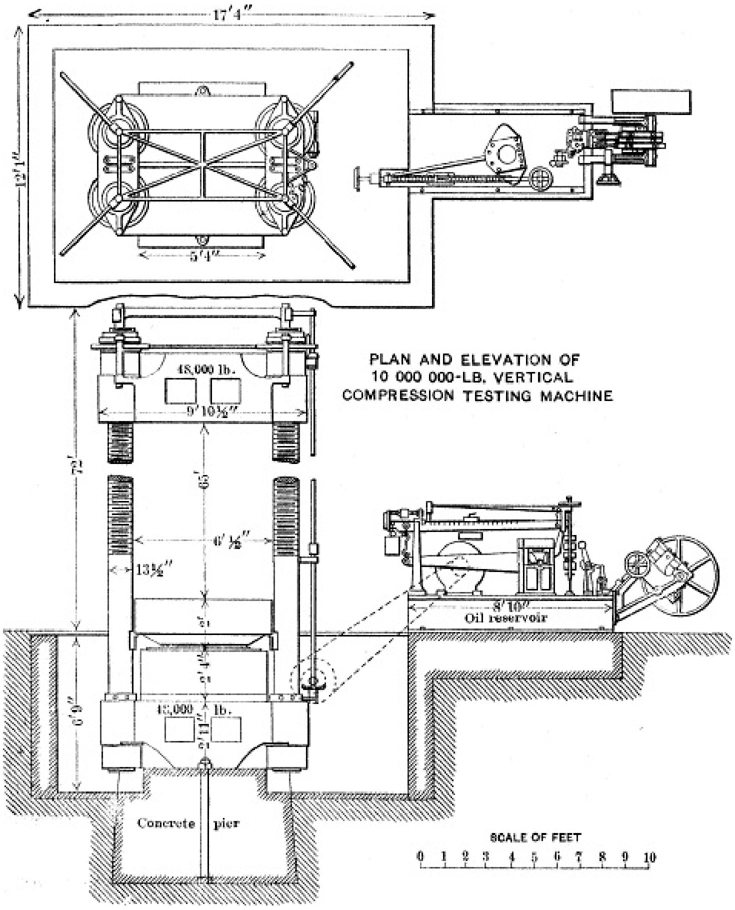


10,000,000-Lb. Testing Machine.

This machine is a large hydraulic press, with an adjustable head, and a weighing system for recording the loading developed by a triple-plunger pump. It has a maximum clearance of 65 ft. between heads; the clearance in the machine is a trifle more than 6 ft. between screws, and the heads are 6 ft. square. 247

The machine consists of a base containing the main cylinder, with a sectional area of 2,000 sq. in., upon which rests the lower platform or head, which is provided with a ball-and-socket bearing. The upper head is adjustable over four vertical screws, 13½ in. in diameter and 72 ft. 2 in. long, by a system of gearing operating four nuts with ball-bearings upon which the head rests. The shafting operating this mechanism is connected with a variable-speed motor which actuates the triple-plunger pump supplying the pressure to the main cylinder (Fig. 4).

Fig. 4.



The weighing device consists of a set of standard Olsen levers for weighing one-eightieth of the total load on the main cylinder. This reduction is effected through the medium of a piston and a diaphragm. The main cylinder has a diameter of 50 in., and the smaller one, a diameter of 5 9/16 in. The weighing beam is balanced by an automatically-operated poise weight, and is provided with a device for applying successive counterweights of 1,000,000 lb. each. Each division on the dial is equivalent to a 100-lb. load, and smaller subdivisions are made possible by an additional needle-beam.

The power is applied by a 15-h.p., 220-volt, variable-speed motor operating a triple-plunger pump, the gearing operating the upper head being driven by the same motor. The extreme length of the main screws necessitates splicing, which is accomplished as follows:

In the center of the screws, at the splice, is a 3-in. threaded pin for centering the upper and lower screws; this splice is strengthened by sleeve nuts, split to facilitate their removal whenever it is necessary to lower the upper head; after the head has passed the splice, the sleeve nuts are replaced.

In order to maintain a constant load, a needle-valve has been provided, which, when the pump is operated at its lowest speed, will allow a sufficient quantity of oil to flow into the main cylinder to equalize whatever leakage there may be. The main cylinder has a vertical movement of 24 in. The speed of the machine, for the purpose of adjustment, using the gearing
attached to the upper head, is 10 in. per min. The speed for applying loads, controlled by the 248
variable-speed motor driving the pump, varies from a minimum of at least 1/60 in. per min. to a maximum of at least ½ in. per min. The machine has a guaranteed accuracy of at least one-third of 1%, for any load of more than 100,000 lb., up to its capacity.

The castings for the base and the top head weigh approximately 48,000 lb. each. Each main screw weighs more than 40,000 lb., the lower platform weighing about 25,000 lb., and the
main cylinder, 16,000 lb. The top of the machine will be about 70 ft. above the top of the floor, 249
and the concrete foundation, upon which it rests, is about 8 ft. below the floor line.

Concrete and Cement Investigations.—The investigations relating to concrete include the examination of the deposits of sand, gravel, stone, etc., in the field, the collection of representative samples, and the shipment of these samples to the laboratory for analysis and test. These tests are conducted in connection with the investigation of cement mortars, made from a typical Portland cement prepared by thoroughly mixing a number of brands, each of which must meet the following requirements:

Specific gravity, not less than 3.10;

Fineness, residue not to exceed 8% on No. 100, nor 25% on No. 200 sieve;

Time of setting: Initial set, not less than 30 min.; hard set, not less than 1 hour, nor more than 10 hours.

Tensile strength: Requirements applying to neat cement and to 1 part cement with 3 parts standard sand:

Time specification.	Neat cement. Pounds.	1:3 Mix. Pounds.
24 hours in moist air	175	...
7 days (1 day in moist air, 6 days in water)	500	175
28 days (1 day in moist air, 27 days in water)	600	250

Constancy of volume: Pats of neat cement, 3 in. in diameter, ½ in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours. A pat is kept in air at normal temperature and observed at intervals for at least 28 days. Another pat is kept in water maintained as near 70° Fahr. as practicable, and is observed at intervals for at least 28 days. A third pat is exposed in an atmosphere of steam above boiling water, in a loosely-closed vessel, for 5 hours. These pats must remain firm and hard and show no signs of distortion, checking, cracking, or disfiguration.

The cement shall not contain more than 1.75% of anhydrous sulphuric acid, nor more than 4% of magnesium oxide.

A test of the neat cement must be made with each mortar series for comparison of the quality of the typical Portland cement.

The constituent materials are subjected to the following examination and determinations, and, in addition, are analyzed to determine the composition and character of the stone, sand, etc.:

1.—Mineralogical examination,

2.—Specific gravity,

3.—Weight, per cubic foot, 250

4.—Sifting (granulometric composition),

5.—Percentage of silt and character of same,

6.—Percentage of voids,

7.—Character of stone as to percentage of absorption, porosity, permeability, compressive strength, and behavior under treatment.

Physical tests are made to determine the tensile, compressive, and transverse strengths of the cement and mortar test pieces, with various preparations of cement and various percentages of material. Tests are also made to determine porosity, permeability, volumetric changes in setting, absorption, coefficient of expansion, effect of oil, etc.

Investigation of concretes made from mixtures of typical Portland cement, sand, stone, and gravel, includes tests on cylinders, prisms, cubes, and other standard test pieces, with various proportions of materials and at ages ranging from 30 to 360 days. Full-sized plain concrete beams, moulded building blocks, reinforced concrete beams, columns, floor slabs, arches, etc., are tested to determine the effect, character, and amount of reinforcement, the effect of changes in volume, size, and composition, and the effect of different methods of loading and of supporting these pieces, etc.

These investigations include detailed inquiry in the field and research in the chemical and physical laboratories regarding the effects of alkaline soils and waters on structures of concrete being built by the Reclamation Service in the arid regions. It has been noted that on certain of the Reclamation projects, notably on the Sun River Project, near Great Falls, Mont., the Shoshone Project, near Cody, Wyo., and the Carlsbad and Hondo Projects in the Pecos Valley, N. Mex., structures of concrete, reinforced concrete, building stones, brick, and tile, show evidence of disintegration. This is attributed to the effects of alkaline waters or soils coming into contact with the structures, or to the constituent materials used. In co-operation with the Reclamation Service, samples of the waters, soils, and constituent materials, are collected in the field, and are subjected to careful chemical examination in the mineral laboratories at Pittsburg.

PLATE XV. [opp. 250]

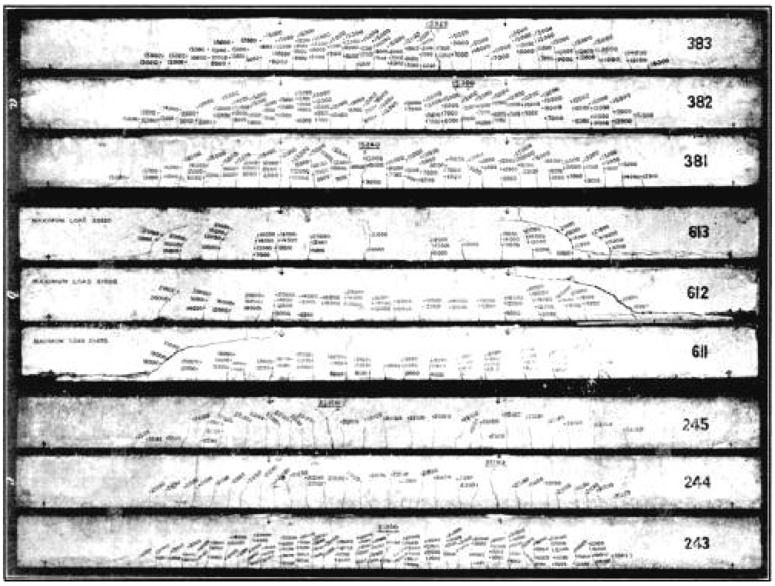


FIG. 1.—CHARACTERISTIC FAILURES OF REINFORCED CONCRETE BEAMS.

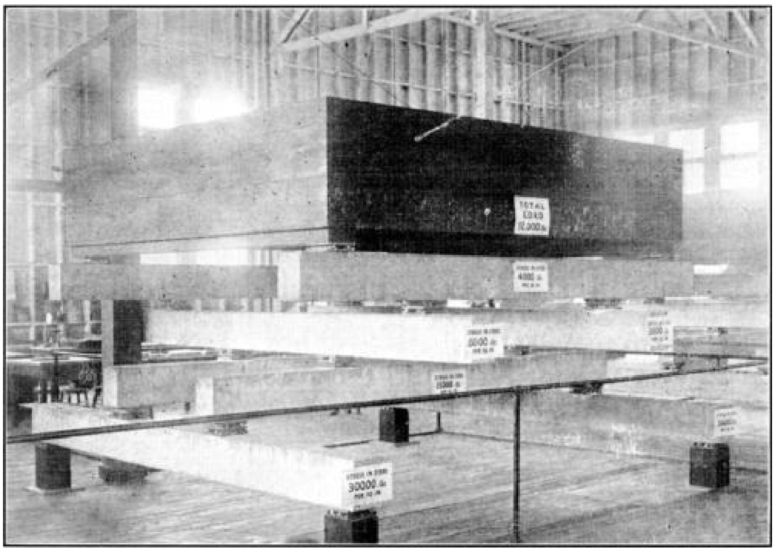


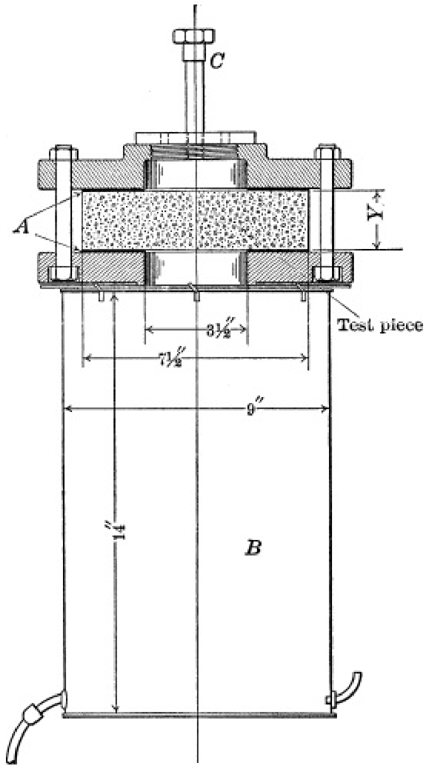
FIG. 2.—ARRANGEMENT OF STATIC LOAD TEST FOR REINFORCED CONCRETE BEAMS.

The cylinders used in the percolation tests are composed of typical Portland cement mixed with sand, gravel, and broken stone of known composition and behavior, and of cement mixed with sand, gravel, and broken stone collected in the neighborhood of the Reclamation projects 251
under investigation.

It is also proposed to subject these test pieces, some made with water of known purity, and others with alkaline water, to contact with alkaline soils near the projects, and with soil of known composition near the testing laboratories at

FIG. 5.

Pittsburg. As these tests progress and other lines of investigation are developed, the programme will be extended, in the hope that the inquiry may develop methods of preparing and mixing concrete and reinforced concrete which can be used in alkaline soils without danger of disintegration.



Investigations into the effect of salt water on cement mortars and concretes, and the effect of electrolysis, are being conducted at Atlantic City, N. J., where the test pieces may be immersed in deep sea water for longer or shorter periods of time.

At the Pittsburg laboratory a great amount of investigative work is done for the purpose of determining the suitability and availability of various structural materials submitted for use by the Government. While primarily valuable only to the Government, the results of these tests are of indirect value to all who are interested in the use of similar materials. Among such investigations have been those relating to the strength, elasticity, and chemical properties of wire rope for use in the Canal Zone; investigations of the suitability and cementing value of concrete, sand, stone, 252
and pozzuolanic material found on the Isthmus; investigations as to the relative resistance to corrosion of various types of wire screens for use in the Canal Zone; into the suitability for use, in concrete sea-wall construction, of sand and stone from the vicinity of San Francisco; into the properties of reinforced concrete floor slabs; routine tests of reinforcing metal, and of reinforced concrete beams and columns, for the Supervising Architect of the Treasury Department, etc. The results have been set forth in three bulletins[9] which describe the methods of conducting these tests and also tests on constituent materials of concrete and plain concrete beams. In addition, there are in process of publication a number of bulletins giving the results of tests on reinforced concrete beams, columns, and floor slabs, concrete building blocks, etc.

The Northampton laboratory was established because it is in the center of the Lehigh cement district, and therefore available for the mill sampling and testing of purchases of cement made by the Isthmian Canal Commission; it is also available for tests of cement purchased in the Lehigh district by the Supervising Architect and others. It is in a building, the outer walls of which are of cement plaster applied over metal lath nailed to studding. The partitions are of the same construction, and the floors and roof are of concrete throughout.

The inspection at the factories and the sampling of the cement are under the immediate direction of the Commission; the testing is under the direction of the U. S. Geological Survey. A large force of employees is required, in view of the magnitude of the work, which includes the daily testing of consignments ranging from 5,000 to 10,000 bbl., sampled in lots of 100 bbl., which is equivalent to from 50 to 100 samples tested per day.

The cement to be sampled is taken from the storage bins and kept under seal by the chief inspector pending the results of the test. The quantity of cement sampled is sufficient for the tests required under the specifications of the Isthmian Canal Commission, as well as for preliminary tests made by the cement company, and check tests made at the Geological Survey laboratory, at Pittsburg.

The tests specified by the Commission include determination of specific gravity, fineness of 253
grinding, time of setting, soundness, tensile strength (with three parts of standard quartz sand for 7 and 28 days, respectively), and determination of sulphur anhydride (SO_3), and magnesia (MgO).

The briquette-making and testing room is fitted with a mixing table, moist closet, briquette-storage tanks, and testing machines. The mixing table has a concrete top, in which is set plate glass, 18 in. square and 1 in. thick. Underneath the table are shelves for moulds, glass plates, etc.

The moist closet, 5 ft. high, 3 ft. 10 in. wide, and 1 ft. 8 in. deep, is divided into two compartments by a vertical partition, and each compartment is fitted with cleats for supporting thirteen tiers of glass plates. On each pair of cleats, in each compartment, can be placed four glass plates, each plate containing a 4-gang mould, making storage for 416 briquettes. With the exception of the doors, which are of wood lined with copper, the closet is of 1:1 cement mortar, poured monolithic, even to the cleats for supporting the glass plates.

The immersion tanks, of the same mortar, are in tiers of three, supported by a steel structure. They are 6¼ ft. long, 2¼ ft. wide, and 6 in. deep, and 2,000 briquettes can be stored in each tank. The overflow from the top tank wastes into the second, which, in turn, wastes into the third. Water is kept running constantly.

The briquette-testing machine is a Fairbanks shot machine with a capacity of 2,000 lb., and is regulated to apply the load at the rate of 600 lb. per min. Twenty-four 4-gang moulds, of the type recommended by the Special Committee on Uniform Tests of Cement, of the American

Society of Civil Engineers, are used.

The room for noting time of set and soundness is fitted with a mixing table similar to that in the briquette-making room. The Vicat apparatus is used for determining the normal consistency, and the Gilmore apparatus for the time of setting. While setting, the soundness pats are stored in galvanized-iron pans having about 1 in. of water in the bottom, and covered with dampened felt or burlap. The pats rest on a rack slightly above the water and well below the felt.

For specific gravity tests, the Le Chatelier bottles are used. A pan, in which five bottles can be immersed at one time, is used for maintaining the benzine at a constant temperature. The samples are weighed on a pair of Troemner's No. 7 scales.

The fineness room is fitted with tables, two sets of standard No. 100 and No. 200 sieves, and 254
two Troemner's No. 7 scales similar to those used for the specific gravity tests.

The storage room is fitted with shelves for the storage of samples being held for 28-day tests.

The mould-cleaning room contains tables for cleaning moulds, and racks for air pats.

An effort is made to keep all the rooms at a temperature of 70° Fahr., and, with this in view, a Bristol recording thermometer is placed in the briquette-room. Two wet-and-dry bulb hygrometers are used to determine the moisture in the air.

Samples are taken from the conveyor which carries the cement to the storage bins, at the approximate rate of one sample for each 100 bbl. After each 4,000-bbl. bin has been filled, it is sealed until all tests have been made, when, if these have been satisfactory, it is released for shipment.

The samples are taken in cans, 9 in. high and 7½ in. in diameter. These cans are delivered in the preparation room where the contents are mixed and passed through a No. 20 sieve. Separate samples are then weighed out for mortar briquettes, for soundness pats, and for the specific-gravity and fineness tests. These are placed in smaller cans and a quantity sufficient for a re-test is held in the storage room awaiting the results of all the tests.

The sample for briquettes is mixed with three parts standard crushed quartz, and then taken to the briquette-making room, where eight briquettes are made, four for 7-day and four for 28-day tests. These are placed in the moist closet in damp air for 24 hours, then removed from the moulds, and placed in water for the remainder of the test period. At the proper time they are taken from the immersion tank and broken.

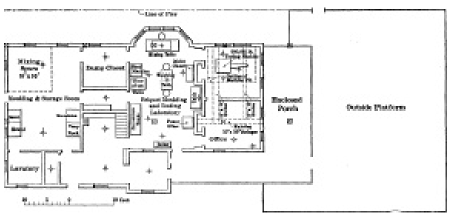
From the sample for soundness, four pats are made. The time of setting is determined on one of these pats. They are placed in the pan previously described, for 24 hours, then one is placed in running water and one in air for 28 days. The others are treated in the boiler, one in boiling water for 3 hours and one in steam at atmospheric pressure for 5 hours.

The sample taken for specific gravity and fineness is dried in the oven at 100° cent. in order to drive off moisture. Two samples are then carefully weighed out, 50 grammes for fineness and
64 grammes for specific gravity, and the determinations are made. As soon as anything 255
unsatisfactory develops, a re-test is made. If, however, the cement satisfies all requirements, a report sheet containing all the data for a bin, is made out, and the cement is ready for shipment. From every fifth bin, special neat and mortar briquettes are made, which are intended for tests at ages up to ten years.

Salt-Water Laboratory.—The laboratory at Atlantic City, for conducting investigations into the effects of salt water on concrete and reinforced concrete, is situated so that water more than 25 ft. deep is available for immersion tests of the setting and deterioration of such materials.

Through the courtesy of the municipality of Atlantic City, Young's cottage, on old Young's Pier, has been turned over, at a nominal rental, to the Geological Survey for the conduct of these tests. The laboratory building is about 700 ft. from the boardwalk, and occupies a space about 100 by 45 ft. It is one story high, of frame-cottage construction, and stands on wooden piles at one side of the pier proper and about 20 ft. above the water, which is about 19 ft. deep at this point. Fresh running water, gas, electric light, and electric power are supplied to the building (Fig. 6).

Fig. 6. [257]



PLAN OF LABORATORY FOR SALT-WATER TESTS AT ATLANTIC CITY, N. J.

In this laboratory investigations will be made of the cause of the failure and disintegration of cement and concrete subjected to the action of sea water. Tests are conducted so as to approach, as nearly as possible, the actual conditions found in concrete construction along the sea coast. All sea-water tests are made in the ocean, some will probably be paralleled by ocean-water laboratory tests and all by fresh-water comparative tests.

Cements, in the form of pats, briquettes, cubes, cylinders, and in a loose ground state, and also mortars and concretes in cube, cylinder, and slab form, are subjected to sea water.

The general plan for the investigations is as follows:

1.—Determination of the failing elements and the nature of the failure;

2.—Determination of the value of the theories advanced at the present time; and,

3.—Determination of a method of eliminating or chemically recombining the injurious elements.

Preliminary tests are in progress, including a study of the effect of salt water on mortars and
concretes of various mixtures and ages. The proportions of these mixtures and the methods of 256
mixing will be varied from time to time, as suggested by the progress of the tests.

Fire-Proofing Tests.—Tests of the fire-proofing and fire-resistive properties of various structural materials are carried on in the laboratories in Building No. 10, at Pittsburg, and in co-operation with the Board or Fire Underwriters at its Chicago laboratory (Fig. 2, Plate XIII). These tests include three essential classes of material: (*a*), clay products, protective coverings representative of numerous varieties of brick and fire-proofing tiles, including those on the market and those especially manufactured for these tests in the laboratory at Pittsburg; (*b*), characteristic granites of New England, with subsequent tests of the various building stones found throughout the United States; and (*c*), cement and concrete covering material, building blocks, and concrete reinforced by steel bars embedded at different depths for the purpose of studying the effect of expansion on the protective covering.

In co-operation with the physical laboratory, these tests include a study of the relative rates of conductivity of cement mortars and concretes. By embedding thermo-couples in cylinders composed of the materials under test, obtaining a given temperature by an electric coil, and noting the time required to raise the temperature at the various embedded couples to a given degree, the rate of conductivity may be determined. Other tests include those in muffles to determine the rate of expansion and the effect of heat and compressive stresses combined on the compressive strength of the various structural materials. The methods of making the panel tests, and the equipment used, are described and illustrated in Bulletin No. 329, and the results of the tests have been published in detail.[10]

Building Stones Investigations.—The field investigations of building stones are conducted by Mr. E. F. Burchard, and include the examination of the various deposits found throughout the United States. A study of the granites of New England has been commenced, which includes the collection of type specimens of fine, medium, and coarse-grained granites, and of dark, medium, and light-gray or white granites. A comparative series of these granites, consisting of prisms and cubes of 4 and 2 in., respectively, has been prepared.

The standard adopted for compressive test pieces in the 10,000,000-lb. machine is a prism, 258
having a base of 12 in. and being 24 in. high. The tests include not only those for compression or crushing strength, but also those for resistance to compressive strains of the prisms and cubes, when raised to high temperatures in muffles or kilns; resistance to weathering, freezing, and thawing; porosity; fire-resisting qualities, etc.

In collecting field samples, special attention is paid to the occurrence of the stone, extent of the deposit, strike, dip, etc., and specimens are procured having their faces cut with reference to the bedding planes, in order that compressive and weathering tests may be made, not only in relation to these planes but at those angles thereto in which the material is most frequently used commercially. Attention is also paid to the results of blasting, in its relation to compressive strains, as blasting is believed to have a material effect on stones, especially on those which may occur in the foundations of great masonry dams, and type specimens of stone quarried by channeling, as well as by blasting, are collected and tested.

Clay and Clay Products Investigations.—These investigations are in charge of Mr. A. V. Bleininger, and include the study of the occurrence of clay beds in various parts of the United States, and the adaptability of each clay to the manufacture of the various clay products.

Experiments on grinding, drying, and burning the materials are conducted at the Pittsburg testing station, to ascertain the most favorable conditions for preparing and burning each clay, and to determine the most suitable economic use to which it may be put, such as the manufacture of building or paving bricks, architectural tiles, sewer tiles, etc.

The laboratory is equipped with various grinding and drying devices, muffles, kilns, and apparatus for chemical investigations, physical tests, and the manufacture and subsequent investigative tests of clay products.

This section occupies the east end of Building No. 10, and rooms on the first and second floors have been allotted for this work. In addition, a brick structure, 46 by 30 ft., provided with a 60-ft. iron stack, has been erected for housing the necessary kilns and furnaces.

On the ground floor of Building No. 10, adjoining the cement and concrete section, is a storage 259
room for raw materials and product under investigation. Adjoining this room, and connecting with it by wide doors, is the grinding room, containing a 5-ft. wet pan, with 2,000-lb. rollers, to be used for both dry and wet grinding. Later, a heavy dry pan is to be installed. With these machines, even the hardest material can be easily disintegrated and prepared. In this room there is also a jaw crusher for reducing smaller quantities of very hard material, as well as a 30 by 16-in. iron ball mill, for fine grinding. These machines are belted to a line shaft along the

wall across the building. Ample sink drainage is provided for flushing and cleaning the wet pan, when changing from one clay to another.

A large room adjoining is for the operation of all moulding and shaping machines, representing the usual commercial processes. At present these include an auger machine, with a rotary universal brick and tile cutter, Fig. 1, Plate XVI, and a set of brick and special dies, a hand repress for paving brick, and a hand screw press for dry pressing. The brick machine is operated from the main shaft which crosses the building in this room and is driven from a 50-h.p. motor. It is possible thus to study the power consumption under different loads and with different clays, as well as with varying degrees of water content in the clay. As the needs of the work demand it, other types of machines are to be installed. For special tests in which pressure is an important factor it is intended to fit up one of the compression testing machines of the cement section with the necessary dies, thus enabling the pressing to be carried on under known pressures. Crushing, transverse, and other tests of clay products are made on the testing machines of the cement and concrete laboratories.

Plate XVI. [opp. 258]

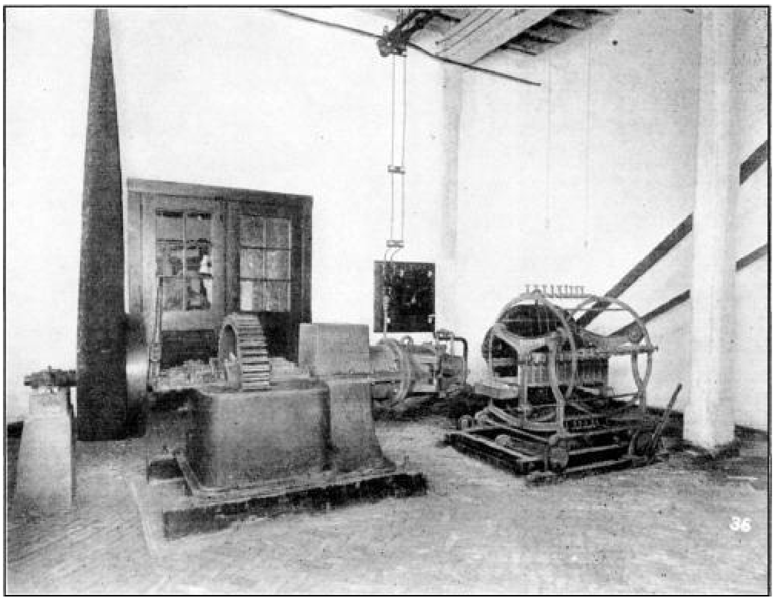


Fig. 1.—Brick Machine and Universal Cutter.

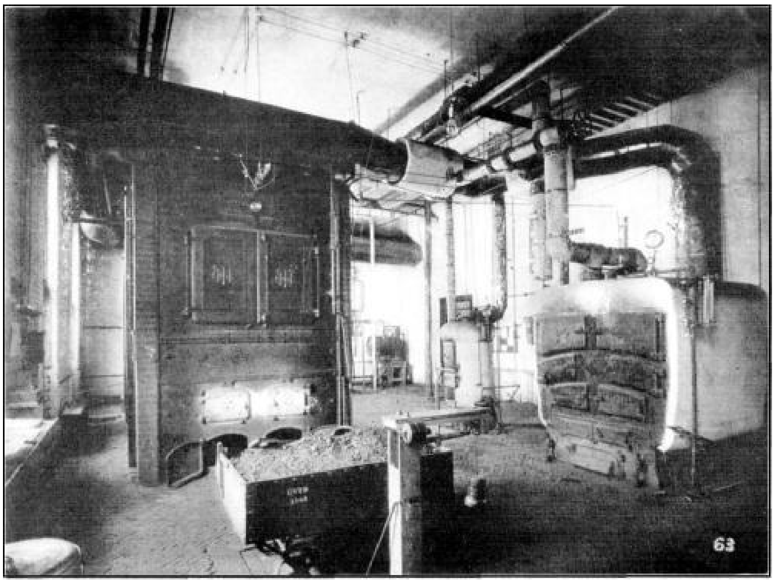


Fig. 2.—House-Heating Boilers, Building No. 21.

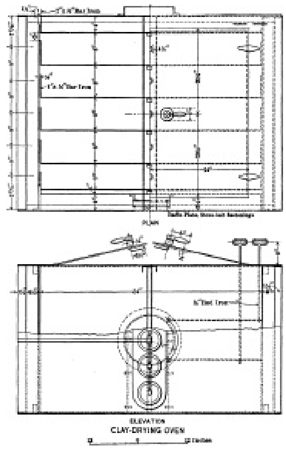
Outside of the building, in a lean-to, there is a double-chamber rattler for the testing of paving brick according to the specifications of the National Brick Manufacturers' Association.

In the smaller room adjoining the machine laboratory there are two small wet-grinding ball mills, of two and four jars, respectively, and also a 9-leaf laboratory filter press.

The remaining room on the first floor is devoted to the drying of clays and clay wares. The equipment consists of a large sheet-iron drying oven of special construction, which permits of close regulation of the temperature (Fig. 7). It is heated by gas burners, and is used for the preliminary heat treatment of raw clays, in connection with the study of the drying problems of certain raw materials. It is intended to work with temperatures as high as 250° cent.

Fig. 7. [261]

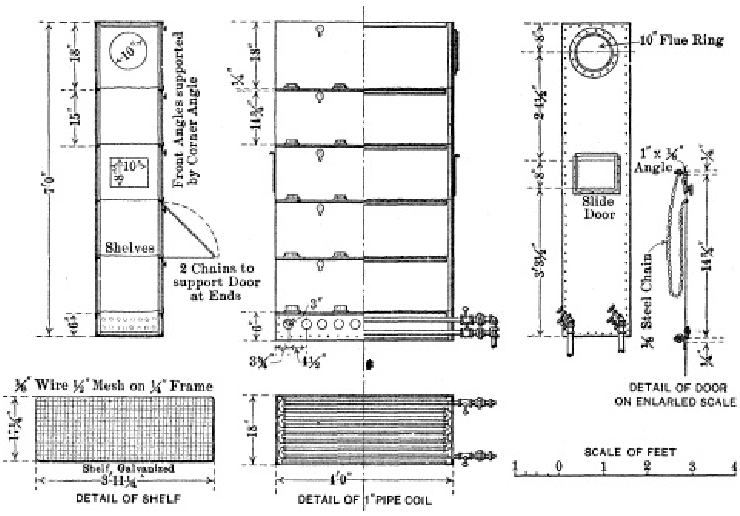
Another drying closet, heated by steam coils (Fig. 8), intended for drying various clay products, has been designed with special reference to the exact regulation of the temperature, humidity, and velocity of the air flowing through it. Both dryers connect by flues with an iron stack outside the building. This stack is provided with a suction fan, driven by a belt from an electric motor.



CLAY-DRYING OVEN

On the second floor are the chemical, physical, and research laboratories, dealing with the precise manipulations of the tests and investigations.

Fig. 8.



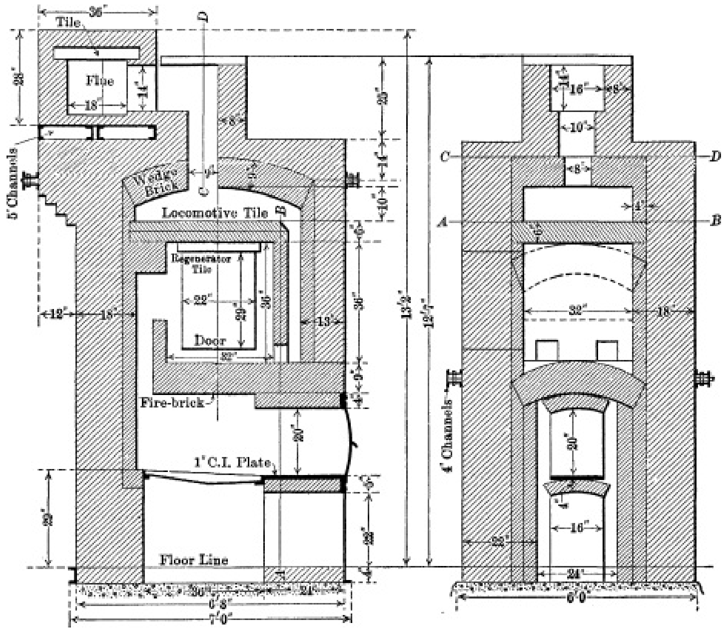
DRYING CLOSETS FOR CERAMICS

The chemical laboratory is fully equipped with the necessary apparatus for carrying on special chemical research in silicate chemistry, including electrical resistance furnaces, shaking devices, etc. It is not the intention to do routine work in this laboratory. The office adjoins this laboratory, and near it is the physical laboratory, devoted to the study of the structure of raw materials. The latter contains Nobel and Schoene elutriators, together with viscosimeters of the flow and the Coulomb and Clark electrical types, sieves, voluminometers, colorimeters, vernier shrinkage gauges, micrometers, microscopes, and the necessary balances.

The room across the hall is devoted to the study of the specific gravity, absorption, porosity, permeability, hardness, translucency, etc., of burnt-clay products, all the necessary apparatus being provided. In the two remaining rooms, intended for research work, special apparatus adapted to the particular investigation may be set up. All the rooms are piped for water, gas, compressed air, steam, and drainage, and wired for light and power.

In the kiln house there is a test kiln adapted for solid fuel and gas. It is of the down-draft type, with an available burning space of about 8 cu. ft. (Fig. 9). For heavier ware and the study of the fire behavior of clay products under conditions approaching those of practice, a round down-draft kiln, with an inside diameter of 6 ft., is installed. About 13 ft. above the floor level, and supported by iron beams, there is a flue parallel to the long side of the structure. This flue conducts the gases of the kilns to the stack, which is symmetrically located with reference to the kiln house. Natural gas is the principal fuel. In addition to these kilns, a small muffle
furnace, fired with petroleum, is provided for the determination of melting points, and an 262
electric carbon resistance furnace, with an aluminum muffle for high-temperature work. For crucible-fusion work, a gas-fired pot furnace is installed.

Fig. 9.



DOWN-DRAFT KILN

Along the north wall, bins are provided for the storage of fuel, clay, sand, and other kiln supplies. There are two floor drainage sinks, and electric current, steam, water, and compressed air, are provided.

Results of the Work.—More than 39,300 separate test pieces have been made at the structural-materials testing laboratory. In connection with the study of these, 86,000 tests and nearly 14,000 chemical analyses have been made. Of these tests more than 13,600 have been of the constituent materials of concrete, including tensile tests of cement briquettes, compression tests of cylinders and cubes, and transverse tests of various specimens.

Nearly 1,200 beams of concrete or reinforced concrete, each 13 ft. long and 8 by 11 in. in cross-section, have been made, and, in connection with the investigation of the behavior of these beams, nearly 3,000 tests have been made. Nearly 900 of these beams, probably more than double the entire number made in other laboratories in the United States, during a period 263
of more than 15 years, have been tested.

In the section of building blocks, 2,200 blocks have been tested, including, with auxiliary pieces, more than 4,500 tests; also, more than 900 pieces of concrete have been tested for permeability and shear. The physical tests have numbered 14,000; tests of steel for reinforcement, 3,800; and 550 tests to determine fire-resistive qualities of various building materials, have been made on 30 special panels, and on miscellaneous pieces.

The tests of the permeability of cement mortars and concretes, and of water-proofing and damp-proofing materials, have numbered 3,470.

The results of the work of the Structural Materials Division have already appeared in preliminary bulletins, as follows: No. 324, "San Francisco Earthquake and Fire of April 18, 1906, and Their Effects on Structures and Structural Materials"; No. 329, "Organization, Equipment, and Operation of the Structural-Materials Testing Laboratories at St. Louis, Mo."; 264
No. 331, "Portland Cement Mortars and Their Constituent Materials" (based on nearly 25,000 tests); No. 344, "Strength of Concrete Beams" (based on tests of 108 beams); No. 370, "Fire-Resistive Properties of Various Building Materials"; No. 387, "The Colloid Matter of Clay and its Measurements." A bulletin on the results of tests of reinforced concrete beams, one on the manufacture and chemistry of lime, and one on drying tests of brick, are in course of publication.

Fuel Investigations.

The scope of the fuel investigations has been planned to conform to the provisions of the Act of Congress which provides for analyzing and testing coals, lignites, and other mineral fuel substances belonging to the United States, or for the use of the United States Government, and examinations for the purpose of increasing the general efficiency or available supply of the fuel resources in the United States.

In conformity with this plan, the investigations inaugurated at St. Louis had for their initial object the analyzing and testing of the coals of the United States, using in this work samples of from 1 to 3 carloads, collected with great care from typical localities in the more important coal fields of the country, with a view to determining the relative values of those different fuels. In the work at Norfolk, during 1907, this purpose was modified to the extent of keeping in view relative fuel efficiencies for naval purposes. The tests at Denver have been on coal from Government land or from land contiguous thereto, and are conducted solely with a view to perfecting methods of coking this coal by prior washing and by manipulation in the process of coking.

Three general lines of inquiry are embodied in the plan of investigation undertaken and

contemplated by the Technologic Branch, after conference and with the advice and approval of the Advisory Board: 1. The ascertainment of the best mode of utilizing any fuel deposit owned or to be used by the Government, or the fuel of any extensive deposit as a whole, by conducting a more thorough investigation into its combustion under steam boilers, conversion into producer gas, or into coke, briquettes, etc. 2. The prevention of waste, through the study of the possibility of improvement in the methods of mining, shipping, utilizing, etc. 3. The inspection and analysis of coal and lignite purchased under specification for the use of the 265
Government, to ascertain its heating value, ash, contained moisture, etc.

The first general line of work concerns the investigation and testing of the fuel resources of the United States, and especially those belonging to the Federal Government, to determine a more efficient and more economical method of utilizing the same. This work has developed along the following lines:

The collection of representative samples for chemical analysis, and calorimeter tests by a corps of skilled mine samplers, from the mines selected as typical of extensive deposits of coal in a given field or from a given bed of coal; and the collection from the same mines of larger samples of from 1 to 3 carloads, shipped to the testing station for tests in boiler furnaces, gas producers, etc., as a check on the analysis and calorimeter tests;

The testing of each coal received to determine the most efficient and least wasteful method of use in different furnaces suitable for public buildings or power plants or ships of the Government;

The testing of other portions of the same shipment of coal in the gas producer, for continuous runs during periods of a few days up to several weeks, in order to determine the availability of this fuel for use in such producers, and the best method of handling it, to determine the conditions requisite to produce the largest amount of high-grade gas available for power purposes;

The testing of another portion of the same coal in a briquette machine at different pressures and with different percentages and kinds of binder, in order to determine the feasibility of briquetting the slack or fine coal. Combustion tests are then made of these briquettes, to determine the conditions under which they may be burned advantageously;

Demonstrations, on a commercial scale, of the possibility of producing briquettes from American lignites, and the relative value of these for purposes of combustion as compared with the run-of-mine coal from which the briquettes are made;

The finding of cheaper binders for use in briquetting friable coals not suited for coking purposes;

Investigations into the distribution, chemical composition, and calorific value of the peat deposits available in those portions of the United States where coal is not found, and the preparation of such peat for combustion, by drying or briquetting, to render it useful as a local 266
substitute for coal;

Investigations into the character of the various petroleums found throughout the United States, with a view to determining their calorific value, chemical composition, and the various methods whereby they may be made most economically available for more efficient use as power producers, through the various methods of combustion;

Investigations and tests into the relative efficiency, as power producers in internal-combustion engines, of the heavier distillates of petroleum, as well as of kerosene and gasoline, in order to ascertain the commercial value and relative efficiency of each product in the various types of engines;

Investigations into the most efficient methods of utilizing the various coals available throughout the United States for heating small public buildings, army posts, etc., in order that these coals may be used more economically than at present;

Investigative studies into the processes of combustion within boiler furnaces and gas producers to ascertain the temperatures at which the most complete combustion of the gases takes place, and the means whereby such temperatures may be produced and maintained, thus diminishing the loss of values up the smokestack and the amount of smoke produced;

Investigations and tests into the possibilities of coking coals which have hitherto been classed as non-coking, and the making of comparative tests of all coals found in the United States, especially those from the public lands of the West;

Investigations, by means of washing in suitable machines, to determine the possibility of improving the quality of American coals for various methods of combustion, and with a view to making them more available for the production of coke of high-grade metallurgical value, as free as possible from sulphur and other injurious substances.

At each stage of the process of testing, samples of the coal have been forwarded to the chemical laboratory for analyses; combustion temperatures have been measured; and samples of gas collected from various parts of the combustion chambers of the gas producers and boiler furnaces have been analyzed, in order that a study of these data may throw such light on the processes of combustion and indicate such necessary changes in the apparatus, as might result in larger economies in the use of coal.

The second line of investigation concerns the methods of mining and preparing coal for the 267
market, and the collection of mine samples of coal, oil, etc., for analysis and testing. It is well

known that, under present methods of mining, from 10 to 75% of any given deposit of coal is left underground as props and supports, or as low-grade material, or in overlying beds broken up through mining the lower bed first. An average of 50% of the coal is thus wasted or rendered valueless, as it cannot be removed subsequently because of the caving or falling in of the roofs of abandoned galleries and the breaking up of the adjoining overlying beds, including coal, floor, and roof.

The investigations into waste in mining and the testing of the waste, bone, and slack coal in gas producers, as briquettes, etc., have, for their purpose, the prevention of this form of waste by demonstrating that these materials, now wasted, may be used profitably, by means of gas producers and engines, for power purposes.

The third general line of investigation concerns the inspection and sampling of fuel delivered to the Government under purchase contracts, and the analyzing and testing of the samples collected, to determine their heating value and the extent to which they may or may not comply with the specifications under which they are purchased. The coal delivered at the public buildings in the District of Columbia is sampled by special representatives of the Technologic Branch of the Survey. The taking of similar samples at public buildings and posts throughout the United States, and the shipment of the samples in hermetically sealed cans or jars to the chemical laboratory at Washington, is for the most part looked after by special officers or employees at each place. These purchases are made, to an increasing extent, under specifications which provide premiums for coal delivered in excess of standards, and penalties for deliveries below standards fixed in the specifications. The standard for bituminous coals is based mainly on the heat units, ash, and sulphur, while that for anthracite coal is based mainly on the percentage of ash and the heat units.

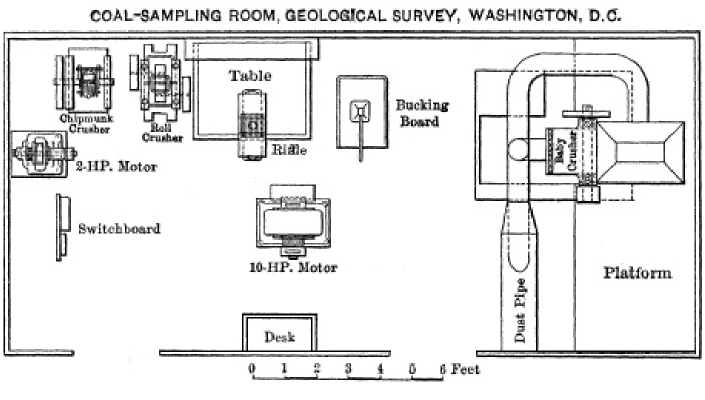
In connection with all these lines of fuel testing, certain research work, both chemical and physical, is carried on to determine the true composition and properties of the different varieties of coal, the changes in the transformation from peat to lignite, from lignite to bituminous coal, and from bituminous to anthracite coal, and the chemical and physical processes in combustion. Experiments are conducted concerning the destructive distillation of fuels; the by-products of coking processes; the spontaneous combustion of coal; the storage of 268
coal, and the loss in value in various methods of storing; and kindred questions, such as the weathering of coal. These experiments may yield valuable results through careful chemical research work supplemented by equally careful observations in the field.

Inspection and Mine Sampling.—In the Geological Survey Building, at Washington, coal purchased for Government use on a guaranteed-analysis or heat-value basis, is inspected and sampled.

Some of the employees on this work are constantly at the mines taking samples, or at public works inspecting coal for Government use, while others are stationed at Washington to look after the deliveries of coal to the many public buildings, and to collect and prepare samples taken from these deliveries for analysis, as well as to prepare samples received from public works and buildings in other parts of the country.

The preparation of these samples is carried on in a room in the basement of the building, where special machinery has been installed for this work. Fig. 10 shows a plan of this room and the arrangement of the sampling and crushing machinery.

Fig. 10.



The crushing of the coal produces great quantities of objectionable dust, and to prevent this dust from giving trouble outside the sampling room, the wooden partitions on three sides of the room (the fourth side being a masonry wall) are completely covered on the outside with galvanized sheet iron. The only openings to the room are two doors, which are likewise covered with sheet iron, and provided with broad flanges of the same material, in order to seal 269
effectually the openings when the doors are shut. Fresh air is drawn into the room by a fan, through a pipe leading to the outer air. A dust-collecting system which carries the coal dust and spent air from the room, consists of an arrangement of 8-in. and 12-in. pipes leading from hoods, placed over the crushing machines, to the main furnace stack of the building. The draft in this stack draws all the dust from the crushers directly through the hoods to the main pipe, where most of it is deposited.

The equipment of the sampling room consists of one motor-driven, baby hammer crusher, which has a capacity of about 1 ton per hour and crushes to a fineness of ¼-in. mesh; one adjustable chipmunk jaw crusher, for 5- and 10-lb. samples; one set of 4½ by 7½-in. rolls, crushing to 60 mesh, for small samples; one large bucking board, and several different sizes of riffle samplers for reducing samples to small quantities. The small crushers are belted to a shaft driven by a separate motor from that driving the baby crusher.

In conducting the inspection of departmental purchases of coal in Washington, the office is notified whenever a delivery of coal is to be made at one of the buildings, and an inspector is sent, who remains during the unloading of the coal. He is provided with galvanized-iron buckets having lids and locks; each bucket holds about 60 lb. of coal. In these buckets he puts small quantities of the coal taken from every portion of the delivery, and when the delivery has been completed, he locks the buckets and notifies the office to send a wagon for them. The buckets are numbered consecutively, and the inspector makes a record of these numbers, the date, point of delivery, quality of coal delivered, etc. The buckets are also tagged to prevent error. He then reports to the office in person, or by telephone, for assignment to another point in the city. All the samples are delivered to the crushing room in the basement of the Survey Building, to be prepared for analysis.[11]

Samples taken from coal delivered to points outside of Washington are taken by representatives of the department for which the coal is being purchased, according to instructions furnished them, and, from time to time, the regular inspectors are sent to see that these instructions are being complied with. These samples are crushed by hand, reduced to
about 2 lb. at the point where they are taken, and sent to Washington, in proper air-tight 270
containers, by mail or express, accompanied by appropriate descriptions.

Each sample is entered in the sample record book when received, and is given a serial number. For each contract a card is provided giving information relative to the contract. On this card is also entered the serial number of each sample of coal delivered under that contract.

After the samples are recorded, they are sent to the crushing room, where they are reduced to the proper bulk and fineness for analysis. They are then sent, in rubber-stoppered bottles, accompanied by blank analysis report cards and card receipts, one for each sample, showing the serial numbers, to the fuel laboratory for analysis. The receipt card for each sample is signed and returned to the inspection office, and when the analysis has been made, the analysis report card showing the result is returned. This result is entered at once on the contract card, and when all analyses have been received, covering the entire delivery of coal, the average quality is calculated, and the results are reported to the proper department.

The matter of supplying the Pittsburg plant with fuel for test purposes is also carried on from the Washington office. Preliminary to a series of investigations, the kinds and amounts of coal required are decided on, and the localities from which these coals are to be obtained are determined. Negotiations are then opened with the mine owners, who, in most cases, generously donate the coal. When the preliminaries have been arranged, an inspector is sent to the mine to supervise the loading and shipment of the coal. This inspector enters the mine and takes, for chemical analysis, small mine samples which are sent to the laboratory at Pittsburg in metal cans by mail, accompanied by proper identification cards. The results of the analysis are furnished to the experts in charge at the testing plant, for their information and guidance in the investigations for which the coal was shipped.

All samples for testing purposes are designated consecutively in the order of shipment, “Pittsburg No. 1,” “Pittsburg No. 2,” etc. A complete record of all shipments is kept on card forms at the Pittsburg plant, and a duplicate set of these is on file in the inspection office at Washington.

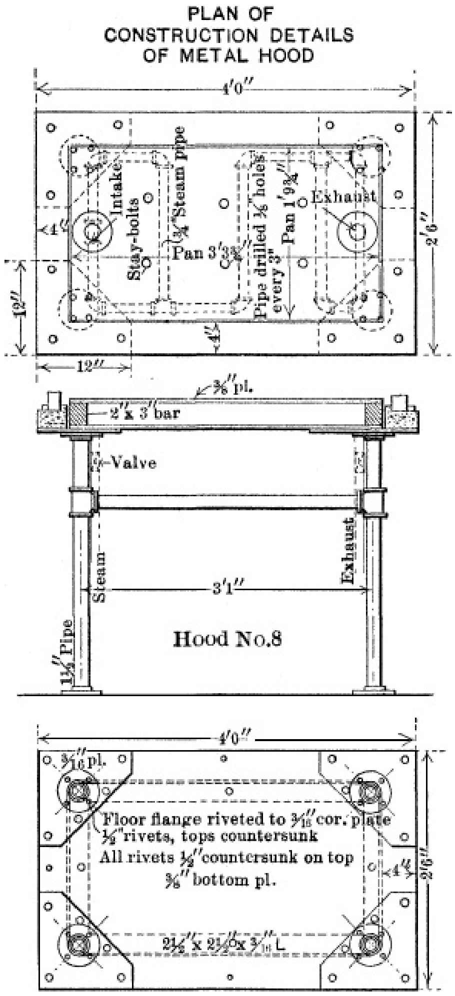
Analysis of Fuels.—The routine analyses of fuel used in the combustion tests at Pittsburg, and
of the gases resulting from combustion or from explosions in the testing galleries, or sampled 271
in the mines, are made in Building No. 21.[12] A small laboratory is also maintained on the second floor of the south end of Building No. 13, for analyses of gases resulting from combustion in the producer-gas plant, and from explosions in Galleries Nos. 1 and 2, etc. From four to six chemists are continually employed in this laboratory (in 8-hour shifts), during prolonged gas-producer tests, and three chemists are also employed in analyzing gases relating to mine explosions.

In addition to these gas analyses, there are also made in the main laboratory, analyses and calorific tests of all coal samples collected by the Geological Survey in connection with its land-classification work on the coal lands of the Western States. Routine analyses of mine, car, and furnace samples of fuels for testing, before and after washing and briquetting, before coking and the resultant coke, and extraction analyses of binders for briquettes, etc., are also made in this laboratory.

The fuel-testing laboratory at Washington is equipped with three Mahler bomb calorimeters and the necessary balances and chemical equipment required in the proximate analysis of coal. More than 650 deliveries of coal are sampled each month for tests, representing 50,000 tons purchased per month, besides daily deliveries, on ship-board, of 550,000 tons of coal for the Panama Railroad. The data obtained by these tests furnish the basis for payment. The tests cover deliveries of coal to the forty odd bureaus, and to the District Municipal buildings in Washington; to the arsenals at Watertown, Mass., Frankford, Pa., and Rock Island, Ill.; and to a number of navy yards, through the Bureau of Yards and Docks; to military posts in various parts of the country; for the Quartermaster-General’s Department; to the Reclamation Service; to Indian Agencies and Soldiers’ Homes; to several lighthouse districts; and to the superintendents of the various public buildings throughout the United States, through the Treasury Department; etc. During 1909, the average rate of reporting fuel samples was 540 per month, requiring, on an average, six determinations per sample, or about 3,240 determinations per month.

Fuel-Research Laboratories.—Smaller laboratories, occupying, on the average, three rooms each, are located in Building No. 21. One is used for chemical investigations and calorific tests of petroleum collected from the various oil fields of the United States; another is used for investigations relative to the extraction of coal 272
and the rapidity of oxidization of coals by standard solutions of oxidizing agents; and another is occupied with investigations into the destructive distillation of coal. The researches under way show the wide variation in chemical composition and calorific value of the various crude oils, indicate the possibility of the extraction of coal constituents by solvents, and point to important results relative to the equilibrium of gases at high temperatures in furnaces and gas producers. The investigations also bear directly on the coking processes, especially the by-product process, as showing the varying proportion of each of the volatile products derivable from types of coals occurring in the various coal fields of the United States, the time and temperature at which these distillates are given off, the variation in quality and quantity of the products, according to the conditions of temperature, and, in addition, explain the deterioration of coals in storage, etc.

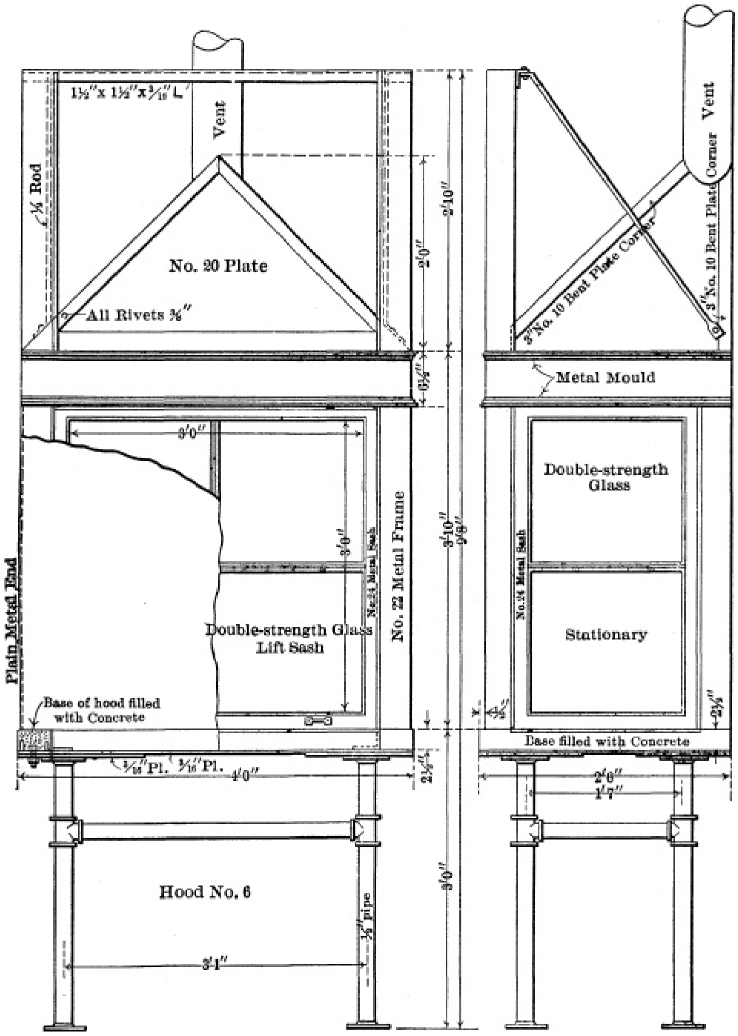
FIG. 11.



At the Washington office, microscopic investigations into the life history of coal, lignite, and peat are being conducted. These investigations have already progressed far enough to admit of the identification of some of the botanical constituents of the older peats and the younger lignites, and it is believed that the origin of the older lignites, and even of some of the more recent bituminous coals, may be developed through this examination.

In the chemical laboratories, in Building No. 21, the hoods (Figs. 11 and 12) are of iron, with a brick pan underneath. They are supported on iron pipes, as are most of the other fixtures in the laboratories in this 274
building. The hood proper is of japanned, pressed-iron plate, No. 22 gauge, the same material being used for the boxes, slides, and bottom surrounding the hood. The sash is hung on red copper pulleys, and the corners of the hood are reinforced with pressed, japanned, riveted plate to which the ventilating pipe is riveted.

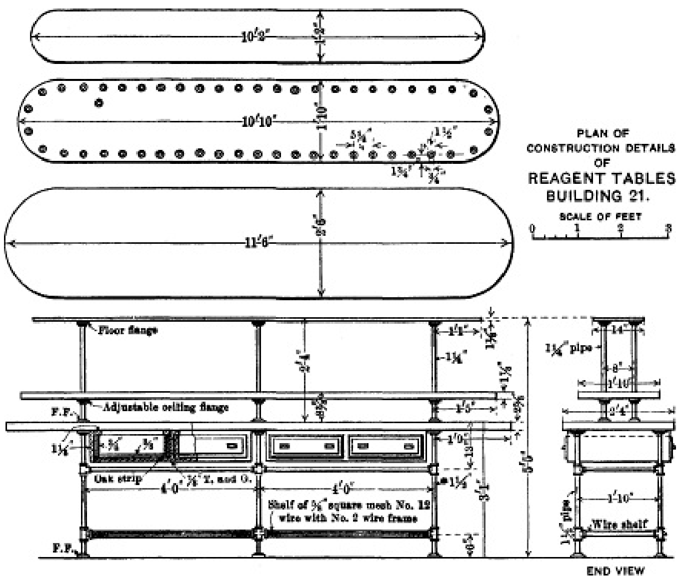
FIG. 12. [273]



ELEVATION OF CONSTRUCTION DETAILS OF METAL HOOD

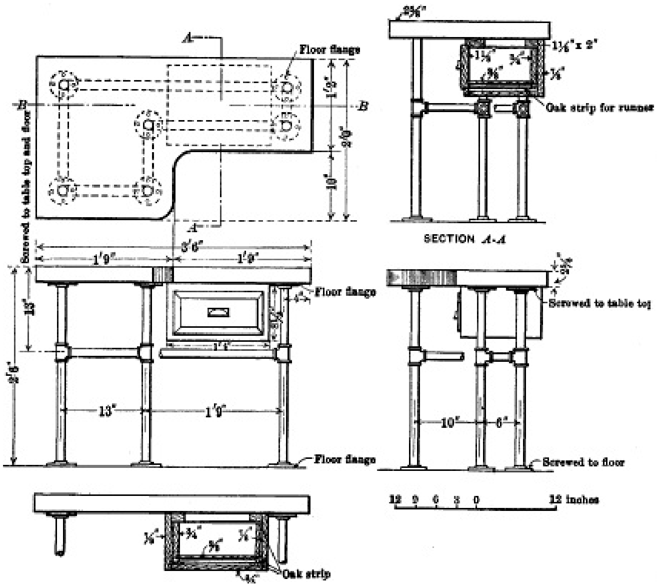
There is some variety in the cupboards and tables provided in the various laboratories, but, in general, they follow the design shown in Fig. 13. The table tops, 12 ft. long, are of clear maple in full-length pieces, ⅞ in. thick and 2⅝ in. wide, laid on edge and drilled at 18-in. intervals for bolts. These pieces are glued and drawn together by the bolts, the heads of which are countersunk. The tops, planed off, sanded, and rounded, are supported on pipe legs and frames of 1¼ by 1½-in. galvanized-iron pipe with screw flanges fitting to the floor and top. Under the tops are drawers and above them re-agent shelves. Halfway between the table top and the floor is a wire shelf of a frame-work of No. 2 wire interlaced with No. 12 weave of ⅝-in. square mesh.

FIG. 13. [275]



Certain of the tables used in the laboratory are fitted with cupboards beneath and with drawers, and, in place of re-agent stands, porcelain-lined sinks are sunk into them. These tables follow, in general style and construction, the re-agent tables. The tables used in connection with calorimeter determinations are illustrated in Fig. 14. The sinks provided throughout these laboratories are of standard porcelain enamel, rolled rim, 18 by 13 in., with enameled back, over a sink and drain board, 24 in. long on the left side, though there are variations from this type in some instances.

Fig. 14.



CONSTRUCTION DETAILS OF CALORIMETER TABLES

The plumbing includes separate lines of pipe to each hood and table; one each for cold water, steam at from 5 to 10 lb. pressure, compressed air, natural gas, and, in some cases, live steam at a pressure of 60 lb.

On each table is an exposed drainage system of 2½-in. galvanized-iron pipe, in the upper surface of which holes have been bored, through which the various apparatus drain by means of flexible connections of glass or rubber. These pipes and the sinks, etc., discharge into main drains, hung to the ceiling of the floor beneath. These drains are of wood, asphaltum coated, with an inside diameter ranging from 3 to 6 in., and at the proper grades to secure free discharge. These wooden drain-pipes are made in short lengths, strengthened by a spiral wrapping of metal bands, and are tested to a pressure of 40 lb. per sq. in. Angles are turned and branches connected in 4- and 6-in. square headers.

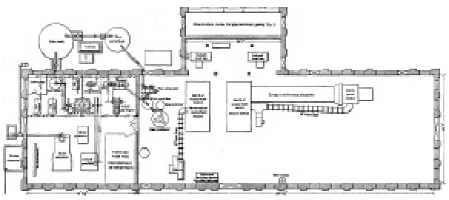
The entire building is ventilated by a force or blower fan in the basement, and by an exhaust fan in the attic with sufficient capacity to insure complete renewal of air in each laboratory once in 20 min. 276

The blower fan is placed in the center of the building, on the ground floor, and is 100 in. in diameter. Its capacity is about 30,000 cu. ft. of air per min., and it forces the air, through a series of pipes, into registers placed in each of the laboratories.

The exhaust fan, in the center of the attic, is run at 550 rev. per min., and has a capacity of 22,600 cu. ft. of air per min. It draws the air from each of the rooms below, as well as from the hoods, through a main pipe, 48 in. in diameter.

Steaming and Combustion Tests.—The investigations included under the term, fuel efficiency, relate to the utilization of the various types of fuels found in the coal and oil fields, and deal primarily with the combustion of such fuels in gas producers, in the furnaces of steam boilers, in locomotives, etc., and with the efficiency and utilization of petroleum, kerosene, gasoline, etc., in internal-combustion engines. This work is under the general direction of Mr. R. L. Fernald, and is conducted principally in Buildings Nos. 13 (Plate XVII) and 21.

Plate XVII. [fold-in]



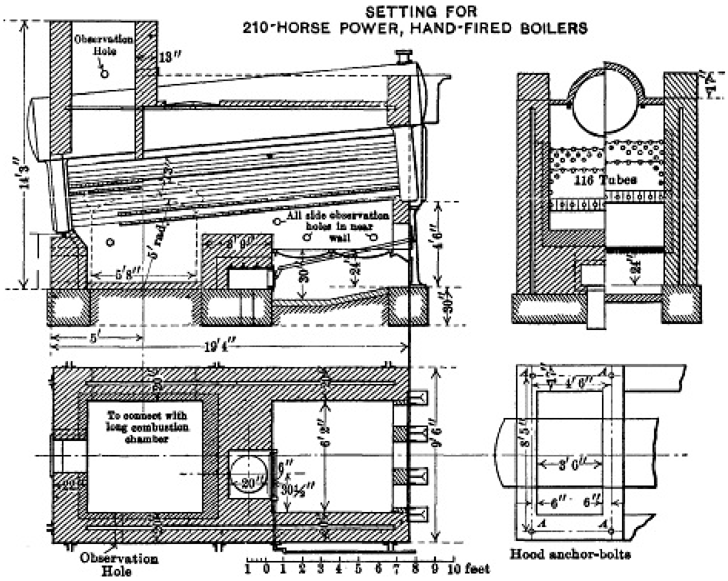
PLAN OF BUILDING 13,
TESTING STATION AT PITTSBURG, PA.

For tests of combustion of fuels purchased by the Government, the equipment consists of two Heine, water-tube boilers, each of 210 h.p., set in Building No. 13. One of these boilers is equipped with a Jones underfeed stoker, and is baffled in the regular way. At four points in the setting, large pipes have been built into the brick wall, to permit making observations on the temperature of the gas, and to take samples of the gas for chemical analysis.

The other boiler is set with a plain hand-fired grate. It is baffled to give an extra passage for

the gases (Fig. 15). Through the side of this boiler, at the rear end, the gases from the long combustion chamber (Plate XVIII) enter and take the same course as those from the hand-fired grate. Both the hand-fired grate and the long combustion chamber may be operated at the same time, but it is expected that usually only one will be in operation. A forced-draft fan has been installed at one side of the hand-fired boiler, to provide air pressure when coal is being burned at high capacity. This fan is also connected in such a way as to furnish air for the long combustion chamber when desired. A more complete description of the boilers may be found in Professional Paper No. 48, and Bulletin No. 325 of the U. S. Geological Survey, in which the 277
water-measuring apparatus is also described.[13]

Fig. 15.



On account of the distance from Building No. 21 to the main group of buildings, it was considered inadvisable to attempt to furnish steam from Building No. 13 to Building No. 21, either for heating or power purposes. In view, moreover, of the necessity of installing various types and sizes of house-heating boilers, on account of tests to be made thereon in connection with these investigations, it was decided to install these boilers in the lower floor of Building No. 21, where they could be utilized, not only in making the necessary tests, but in furnishing heat and steam for the building and the chemical laboratories therein.

In addition to the physical laboratory on the lower floor of Building No. 21, and the house-heating boiler plant with the necessary coal storage, there are rooms devoted to the storage of heavy supplies, samples of fuels and oils, and miscellaneous commercial apparatus. One room is occupied by the ventilating fan and one is used for the necessary crushers, rolls, sizing 278
screens, etc., required in connection with the sampling of coal prior to analysis.

The Quartermaster’s Department having expressed a wish that tests be made of the heating value and efficiency of the various fuels offered that Department, in connection with the heating of military posts throughout the country, three house-heating boilers were procured which represent, in a general way, the types and sizes used in a medium-sized hospital or other similar building, and in smaller residences (Fig. 2, Plate XVI). The larger apparatus is a horizontal return-tubular boiler, 60 in. in diameter, 16 ft. long, and having fifty-four 4-in. tubes.[14]

In order to determine whether such a boiler may be operated under heating conditions without making smoke, when burning various kinds of coal, it has been installed in accordance with accepted ideas regarding the prevention of smoke. A fire-brick arch extends over the entire grate surface and past the bridge wall. A baffle wall has been built in the combustion chamber, which compels the gases to pass downward and to divide through two openings before they reach the boiler shell. Provision has been made for the admission of air at the front of the furnace, underneath the arch, and at the rear end of the bridge wall, thus furnishing air both above and below the fire. It is not expected that all coals can be burned without smoke in this furnace, but it is desirable to determine under what conditions some kinds of coals may be burned without objectionable smoke.[15]

For sampling the gases in the smokebox of the horizontal return-tubular boiler, a special flue-gas sampler was designed, in order to obtain a composite sample of the gases escaping from the boiler.

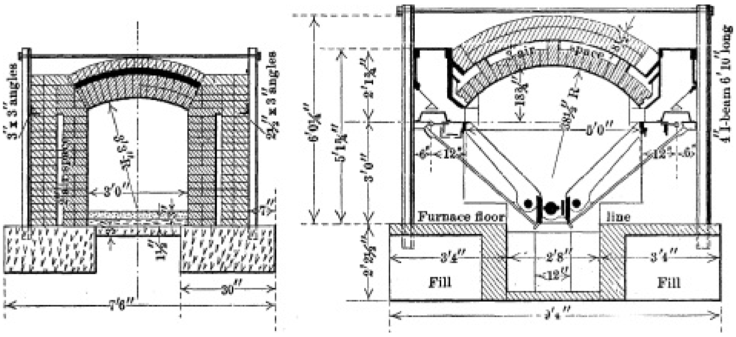
The other heaters are two cast-iron house-heating boilers. One can supply 400 sq. ft. of radiation and the other about 4,000 sq. ft. They were installed primarily for the purpose of testing coals to determine their relative value when burned for heating purposes. They are piped to a specially designed separator, and from this to a pressure-reducing valve. Beyond this valve an orifice allows the steam to escape into the regular heating mains. This arrangement makes it possible to maintain a practically constant load on the boilers.

There is a fourth boiler, designed and built for testing purposes by the Quartermaster’s 279
Department. This is a tubular boiler designed on the lines of a house-heating boiler, but for use

as a calorimeter to determine the relative heat value of different fuels reduced to the basis of a standard cord of oak wood.

A series of research tests on the processes of combustion is being conducted in Building No. 13, by Mr. Henry Kreisinger. These tests are being made chiefly in a long combustion chamber (Figs. 16 and 17, and Figs. 1 and 2, Plate XVIII), which is fed with coal from a Murphy mechanical stoker, and discharges the hot gases at the rear end of the combustion chamber, into the hand-fired Heine boiler. The walls and roof of this chamber are double; the inner wall is 9 in. thick, of fire-brick; the outer one is 8 in. thick, and is faced with red pressed brick. Between the walls of the sides there is a 2-in. air space, and between them on the roof a 1-in. layer of asbestos paste is placed. The inner walls and roof have three special slip-joints, to allow for expansion. The floor is of concrete, protected by a 1½-in. layer of asbestos board, which in turn is covered by a 3-in. layer of earth; on top of this earth there is a 4-in. layer of fire-brick (not shown in the drawings).

Fig. 16.



CROSS-SECTIONS OF CHAMBER AND OF FURNACE, LONG COMBUSTION CHAMBER

Inasmuch as one of the first problems to be attacked will be the determination of the length of travel and the time required to complete combustion in a flame in which the lines of stream flow are nearly parallel, great care was taken to make the inner surfaces of the tunnel smooth, 280
and all corners and hollows are rounded out in the direction of travel of the gases.

Provision is made, by large peep-holes in the sides, and by smaller sampling holes in the top, for observing the fuel bed at several points and also the flame at 5-ft. intervals along the tunnel. Temperatures and gas samples are taken simultaneously at a number of points through these holes, so as to determine, if possible, the progress of combustion (Fig. 1, Plate XVIII).

About twenty thermo-couples are embedded in the walls, roof, and floor, some within 1 in. of the inside edge of the tunnel walls, and some in the red pressed brick near the outer surface, the object of which is to procure data on heat conduction through well-built brick walls[16] (Fig. 2, Plate XVIII).

Plate XVIII. [opp. 278]

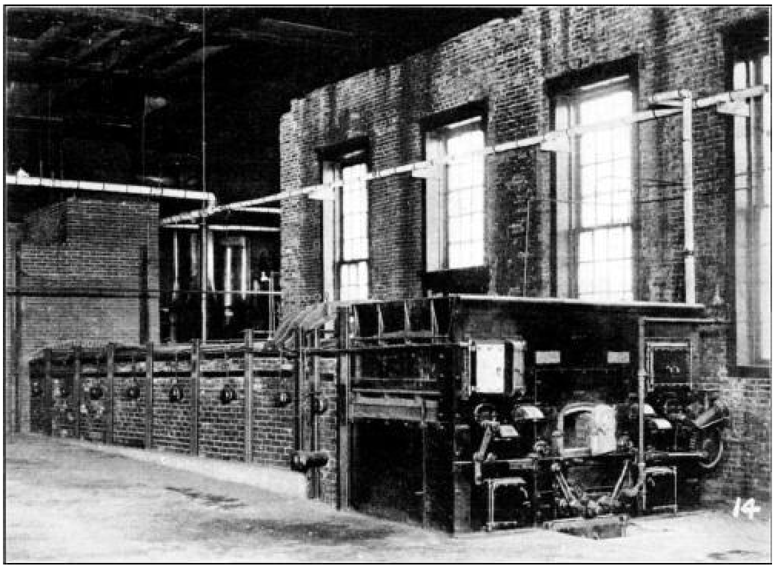


Fig. 1.—Long Combustion Chamber.

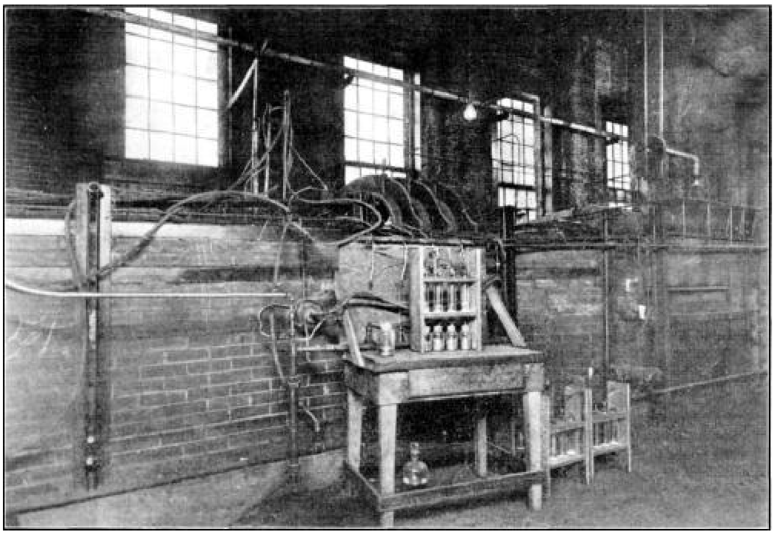


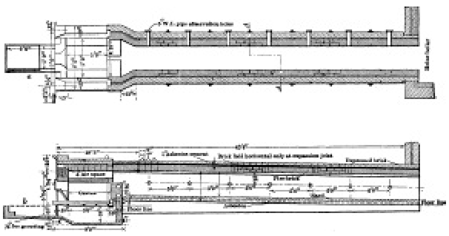
Fig. 2.—Gas Sampling Apparatus, Long Combustion Chamber.

In order to minimize the leakage of air through the brickwork, the furnace and tunnel are kept as nearly as possible at atmospheric pressure by the combined use of pressure and exhausting fans. Nevertheless, the leakage is determined periodically as accurately as possible.

At first a number of tests were run to calibrate the apparatus as a whole, all these preliminary tests being made on cheap, carefully inspected, uniform screenings from the same seam of the same mine near Pittsburg. Later tests will be run with other coals of various volatile contents and various distillation properties.

It is anticipated that the progress of the tests may suggest changes in the construction or operation of this chamber. It is especially contemplated that the section of the chamber may be narrowed down by laying sand in the bottom and fire-brick thereon; also that baffle walls may be built into various portions of it, and that cooling surfaces with baffling may be introduced. In addition to variations in the tests, due to changes in construction in the combustion chamber, there will be variations in the fuels tested. Especial effort will be made to procure fuels ranging in volatile content from 15 to 27 and to 40%, and those high in tar and heavy hydro-carbons. It is also proposed to vary the conditions of testing by burning at high rates, such as at 15, 20, and 30 lb. per ft. of grate surface, and even higher. Records will be kept of the weight of coal fired and of each firing, of the weight of ash, etc.; samples of coal and of ash 282
will be taken for chemical and physical analysis, as well as samples of the gas, and other essential data. These records will be studied in detail.

Fig. 17. [281]



LONGITUDINAL SECTIONS OF LONG COMBUSTION CHAMBER

A series of heat-transmission tests undertaken two years ago, is being continued on the ground floor of Building No. 21, on modified apparatus reconstructed in the light of the earlier experiments by Mr. W. T. Ray. The purpose of the tests on this apparatus has been to determine some of the laws controlling the rate of transmission of heat from a hot gas to a liquid and *vice versa*, the two being on the opposite sides of a metal tube.

It appears that four factors determine the rate of heat impartation from the gas to any small area of the metal[17]:

(1).—The temperature difference between the body of the gas and the metal;

(2).—The weight of the gas per cubic foot, which is proportional to the number of molecules in any unit of volume;

(3).—The bodily velocity of the motion of the gas parallel to any small area under consideration; and (probably),

(4).—The specific heat of the gas at constant pressure.

The apparatus consists of an electric resistance furnace containing coils of nickel wire, a small (interchangeable) multi-tubular boiler, and a steam-jet apparatus for reducing the air pressure at the exit end, so as to cause a flow of air through the boiler. A surface condenser was attached to the boiler's steam outlet, the condensed steam being weighed as a check on the feed-water measurements. A number of thermometers and thermo-couples were used to obtain atmospheric-air temperature, temperatures of the air entering and leaving the boilers, and feed-water temperature.

The apparatus is now being reconstructed with appliances for measuring the quantity of air entering the furnace, and an automatic electric-furnace temperature regulator.

Three sizes of boiler have been tested thus far, the dimensions being as given in Table 4.

Each of the three boilers was tested at several temperatures of entering air, up to 1,500° Fahr., about ten tests being made at each temperature. It is also the intention to run, on these three boilers, about eight tests at temperatures of 1,800°, 2,100° and 2,400° Fahr., respectively. A bulletin on the work already done, together with much incidental matter, is in course of preparation.[18]

TABLE 4.—DIMENSIONS OF BOILERS NOS. 1, 2, AND 3.

Items.	Boiler No. 1.	Boiler No. 2.	Boiler No. 3.
Distance, outside to outside of boiler heads, in inches	8.28	8.28	16.125
Actual outside diameter of flues, in inches	0.252	0.313	0.252
Actual inside diameter of flues, in inches	0.175	0.230	0.175
Number of flues (tubes)	10	10	10

The work on the first three boilers is only a beginning; preparations are being made to test eight more multi-tubular boilers of various lengths and tube diameters, under similar conditions. Because of the experience already obtained, it will be necessary to make only eight tests at each initial air temperature.

When the work on multi-tubular boilers is completed, water-tube boilers will be taken up, for which a fairly complete outline has been prepared. This second or water-tube portion of the investigation is really of the greater scientific and commercial interest, but the multi-tubular boilers were investigated first because the mathematical treatment is much simpler.

Producer-Gas Tests.—The producer-gas plant at the Pittsburg testing station is in charge of Mr. Carl D. Smith, and has been installed for the purpose of testing low-grade fuel, bone coal, roof coal, mine refuse, and such material as is usually considered of little value, or even worthless for power purposes. The gas engine, gas producer, economizer, wet scrubber (Fig. 1, Plate XIX), and accessories, are in Building No. 13, and the dry scrubber, gas-holder, and water-cooling apparatus are immediately outside that building (Fig. 2, Plate XIX).

PLATE XIX. [opp. 282]

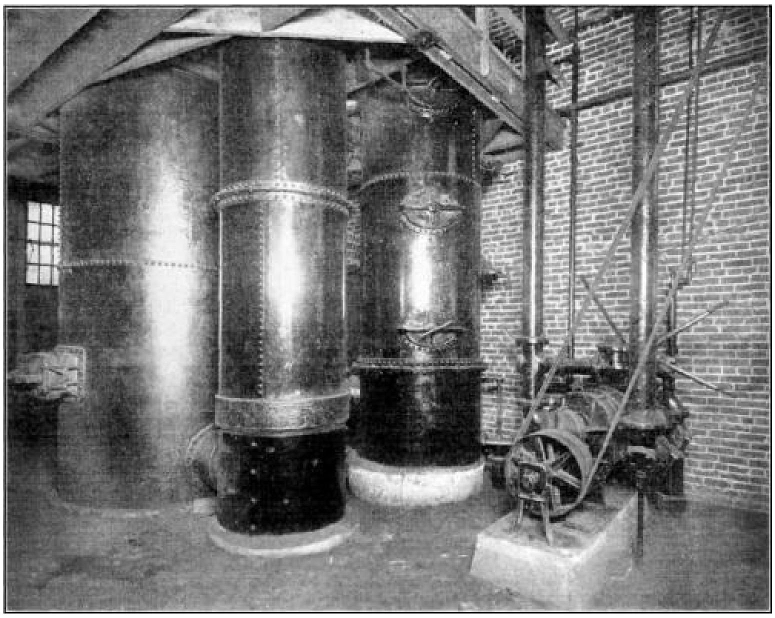


FIG. 1.—GAS PRODUCER, ECONOMIZER, AND WET SCRUBBER.

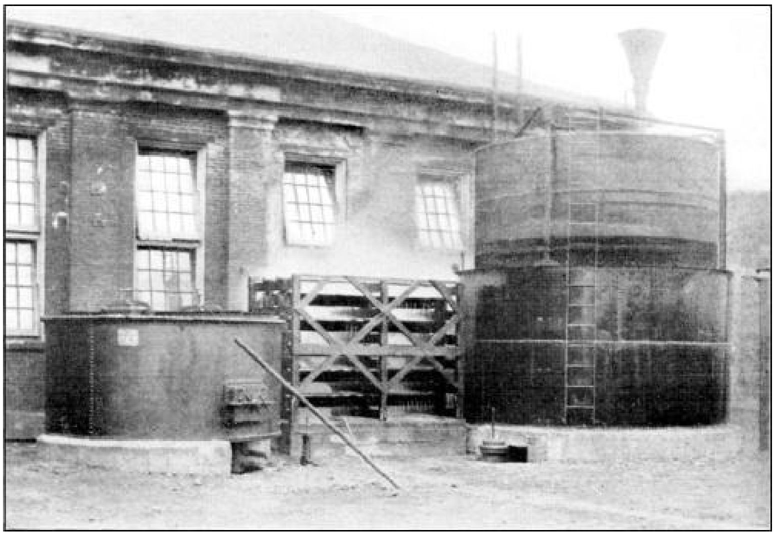


Fig. 2.—Producer Gas: Dry Scrubber and Gas Holder.

At present immense quantities of fuel are left at the mines, in the form of culm and slack, which, in quality, are much below the average output. Such fuel is considered of little or no value, chiefly because there is no apparatus in general use which can burn it to good advantage. The heat value of this fuel is often from 50 to 75% of that of the fuel marketed, and if not utilized, represents an immense waste of natural resources. Large quantities of low- 284 grade fuel are also left in the mines, simply because present conditions do not warrant its extraction, and it is left in such a way that it will be very difficult, if not practically impossible, for future generations to take out such fuel when it will be at a premium. Again, there are large deposits of low-grade coal in regions far remote from the sources of the present fuel supply, but where its successful and economic utilization would be a boon to the community and a material advantage to the country at large. The great importance of the successful utilization of low-grade fuel is obvious. Until within very recent years little had been accomplished along these lines, and there was little hope of ever being able to use these fuels successfully.

The development of the gas producer for the utilization of ordinary fuels,[19] however, indicates that the successful utilization of practically all low-grade fuel is well within the range of possibility. It is notable that, although all producer-gas tests at the Government testing stations, at St. Louis and Norfolk, were made in a type of producer[20] designed primarily for a good grade of anthracite coal, the fuels tested included a wide range of bituminous coals and lignites, and even peat and bone coal, and that, in nearly every test, little serious difficulty was encountered in maintaining satisfactory operating conditions.[21] It is interesting to note that in one test, a bone coal containing more than 45% of ash was easily handled in the producer, and that practically full load was maintained for the regulation test period of 50 hours.[22]

It is not expected that all the fuels tested will prove to be of immediate commercial value, but it is hoped that much light will be thrown on this important problem.

The equipment for this work consists of a single gas generator, rated at 150 h.p., and a three-cylinder, vertical gas engine of the same capacity. The producer is a Loomis-Pettibone, down-draft, made by the Power and Mining Machinery Company, of Cudahy, Wis., and is known as its “Type C” plant. The gas generator consists of a cylindrical shell, 6 ft. in diameter, carefully 285 lined with fire-brick, and having an internal diameter of approximately 4 ft. Near the bottom of the generator there is a fire-brick grate, on which the fuel bed rests. The fuel is charged at the top of the producer through a door (Fig. 1, Plate XX), which may be left open a considerable time without affecting the operation of the producer, thus enabling the operator to watch and control the fuel bed with little inconvenience. As the gas is generated, it passes downward through the hot fuel bed and through the fire-brick grate. This down-draft feature “fixes,” or makes into permanent gases, the tarry vapors which are distilled from bituminous coal when it is first charged into the producer. A motor-driven exhauster with a capacity of 375 cu. ft. per min., draws the hot gas from the base of the producer through an economizer, where the sensible heat of the gas is used to pre-heat the air and to form the water vapor necessary for the operation of the producer. The pre-heated air and vapor leave the economizer and enter the producer through a passageway near the top and above the fuel bed. From the economizer the gas is drawn through a wet scrubber where it undergoes a further cooling and is cleansed of dirt and dust. After passing the wet scrubber, the gas, under a light pressure, is forced, by the exhauster, through a dry scrubber to a gas-holder with a capacity of about 1,000 cu. ft.

All the fuel used is carefully weighed on scales which are checked from time to time by standard weights; and, as the fuel is charged into the producer, a sample is taken for chemical analysis and for the determination of its calorific power. The water required for the generation of the vapor is supplied from a small tank carefully graduated to pounds; this observation is made and recorded every hour. All the water used in the wet scrubber is measured by passing it through a piston-type water meter, which is calibrated from time to time to insure a fair degree of accuracy in the measurement. Provision is made for observing the pressure and temperature of the gas at various points; these are observed and recorded every hour.

From the holder the gas passes through a large meter to the vertical three-cylinder Westinghouse engine, which is connected by a belt to a 175-kw., direct-current generator. The load on the generator is measured by carefully calibrated switch-board instruments, and is regulated by a specially constructed water rheostat which stands in front of the building.

Careful notes are kept of the engine operation; the gas consumption and the load on the 286
engine are observed and recorded every 20 min.; the quantity of jacket water used on the gas engine, and also its temperature entering and leaving the engine jackets, are recorded every hour. Indicator cards are taken every 2 hours. The work is continuous, and each day is divided into three shifts of 8 hours each; the length of a test, however, is determined very largely by the character and behavior of the fuel used.

A preliminary study of the relative efficiency of the coals found in different portions of the United States, as producers of illuminating gas, has been nearly completed under the direction of Mr. Alfred H. White, and a bulletin setting forth the results is in press.[23]

Tests of Liquid Fuels.—Tests of liquid fuels in internal-combustion engines, in charge of Mr. R. M. Strong, are conducted in the engine-room of Building No. 13.

The various liquid hydro-carbon fuels used in internal-combustion engines for producing power, range from the light refined oils, such as naphtha, to the crude petroleums, and have a correspondingly wide variation of physical and chemical properties.

The most satisfactory of the liquid fuels for use in internal-combustion engines, are alcohol and the light refined hydro-carbon oils, such as gasoline. These fuels, however, are the most expensive in commercial use, even when consumed with the highest practical efficiency, which, it is thought, has already been attained, as far as present types of engines are concerned.

At present little is known as to how far many of the very cheap distillates and crude petroleums can be used as fuel for internal-combustion engines. It is difficult to use them at all, regardless of efficiency.

Gasoline is comparatively constant in quality, and can be used with equal efficiency in any gasoline engine of the better grade. There are many makes of high-grade gasoline engines, tests on any of which may be taken as representative of the performance and action of gasoline in an internal-combustion engine, if the conditions under which the tests were made are clearly stated and are similar.

Kerosene varies widely in quality, and requires special devices for its use, but is a little
cheaper than gasoline. It is possible that the kerosene engine may be developed so as to 287
permit it to take the place of the smaller stationary and marine gasoline engines. This would mean considerable saving in fuel cost to the small power user, who now finds the liquid-fuel internal-combustion engine of commercial advantage. A number of engines at present on the market use kerosene; some use only the lighter grades and are at best comparatively less efficient than gasoline engines. All these engines have to be adjusted to the grade of oil to be used in order to get the best results.

Kerosene engines are of two general types: the external-vaporizer type, in which the fuel is vaporized and mixed with air before or as it is taken into the cylinder; and the internal-vaporizer type, in which the liquid fuel is forced into the cylinder and vaporized by contact with the hot gases or heated walls of a combustion chamber at the head of the cylinder. A number of special devices for vaporizing kerosene and the lighter distillates have been tried and used with some success. Heat is necessary to vaporize the kerosene as quickly as it is required, and the degree of heat must be held between the temperature of vaporization and that at which the oil will be carbonized. The vapor must also be thoroughly and uniformly mixed with air in order to obtain complete combustion. As yet, no reliable data on these limiting temperatures for kerosene and similar oils have been obtained. No investigation has ever been made of possible methods for preventing the oils from carbonizing at the higher temperatures, and the properties of explosive mixtures of oil vapors and air have not been studied. This field of engineering laboratory research is of vital importance to the solution of the kerosene-engine problem.

Distillates or fuel oils and the crude oils are much the cheapest of the liquid fuels, and if used efficiently in internal-combustion engines would be by far the cheapest fuels available in many large districts.

Several engine builders are developing kerosene vaporizers, which are built as a part of the engine, or are adapted to each different engine, as required to obtain the best results. Most of these vaporizers use the heat and the exhaust gases to vaporize the fuel, but they differ greatly in construction; some are of the retort type, and others are of the float-feed carburetter type. To what extent the lower-grade fuel oils can be used with these vaporizers is yet to be determined.

There are only a few successful oil engines on the American market. The most prominent of 288
these represent specific applications of the principal methods of internal vaporization, and all except one are of the hot-bulb ignition type. It will probably be found that no one of the 4-stroke cycle, or 2-stroke cycle, engines is best for all grades of oil, but rather that each is best for some one grade. The Diesel engine is in a class by itself, its cycle and method of control being somewhat different from the others.

An investigation of the comparative adaptability of gasoline and alcohol to use in internal-combustion engines, consisting of more than 2,000 tests, was made at the temporary fuel-testing plant of the Geological Survey, at Norfolk, Va., in 1907. A detailed report of these tests is in preparation.[24] A similar investigation of the comparative adaptability of kerosenes has been commenced, with a view to obtaining data on their economical use, leading up to the investigation of the comparative fuel values of the cheaper distillates and crude petroleum, as before discussed.

Washing and Coking Tests.—The investigations relating to the preparation of low-grade coals, such as those high in ash or sulphur, by processes that will give them a higher market value or increase their efficiency in use, are in charge of Mr. A. W. Belden. They include the washing and coking tests of coals, and the briquetting of slack and low-grade coal and culm-bank refuse so as to adapt these fuels for combustion in furnaces, etc.

This work has been conducted in the washery and coking plant temporarily located at Denver, Colo., and in Building No. 32 at the Pittsburg testing station, where briquetting is in progress. The details of these tests are set forth in the various bulletins issued by the Geological Survey.[25]

The washing tests are carried out in the following manner: As the raw coal is received at the plant, it is shoveled from the railroad cars to the hopper scale, and weighed. It then passes through the tooth-roll crusher, where the lumps are broken down to a maximum size of 2½ in.
An apron conveyor delivers the coal to an elevator which raises it to one of the storage bins. As 289
the coal is being elevated, an average sample representing the whole shipment is taken. An analysis is made of this sample of raw coal and float-and-sink tests are run to determine the size to which it is necessary to crush before washing, and the percentage of refuse with the best separation. From the data thus obtained, the washing machines are adjusted so that the washing test is made with full knowledge of the separations possible under varying percentages of refuse. The raw coal is drawn from the bin and delivered to a corrugated-roll disintegrator, where it is crushed to the size found most suitable, and is then delivered by the raw-coal elevator to another storage bin. The arrangement of the plant is such that the coal may be first washed on a Stewart jig, and the refuse then delivered to and re-washed on a special jig, or the refuse may be re-crushed and then re-washed.

When the coal is to be washed, it drops to the sluice box, where it is mixed with the water and sluiced to the jigs. In drawing off the washed coal, or when the uncrushed raw coal is to be drawn from a bin and crushed for the washing tests, however, a gate just below the coal-flow regulating gate is thrown in, and the coal falls into a central hopper instead of into the sluice box. Ordinarily, this gate forms one side of the vertical chute. The coal in this central hopper is carried by a chute to the apron conveyor, and thence to the roll disintegrator, or, in case it is washed coal, to a swing-hammer crusher. It will be noted that coal, in this manner, can be drawn from a bin at the same time that coal is being taken from another bin, and sluiced to the jigs for washing, the two operations not interfering in the least.

The washed coal, after being crushed and elevated to the top of the building, is conveyed by a chute to the coke-oven larry, and is weighed on the track scale, after which it is charged to the oven. The refuse is sampled and weighed as it is wheeled to the dump pile, and from this sample the analysis is made and a float-and-sink test run to determine the "loss of good coal" in the refuse and to show the efficiency of the washing test.

The coking tests have been conducted in a battery of two beehive ovens, one 7 ft. high and 12 ft. in diameter, the other, 6¼ ft. high and 12 ft. in diameter. A standard larry with a capacity of
8 tons, and the necessary scales for weighing accurately the coal charged and coke produced, 290
complete the equipment. The coal is usually run through a roll crusher which breaks it to about ½-in. size, or through a Pennsylvania hammer crusher. The fineness of the coals put through the hammer crusher varies somewhat, but the average, taken from a large number of samples, is as follows: Through ⅛-in. mesh, 100%; over 10-mesh, 31.43%; over 20-mesh, 24.29%; over 40-mesh, 22.86%; over 60-mesh, 10 per cent. The results of the coking tests are set forth in detail in the various publications issued on this subject.[26]

Tests of coke produced in the illuminating-gas investigations before referred to, and a study of commercial coking and by-product plants, are included in these investigations.

Briquetting Investigations.—These investigations are in charge of Mr. C. L. Wright, and are conducted in Building No. 32, which is of fire-proof construction, having a steel-skeleton frame work, reinforced-concrete floors, and 2-in. cement curtain walls, plastered on expanded-metal laths. In this building two briquetting machines are installed, one an English machine of the Johnson type, and the other a German lignite machine of very powerful construction.

The investigations include the possibility of making satisfactory commercial fuels from lignite or low-grade coals which do not stand shipment well, the benefiting of culm or slack coals which are wasted or sold at unremunerative prices, and the possibility of improving the efficiency of good coals. Some of the various forms of commercial briquettes, American and foreign, are shown in Fig. 2, Plate XX. After undergoing chemical analysis, the coal is elevated and fed to a storage bin, whence it is drawn through a chute to a hopper on the weighing scales. There it is mixed with varying percentages of different kinds of binding material, and the tests are conducted so as to ascertain the most suitable binder for each kind of fuel, which will produce the most durable and weather-proof briquette at least cost, and the minimum quantity necessary to produce a good, firm briquette. After weighing, the materials to be tested are run through the necessary grinding and pulverizing machines and are fed into the briquetting machines, whence the manufactured briquettes are delivered for loading or storage. The materials to be used in the German machine are also dried and cooled again.

PLATE XX. [opp. 284]

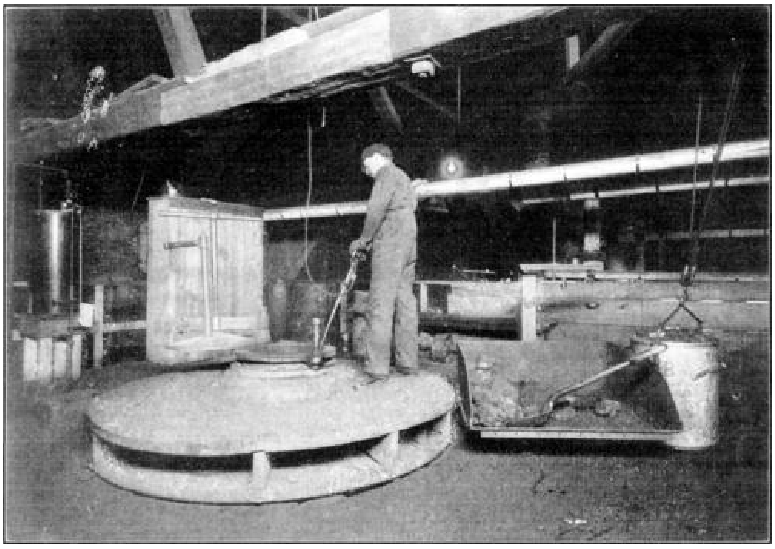


FIG. 1.—CHARGING FLOOR OF GAS PRODUCER.

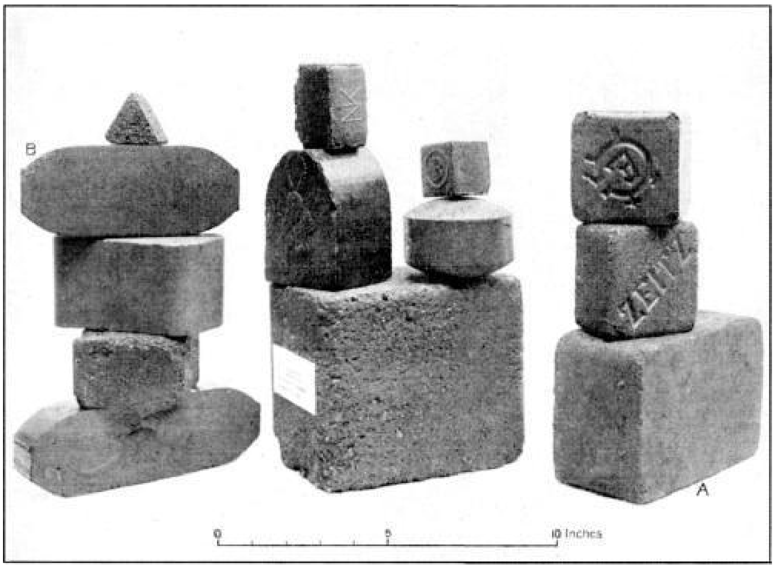


FIG. 2.—EUROPEAN AND AMERICAN BRIQUETTES.

The briquettes made at this plant are then subjected to physical tests in order to determine 291
their weathering qualities and their resistance to abrasion; extraction tests and chemical analyses are also made. Meanwhile other briquettes from the same lots are subjected to combustion tests for comparison with the same coal not briquetted. These tests are made in stationary boilers, in house-heating boilers, on locomotives, naval vessels, etc., and the results, both of the processes of manufacture, and of the tests, are published in various bulletins issued by the Geological Survey.[27]

The equipment includes storage bins for the raw coal, scales for weighing, machines for crushing or cracking the pitch, grinders, crushers, and disintegrators for reducing the coal to the desired fineness, heating and mixing apparatus, presses and moulds for forming the briquettes, a Schulz drier, and a cooling apparatus.

There is a small experimental hand-briquetting press (Fig. 1, Plate XXI) for making preliminary tests of the briquetting qualities of the various coals and lignites. With this it is easily possible to vary the pressure, heat, percentage and kind of binder, so as to determine the best briquetting conditions for each fuel before subjecting it to large-scale commercial tests in the big briquetting machines.

This hand press will exert pressures up to 50 tons or 100,000 lb. per sq. in., on a plunger 3 in. in diameter. This plunger enters a mould, which can be heated by a steam jacket supplied with ordinary saturated steam at a pressure of 125 lb., and compresses the fuel into a briquette, 8 in. long, under the conditions of temperature and pressure desired.

The Johnson briquetting machine, which requires 25 h.p. for its operation, exerts a pressure of about 2,500 lb. per sq. in., and makes briquettes of rectangular form, 6¾ by 4¼ by 2½ in., and having an average weight of about 3¾ lb. The capacity of the machine (Fig. 2, Plate XXI) is about 3.8 tons of briquettes per 8-hour day.

PLATE XXI. [opp. 290]

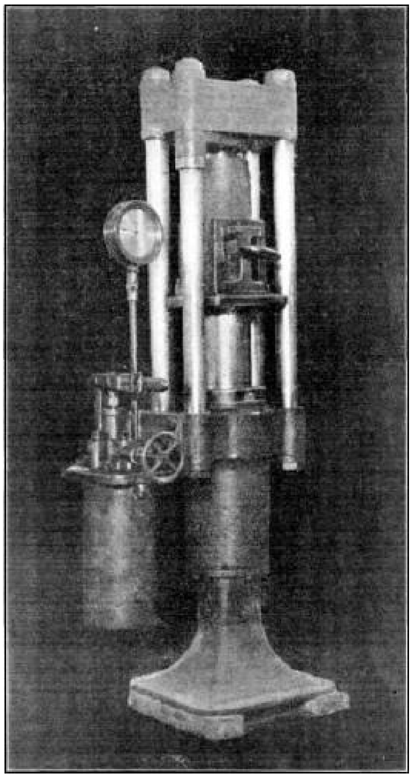


FIG. 1.—HAND BRIQUETTING PRESS.

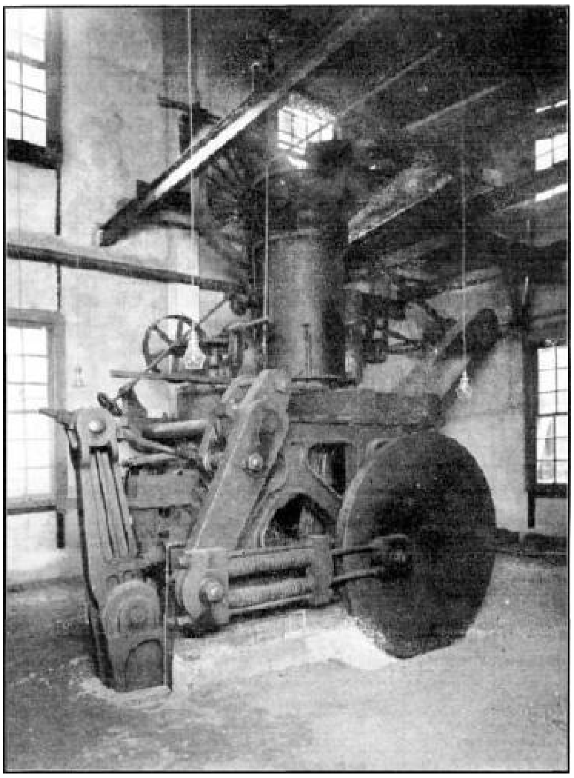


FIG. 2.—COAL BRIQUETTING MACHINE.

Under the hopper on the scales for the raw material is a square wooden reciprocal plunger which pushes the fuel into a hole in the floor at a uniform rate. The pitch is added as uniformly as possible by hand, as the coal passes this hole. Under this hole a horizontal screw conveyor carries the fuel and pitch to the disintegrator, in front of which, in the feeding chute, there is a powerful magnet for picking out any pieces of iron which might enter the machine and cause trouble. 292

The ground mixture is elevated from the disintegrator to a point above the top of the upper mixer of the machine. At the base of this cylinder, steam can be admitted by several openings to heat the material to any desired temperature, usually from 180° to 205° Fahr. There, a plunger, making 17 strokes per min., compresses two briquettes at each stroke.

The German lignite-briquetting machine (Figs. 18 and 19) was made by the Maschinenfabrik Buckau Actien-Gesellschaft, Magdeburg, Germany. Lignite from the storage room on the third floor of the building is fed into one end of a Schulz tubular drier (Fig. 1, Plate XXII), which is similar to a multi-tubular boiler set at a slight angle from the horizontal, and slowly revolved by worm and wheel gearing, the lignite passing through the tubes and the steam being within the boiler. From this drier the lignite passes through a sorting sieve and crushing rolls to a cooling apparatus, which consists of four horizontal circular plates, about 13 ft. in diameter, over which the dried material is moved by rakes. After cooling, the material is carried by a long, worm conveyor to a large hopper over the briquette press, and by a feeding box to the press (Fig. 2, Plate XXII).

PLATE XXII.

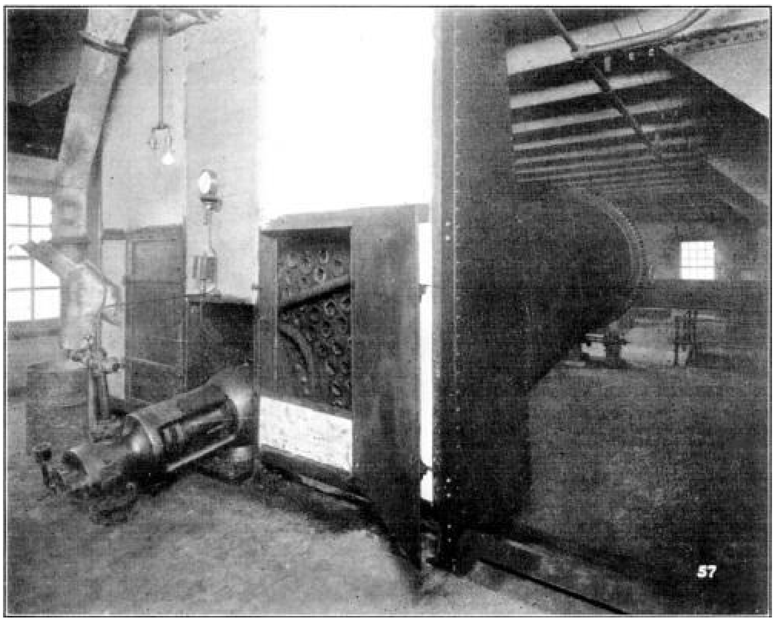


FIG. 1.—DRYER FOR LIGNITE BRIQUETTING PRESS.

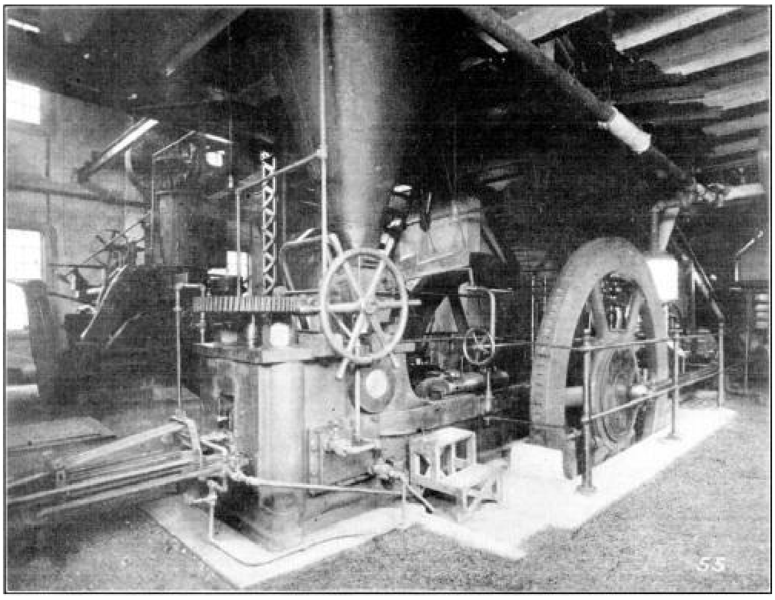


FIG. 2.—LIGNITE BRIQUETTING MACHINE.

The press, which is of the open-mould type, consists of a ram and die plates, the latter being set so as to make a tube which gradually tapers toward the delivery end of the machine. The briquettes have a cross-section similar to an ellipse with the ends slightly cut off; they are about 1¼ in. thick and average about 1 lb. in weight (Fig. 2, Plate XX). The press is operated by a direct connection with a steam engine of 150 h.p., the base of which is continuous with that of the press. The exhaust steam from the engine is used to heat the driver.

The plunger makes from 80 to 100 strokes per min., the pressure exerted ranging from 14,000 to 28,000 lb. per sq. in., the capacity of the machine being 1 briquette per stroke, or from 2½ to 3 tons of completed briquettes per hour. It is expected that no binder will be needed for practically all the brown lignite briquetted by this machine, thus reducing the cost as compared with the briquetting of coals, which require from 5 to 7% of water-gas, pitch binder costing more than 50 cents per ton of manufactured briquettes.

FIG. 18.

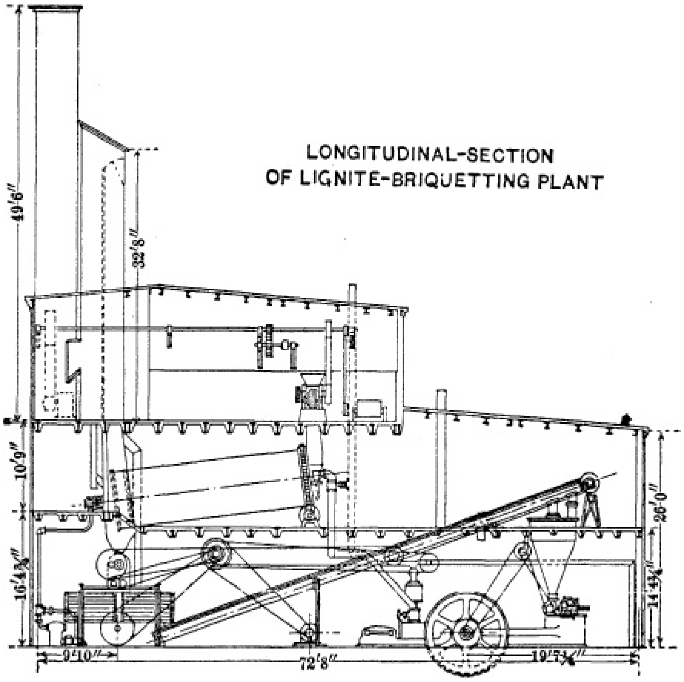
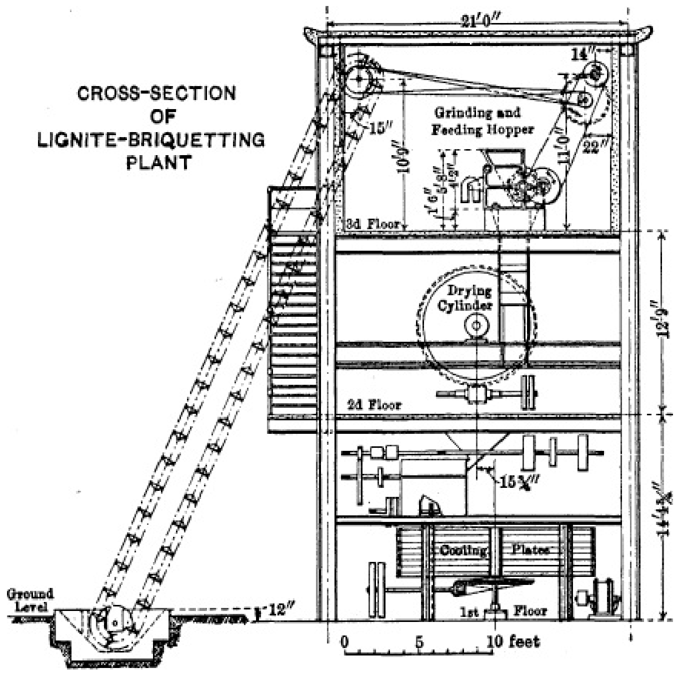


Fig. 19.



Peat Investigations.—Investigations into the distribution, production, origin, nature, and uses 294
of peat are being conducted by Mr. C. A. Davis, and include co-operative arrangements with State Geological Surveys and the Geologic Branch of the U. S. Geological Survey. These organizations conduct surveys which include the mapping of the peat deposits in the field, the determination of their extent and limitations, the sampling of peat from various depths, and the transmittal of samples to the Pittsburg laboratories for analysis and test.[28]

This work is co-ordinated in such a manner as to result in uniform methods of procedure in studying the peat deposits of the United States. The samples of peat are subjected to microscopic examination, in order to determine their origin and age, and to chemical and physical tests at the laboratories in Pittsburg, so as to ascertain the chemical composition and calorific value, the resistance to compressive strains, the ash and moisture content, drying properties, resistance to abrasion, etc. Occasionally, large quantities of peat are disintegrated and machined, and portions, after drying for different periods, are subjected to combustion tests in steam boilers and to tests in the gas producer, to ascertain their efficiency as power producers.

Results.—The full value of such investigations as have been described in the preceding pages cannot be realized for many years; but, even within the four years during which this work has been under way, certain investigations have led to important results, some of which may be briefly mentioned:

The chemical and calorific determinations of coals purchased for the use of the Government have resulted in the delivery of a better grade of fuel without corresponding increase in cost, and, consequently, in saving to the Government. Under this system, of purchasing its coal under specifications and testing, the Government is getting more nearly what it pays for and is paying for what it gets. These investigations, by suggesting changes in equipment and methods, are also indicating the practicability of the purchase of cheaper fuels, such as bituminous coal and the smaller sizes of pea, buckwheat, etc., instead of the more expensive sizes of anthracite, with a corresponding saving in cost. The Government’s fuel bill now aggregates about $10,000,000 yearly.

The making and assembling of chemical analyses and calorific determinations (checked by 295
other tests) of carefully selected samples of coals from nearly 1,000 different localities, in the different coal fields of the United States, with the additions, from time to time, of samples representing parts of coal fields or newly opened beds of coal in the same field, furnish invaluable sources of accurate information, not only for use of the Government, but also for the general public. Of the above-mentioned localities, 501 were in the public-land States and 427 in the Central, Eastern, and Southern States.

The chemical analyses of the coals found throughout the United States have been made with such uniformity of method, both as to collection of samples and analytical procedure, as to yield results strictly comparable for coals from all parts of the country, and furnish complete information, as a basis for future purchases and use by the Government and by the general public, of all types of American coals.

Other researches have resulted in the acquirement of valuable information regarding the distribution of temperature in the fuel bed of gas producers and furnaces, showing a range of from 400° to 1,300° cent., and have thus furnished data indicating specific difficulties to be overcome in gas-producer improvements for greater fuel efficiency.

The recent studies of the volatile matter in coal, and its relation to the operation of coke ovens and other forms of combustion, have demonstrated that as much as one-third of this matter is inert and non-combustible, a fact which may have a direct bearing on smoke prevention by explaining its cause and indicating means for its abatement.

Experiments in the storage of coal have proven that oxygen is absorbed during exposure to air, thereby causing, in some cases, a deterioration in heating value, and indicating that, for certain coals, in case they are to be stored a long time for naval and other purposes, storage under water is advisable.

The tests of different coals under steam boilers have shown the possibility of increasing the general efficiency of hand-fired steam boilers from 10 to 15% over ordinary results. If this saving could be made in the great number of hand-fired boilers now being operated in all parts of the United States, it would result in large saving in the fuel bill of the country. Experiments which have been made with residence-heating boilers justify the belief that it will be possible
to perfect such types of boilers as may economically give a smokeless operation. The tests 296
under steam boilers furnish specific information as to the most efficient method of utilizing each of a number of different types of coal in Government buildings and power plants in different parts of the country.

The tests in the gas producer have shown that many fuels of such low grade as to be practically valueless for steam-furnace purposes, including slack coal, bone coal, and lignite, may be economically converted into producer gas, and may thus generate sufficient power to render them of high commercial value.

Practically every shipment out of several hundred tested in the gas producers, including coals as high in ash content as 45%, and lignites and peats high in moisture, has been successfully converted into producer gas which has been used in operating gas engines. It has been estimated that on an average there was developed from each coal tested in the gas-producer plant two and one-half times the power developed when used in the ordinary steam-boiler plant, and that such relative efficiencies will probably hold good for the average plant of moderate power capacity, though this ratio may be greatly reduced in large steam plants of the most modern type. It was found that the low-grade lignites of North Dakota developed as much power, when converted into producer gas, as did the best West Virginia bituminous coals when utilized under the steam boiler; and, in this way, lignite beds underlying from 20,000,000 to 30,000,000 acres of public lands, supposed to have little or no commercial value, are shown to have a large value for power development.

The tests made with reference to the manufacture and combustion of briquetted coal have demonstrated conclusively that by this means many low-grade bituminous coals and lignites may have their commercial value increased to an extent which more than covers the increased cost of making; and these tests have also shown that bituminous coals of the higher grades may be burned in locomotives with greatly increased efficiency and capacity and with less smoke than the same coal not briquetted. These tests have shown that, with the same fuel consumption of briquettes as of raw coal, the same locomotive can very materially increase its hauling capacity and thus reduce the cost of transportation.

The investigations into smoke abatement have indicated clearly that each type of coal may be 297
burned practically without smoke in some type of furnace or with some arrangement of mechanical stoker, draft, etc. The elimination of smoke means more complete combustion of the fuel, and consequently less waste and higher efficiency.

The investigations into the waste of coal in mining have shown the enormous extent of this waste, aggregating probably from 300,000,000 to 400,000,000 tons yearly, of which at least one-half might be saved. It is being demonstrated that the low-grade coals, high in sulphur and ash, now left underground, can be used economically in the gas producer for power and light, and, therefore, should be mined at the same time that the high-grade coal is being removed. Moreover, attention is now being called to the practicability of a further large reduction of waste through more efficient mining methods.

The washing tests have demonstrated the fact that many coals, too high in ash and sulphur for economic use under the steam boiler or for coking, may be rendered of commercial value by proper treatment in the washery. The coking tests have also demonstrated that, by proper methods of preparation for and manipulation in the beehive oven, many coals which were not supposed to be of economic value for coking purposes, may be rendered so by prior washing and proper treatment. Of more than 100 coals tested during 1906 from the Mississippi Valley and the Eastern States, most of which coals were regarded as non-coking, all except 6 were found, by careful manipulation, to make fairly good coke for foundry and other metallurgical purposes. Of 52 coals from the Rocky Mountain region, all but 3 produced good coke under proper treatment, though a number of these had been considered non-coking coals.

Investigations into the relative efficiency of gasoline and denatured alcohol as power producers, undertaken in connection with work for the Navy Department, have demonstrated that with proper manipulation of the carburetters, igniters, degree of compression, etc., denatured alcohol has the same power-producing value, gallon for gallon, as gasoline. This is a most interesting development, in view of the fact that the heat value of a gallon of alcohol is only a little more than 0.6 that of a gallon of gasoline. To secure these results, compressions of from 150 to 180 lb. per sq. in. were used, these pressures involving an increase in weight of engine. Although the engine especially designed for alcohol will be heavier than a gasoline 298
engine of the same size, it will have a sufficiently greater power capacity so that the weight per horse-power need not be greater.

Several hundred tons of peat have been tested to determine methods of drying, compressing into briquettes, and utilization for power production in the gas producer. In connection with these peat investigations, a reconnoissance survey has been made of the peat deposits of the Atlantic Coast. Samples have been obtained by boring to different depths in many widely distributed peat-bogs, and these samples have been analyzed and tested in order to determine their origin, nature, and fuel value.

The extent and number of tests from which these results have been derived will be appreciated from the fact that, in three years, nearly 15,000 tests were made, in each of which large quantities of fuel were consumed. These tests involved nearly 1,250,000 physical observations and 67,080 chemical determinations, made with a view to analyze the results of the tests and to indicate any necessary changes in the methods as they progressed. For coking, cupola, and washing, 596 tests, of which nearly 300 involved the use of nearly 1,000 tons of coal, have been made at Denver. For briquetting, 312 tests have been made. Briquettes have been used in combustion tests in which 250 tons of briquetted coal were consumed in battleship tests, 210 tons in torpedo-boat tests, 320 tons in locomotive tests on three railway systems, and 70 tons were consumed under stationary steam boilers. Of producer gas tests, 175 have been made, of which 7 were long-time runs of a week or more in duration, consuming in all 105 tons of coal. There have been 300 house-heating boiler tests and 575 steam-boiler tests; also, 83 railway-locomotive and 23 naval-vessel tests have been made on run-of-mine coal in comparison with briquetted coal; also, 125 tests have been made in connection with heat-transmission experiments, and 2,254 gasoline- and alcohol-engine tests. Nearly 10,000 samples of coal were taken for analysis, of which 3,000 were from public-land States. Nearly 5,000 inspection samples, of coal purchased by the Government for its use, have been taken and tested.

The results of the tests made in the course of these investigations, as summarized, have been published in twelve separate Bulletins, three of which, Nos. 261, 290, and 332, set forth in detail the operations of the fuel-testing plant for 1904, 1905, and 1906. Professional Paper No. 299
48, in three volumes, describes in greater detail each stage of the operations for 1904 and 1905.

Separate Bulletins, descriptive of the methods and results of the work in detail, have been published, as follows: No. 323, Experimental work conducted in the chemical laboratory; No. 325, A study of four hundred steaming tests; No. 334, Burning of coal without smoke in boiler plants; No. 336, Washing and coking tests of coal, and cupola tests of coke; No. 339, Purchase of coal under specifications on basis of heating value; No. 343, Binders for coal briquettes; No. 362, Mine sampling and chemical analyses of coals in 1907; No. 363, Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests, and some foreign specifications for briquetted fuel; No. 366, Tests of coal and briquettes as fuel for house-heating boilers; No. 367, Significance of drafts in steam-boiler practice; No. 368, Coking and washing tests of coal at Denver; No. 373, Smokeless combustion of coal in boiler plants, with a chapter on central heating plants; No. 378, Results of purchasing coal under Government specifications; No. 382, The effect of oxygen in coal; and, No. 385, Briquetting tests at Norfolk, Va.

300

DISCUSSION

Mr. Kenneth Allen, M. Am. Soc. C. E.—The speaker would like to know whether anything has been

Allen. done in the United States toward utilizing marsh mud for fuel.

In an address by Mr. Edward Atkinson, before the New England Water Works Association, in 1904, on the subject of "Bog Fuel," he referred to its extensive use in Sweden and elsewhere, and intimated that there was a wide field for its use in America.

The percentage of combustible material in the mud of ordinary marsh lands is very considerable, and there are enormous deposits readily available; but it is hardly probable that its calorific value is sufficiently high to render its general use at this time profitable.

As an example of the amount of organic matter which may remain stored in these muds for many years, the speaker would mention a sample taken from the bottom of a trench, which he had analyzed a few years ago. Although taken from a depth of about 15 ft., much of the vegetable fiber remained intact. The material proved to be 70¾% volatile.

Possibly before the existing available coal deposits are exhausted, the exploitation of meadow muds for fuel may become profitable.

Mr. Kreisinger. Henry Kreisinger, Esq.[29] (by letter).—Mr. Wilson gives a brief description of a long furnace and an outline of the research work which is being done in it. It may be well to discuss somewhat more fully the proposed investigations and point out the practical value of the findings to which they may lead.

In general, the object is to study the process of combustion of coal. When soft coal is burned in any furnace, part of the combustible is driven off shortly after charging, and has to be burned in the space between the fuel bed and the exit of the gases, which is called the combustion space. There is enough evidence to show that, with a constant air supply, the completeness of the combustion of the volatile combustible depends on the length of time the latter stays within the combustion space; but, with a constant rate of charging the coal, this length of time depends directly on the extent of the combustion space. Thus, if the volume of the volatile combustible evolved per second and the admixed air is 40 cu. ft., and the extent of the combustion space is 80 cu. ft., the average time the gas will stay within the latter is 2 sec.; if the combustion space is 20 cu. ft., the average time the mixture can stay in this space is only ½ sec., and its combustion will be less complete than in the first case. Thus it is seen that the extent of the combustion space of a furnace is an important factor in the economic combustion of volatile coals. The specific object of the investigations, thus far planned, is to determine the 301
extent of the combustion space required to attain practically complete combustion when a given quantity of a given coal is burned under definite conditions. With this object in view, the furnace has been provided with a combustion space large enough for the highest volatile coals and for the highest customary rate of combustion. To illustrate the application of the data which will be obtained by these experiments, the following queries are given:

Suppose it is required to design a furnace which will burn coal from a certain Illinois mine at the rate of 1,000 lb. per hour, with a resulting temperature of not less than 2,800° Fahr. How large a combustion space is required to burn, with practical completeness, the volatile combustible? What completeness of combustion can be attained, if the combustion space is only three-fourths of the required extent? In the present state of the knowledge of the process of combustion of coal, these queries cannot be answered definitely. In the literature on combustion one may find statements that the gases must be completely burned before leaving the furnace or before they strike the cooling surfaces of the boiler; but there is no definite information available as to how long the gases must be kept in the furnace or how large the combustion space must be in order to obtain practically complete combustion. It is strange that so little is known of such an old art as the combustion of coal.

The research work under consideration is fundamentally a problem in physical chemistry, and, for that reason, has been assigned to a committee consisting of the writer as Engineer, Dr. J. C. W. Frazer, Chemist, and Dr. J. K. Clement, Physicist. The outcome of the investigation may prove of extreme interest to mechanical and fuel engineers, and to all who have anything to do with the burning of coal or the construction of furnaces. In the experiments thus far planned the following factors will be considered:

Effect of the Nature of Coal on the Extent of Combustion Space Required.—The steaming coals mined in different localities evolve different volumes of volatile combustible, even when burned at the same rate. The coal which analyzes 45% of volatile matter evolves a much greater volume of gases and tar vapors than that analyzing only 15 per cent. These evolved gases and tar vapors must be burned in the space. Consequently, a furnace burning high volatile coal must have a much larger combustion space than that burning coal low in volatile combustible.

There is enough evidence to show that the extent of combustion space required to burn the volatile combustible depends, not only on the volume of the combustible mixture, but also on the chemical composition of the volatile combustible. Thus the volatile combustible of low 302
volatile coal, when mixed with an equal volume of air, may require 1 sec. in the combustion space to burn practically to completeness, while it may require 2 sec. to burn the same volume of the volatile combustible of high volatile coal with the same completeness; so that the extent of the combustion space required to burn various kinds of coal may not be directly proportional to the volatile matter of the coal.

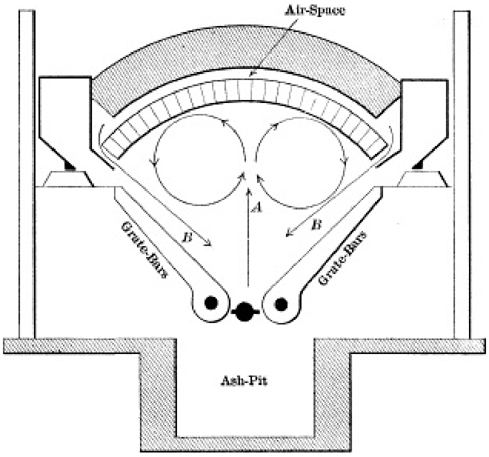
Effect of the Rate of Combustion on the Extent of Combustion Space Required.—With the same coal, the volume of the volatile combustible distilled from the fuel bed per unit of time varies as the rate of combustion. Thus, when this rate is double that of the standard, the volume of gases and tar vapors driven from the fuel is about doubled. To this increased volume of volatile combustible, about double the volume of air must be added, and, if the mixture is to be kept the same length of time within the combustion space, the latter should be about twice as large as for the standard rate of combustion. Thus the combustion space required for complete combustion varies, not only with the nature of the coal, but also with the rate of firing the fuel, which, of course, is self-evident.

Effect of Air Supply on the Extent of Combustion Space Required.—Another factor which influences the extent of the combustion space is the quantity of air mixed with the volatile combustible. Perhaps, within certain limits, the combustion space may be decreased when the supply of air is increased. However, any statement at present is only speculation; the facts must be determined experimentally. One fact is known, namely, that, in order to obtain higher temperatures of the products of combustion, the air supply must be decreased.

Effect of Rate of Heating of Coal on the Extent of Combustion Space Required.—There is still another factor, a very important one, which, with a given coal and any given air supply, will influence the extent of the combustion space. This factor is the rate of heating of the coal when feeding it into the furnace. The so-called "proximate" analysis of coal is indeed only very approximate. When the analysis shows, say, 40% of volatile matter and 45% of fixed carbon, it does not mean that the coal is actually composed of so much volatile matter and so much fixed carbon; it simply means that, under a certain rate of heating attained by certain standard laboratory conditions, 40% of the coal has been driven off as "volatile matter." If the rate or method of heating were different, the amount of volatile matter driven off would also be different. Chemists state that it is difficult to obtain accurate checks on "proximate" analysis. To illustrate this factor, further reference may be made to the operation of the up-draft bituminous gas producers. In the generator of such producers the tar vapors leave the freshly fired fuel, pass through the wet scrubber, and are finally separated by the tar extractor as a black, pasty substance in a semi-liquid state. If this tar is subjected to the standard proximate analysis, it will be shown that from 40 to 50% of it is fixed carbon, although it left the gas 303
generator as volatile matter. It is desired to emphasize the fact that different rates of heating of high volatile coals will not only drive off different percentages of volatile matter, but that the latter itself varies greatly in chemical composition and physical properties as regards inflammability and rapidity of combustion. Thus it may be said that the extent of the combustion space required for the complete oxidation of the volatile combustible depends on the method of charging the fuel, that is, on how rapidly the fresh fuel is heated. If this factor is given proper consideration, it may be possible to reduce very materially the necessary space required for complete combustion.

The Effect of the Rate of Mixing the Volatile Combustible and Air on the Extent of the Combustion Space.—When studying the effects discussed in the preceding paragraphs, the rate of mixing the volatile combustible with the supply of air must be as constant as practicable. At first, tests will be made with no special mixing devices, the mixing will be accomplished entirely by the streams of air entering the furnace at the stoker, and by natural diffusion. Although there appears to be violent stirring of the gases above the fuel bed, the mixture of the gases does not become homogeneous until they are about 10 or 15 ft. from the stoker. The mixing caused by the air currents forced into the furnace at the stoker is very distinct, and can be readily observed through the peep-hole in the side wall of the Heine boiler, opposite the long combustion chamber. This mixing is shown in Fig. 20. *A* is a current of air forced from the ash-pit directly upward through the fuel bed; *B* and *B* are streams of air forced above the fuel bed through numerous small openings at the furnace side of each hopper. Those currents cause the gases to flow out of the furnace in two spirals, as shown in Fig. 20. The velocity of rotation on the outside of the two spirals appears to be about 10 ft. per sec., when the rate of combustion is about 750 lb. of coal per hour. It is reasonable to expect that when the rate of mixing is increased by building piers and other mixing structures immediately back of the grate, the completeness of the combustion will be effected in less time, and a smaller combustion space will be required. Thus, the mixing structures may be an important factor in the extent of the required combustion space.

FIG. 20.



SECTION THROUGH STOKER

To sum up, it can be said that the extent of the space required to obtain a combustion which can be considered complete for all practical purposes, depends on the following factors:

(*a*).—Nature of coal,

(*b*).—Rate of combustion,

(*c*).—Supply of air,

(*d*).—Rate of heating fuel,

(*e*).—Rate of mixing volatile combustible and air.

Just how much the extent of the combustion space required will be influenced by these factors 304
is the object of the experiments under discussion.

The Scope of the Experiments.—With this object in view, as explained in the preceding paragraphs, the following series of experiments are planned:

Six or eight typical coals are to be selected, each representing a certain group of nearly the same chemical composition. Each series will consist of several sets of tests, each set being run with all the conditions constant except the one, the effect of which on the size of the combustion space is to be investigated. Thus a set of four or five tests will be made, varying in rate of combustion from 20 to 80 lb. of coal per square foot of grate per hour, keeping the supply of air per pound of combustible and the rate of heating constant. This set will show the effect of the rate of combustion of the coal on the extent of space required to obtain combustion which is practically complete. Other variables, such as composition of coal, supply of air, and rate of heating, remain constant.

Another set of four or five tests will be made with the same coal and at the same rate of 305
combustion, but the air supply will be different for each test. This set of tests will be repeated for two or three different rates of combustion. Thus each of these sets will give the effect of the air supply on the extent of combustion space when the coal and rate of combustion remain constant.

Still another set of tests should be made in which the time of heating the coal when feeding it into the furnace will vary from 3 to 30 min. In each of the tests of this set, the rate of combustion and the air supply will be kept constant, and the set will be repeated for two or three rates of combustion and two or three supplies of air. Each of these sets of tests will give the effect of the rate of heating of fresh fuel on the extent of combustion space required to burn the distilled volatile combustible. These sets of experiments will require a modification in the stoker mechanism, and, on that account, may be put off until all the other tests on the other selected typical coals are completed. As the investigation proceeds, enough may be learned so that the number of tests in each series may be gradually reduced. After all the desirable tests are made with the furnace as it stands, several kinds of mixing structures will be built successively back of the stoker and tried, one kind at a time, with a set of representative tests. Thus the effectiveness of such mixing structures will be determined.

Determining the Completeness of Combustion.—The completeness of combustion in the successive cross-sections of the stream of gases is determined mainly by the chemical analysis of samples of gases collected through the openings at these respective cross-sections. The first of these cross-sections at which gas samples are collected, passes through the middle of the bridge wall; the others are placed at intervals of 5 ft. through the entire length of the furnace. Measurements of the temperature of the gases, and direct observations of the length and color of the flames and of any visible smoke will be also made through the side peep-holes. These direct observations, together with the gas analysis, will furnish enough data to determine the length of travel of the combustible mixture to reach practically complete combustion.

In other words, these observations will determine the extent of the combustion space for various kinds of coal when burned under certain given conditions. Direct observations and the analysis of gases at sections nearer the stoker than that at which the combustion is practically complete, will show how the process of combustion approaches its completion. This information will be of extreme value in determining the effect of shortening the combustion space on the loss of heat due to incomplete combustion.

Method of Collecting Gas Samples.—The collection of gas samples is a difficult problem in
itself, when one considers that the temperature of the gases, as they are in the furnace, ranges 306
from 2,400° to 3,200° Fahr.; consequently, the samples must be collected with water-cooled tubes. Thus far, about 25 preliminary tests have been made. These tests show that the composition of the gases at the cross-sections near the stoker is not uniform, and that more than one sample must be taken from each cross-section. It was decided to take 9 samples from the cross-section immediately back of the stoker, and reduce the number in the sections following, according to the uniformity of the gas composition. Thus, about 35 simultaneous gas samples must be taken for each test. The samples will be subjected, not only to the usual determination of CO_2, O_2 and CO, but to a complete analysis. It is also realized that some of the carbon-hydrogen compounds which, at the furnace temperature, exist as heavy gases, are condensed to liquids and solids when cooled in the sampling tubes, where they settle and tend to clog it. To neglect the presence of this form of the combustible would introduce considerable error in the determination of the completeness of combustion at any of the cross-

sections. Therefore, special water-cooled sampling tubes are constructed and equipped with filters which separate the liquid and solid combustible from the gases. The contents of these filters are then also subjected to complete analysis. To obtain quantitative data, a measured quantity of gases must be drawn through these filtering sampling tubes.

The Measuring of Temperatures.—At present the only possible known method of measuring the temperature of the furnace gases is by optical and radiation pyrometers. Platinum thermo-couples are soon destroyed by the corrosive action of the hot gases. The pyrometers used at present are the Wanner optical pyrometer and the Fery radiation pyrometer.

The Flow of Heat Through Furnace Walls.—An interesting side investigation has developed, in the study of the loss of heat through the furnace walls. In the description of this experimental furnace it has been said that the side walls contained a 2-in. air space, which, in the roof, was replaced with a 1-in. layer of asbestos. To determine the relative resistance to heat flow of the air space and the asbestos layer, 20 thermo-couples were embedded, in groups of four, to different depths at three places in the side wall and at two places in the roof. In the side wall, one of the thermo-couples of each group was placed in the inner wall near the furnace surface; the second thermo-couple was placed in the same wall, but near the surface facing the air space; the third thermo-couple was placed in the outer wall near the inner surface; and the fourth was placed near the outer surface in the outer wall. In the roof the second and third thermo-couples were placed in the brick near the surface on each side of the asbestos layer. These thermo-couples have shown that the temperature drop across the 2-in. air space was much less than that across the 1-in. layer of asbestos; in fact, that it was considerably less than 307
the temperature drop through the same thickness of the brick wall.

The results obtained prove that, as far as heat insulation is concerned, air spaces in furnace walls are undesirable. The heat is not conducted through the air, but leaps across the space by radiation. In furnace construction a solid wall is a better heat insulator than one of the same total thickness containing an air space. If it is necessary to build a furnace wall in two parts on account of unequal expansion, the space between the two walls should be filled with some solid, cheap, non-conducting materials, such as ash, sand, or crushed brick. A more detailed account of these experiments may be found in a Bulletin of the U. S. Geological Survey entitled “The Flow of Heat Through Furnace Walls.”

Mr. Snelling. Walter O. Snelling, Esq.[30] (by letter).—The work of the United States Testing Station at Pittsburg has been set forth so fully by Mr. Wilson that a further statement as to the results achieved may seem like repetition. It would be most unlikely, however, that studies of such variety should possess no other value than along the direct lines being investigated. In the case of the Mine Accidents Division, at least, it is certain that the indirect benefits of some of the studies have been far-reaching, and are now proving of value in lines far removed from those which were the primary object of the investigation. They are developing facts which will be of great value to all engineers or contractors engaged in tunneling or quarrying. As the writer’s experience has been solely in connection with the chemical examination of explosives, he will confine his discussion to this phase.

In studying the properties of various explosives, and in testing work to separate those in which the danger of igniting explosive mixtures of coal dust and air, or of fire-damp and air, is greatest, from those in which this danger is least, much information has been collected. Mr. Wilson has described many of the tests, and it can be readily seen that in carrying out these and other tests on each of the explosives submitted, a great many facts relating to the properties of explosive compounds have been obtained, which were soon found to be of decided value in directions other than the simple differentiation of explosives which are safe from those which are unsafe in the presence of explosive mixtures of fire-damp or coal dust.

The factors which determine the suitability of an explosive for work in material of any particular physical characteristics depend on the relationship of such properties as percussive force (or the initial blow produced by the products of the decomposition of the explosive at the moment of explosion), and the heaving force (or the continued pressure produced by the products of the decomposition, after the initial blow at the instant of detonation). Where an 308
explosive has been used in coal or rock of a certain degree of brittleness, and where the work of the explosive with that particular coal is not thoroughly satisfactory, it becomes evident that through the systematic use of the information available at the Testing Station (and now in course of publication in the form of bulletins), in regard to the relationship between percussive and heaving forces in different explosives, as shown by the tests with small lead blocks, the Trauzl test, and the ballistic pendulum, that explosives can be selected which, possessing in modified form the properties of the explosive not entirely satisfactory in that type of coal or rock, would combine all the favorable properties of the first explosive, together with such additional advantages as would come from its added adaptation to the material in which it is to be used.

For example, if the explosive in use were found to have too great a shattering effect on the coal, an examination of the small lead-block test of this explosive, and a comparison of this with lead-block tests of other explosives having practically the same strength, as shown by the ballistic pendulum, will enable the mine manager to select from those already on the Permissible List (and therefore vouched for in regard to safety in the presence of gas and coal dust, when used in a proper way), some explosive which will have the same strength, and yet which, because of lessened percussive force or shattering effect, will produce coal in the manner desired. If one takes the other extreme, and considers a mine in which the product is used exclusively for the preparation of coke (and therefore where shattering of the coal is in no way a disadvantage), the mine superintendent’s interest will be primarily to select an explosive which, as indicated by suitable lead-block, Trauzl, and ballistic pendulum tests, will produce the greatest amount of coal at the least cost.

As the cost of the explosive does not form any part of the tables prepared by the Testing Station, the relative cost must be computed from the manufacturer’s prices, but the results tabulated by the Station will contain all the other data necessary to give the mine superintendent (who cares to take the small amount of trouble necessary to familiarize himself with the tables) all the information which is required to compare the action of one explosive with that of any other explosive tested.

In this way it is seen that, aside from the primary consideration of safety in the presence of explosive mixtures of fire-damp and coal dust (a condition alike fulfilled by all explosives admitted to the Permissible List), the data prepared by the Testing Station also give the information necessary to enable the discriminating mine manager to select an explosive adapted to the particular physical qualities of the coal at his mine, or to decide intelligently between two explosives of the same cost on the basis of their actual energy content in the 309
particular form of the heaving or percussive force required in his work.

Up to the present time the investigations have been confined to explosives used in coal mining, because the Act of Congress establishing the Testing Station has thus limited its work. Accordingly, it is not possible to compare, on the systematic basis just mentioned, the explosives generally used in rock work. It is probable that, if the Bill now before Congress in regard to the establishment of a Bureau of Mines is passed, work of this character will be undertaken, and the tables of explosives now prepared will be extended to cover all those intended for general mining and quarrying use. Data of such character are unobtainable to-day, and, as a result, a considerable percentage of explosives now used in all mining operations is wasted, because of their lack of adaptation to the materials being blasted. It is well known, for example, that when an explosive of high percussive force is used in excavating in a soft or easily compressed medium, a considerable percentage of its force is wasted as heat energy, performing no other function than the distortion and compression of the material in which it is fired, without exerting either an appreciable cracking or fissuring effect, or a heaving or throwing of the material.

Owing to lack of information in regard to the exact relationship between the percussive and the heaving force in particular explosives, this waste, as compared with the quantity required for the work with a properly balanced material, will continue; but it is to be hoped that it will soon be possible to give the mining and quarrying industries suitable information in regard to the properties of the various explosives, so that the railroad contractor and the metal miner may have the same simple and exact means of discrimination between suitable and unsuitable explosives that is now being provided for the benefit of the coal miner.

Another of the important but indirect benefits of this work has been the production of uniformity of strength and composition in explosives. An example of this helpful influence is the standardization of detonating caps and electric detonators. In the early days of the explosive industry, it was apparently advantageous for each manufacturer to have a separate system of trade nomenclature by which to designate the strengths of the different detonators manufactured by him. The necessity and even the advantage of such methods have long been outgrown, and yet, until the past year, the explosive industry has had to labor under conditions which made it almost impossible for the user of explosives to compare, in cost or strength, detonators of different manufacturers; or to select intelligently the detonator best suited to the explosive to be used. After conference with the manufacturers of detonating caps and electric detonators, a standard system of naming the strengths of these products has been selected by the Testing Station, and has met with a most hearty response. It is encouraging to note that, in 310
recent trade catalogues, detonators are named in such a way as to enable the user to determine directly the strength of the contained charge, which is a decided advantage to every user of explosives and also to manufacturers.

The uniformity of composition of explosives (and many difficulties in mining work and many accidents have been rightly or wrongly attributed to lack of uniformity) may be considered as settled in regard to all those on the Permissible List. One of the conditions required of every explosive on that list is that its composition must continue substantially the same as the samples submitted originally for official test. Up to the present, all explosives admitted to the Permissible List have maintained their original composition, as determined by subsequent analyses of samples selected from mines in which the explosive was in use, and comparison with the original samples.

The data assembled by the Testing Station in regard to particular explosives have also been of great benefit to the manufacturers. When the explosives tests were commenced, comparatively few explosives were being made in the United States for which it was even claimed by the manufacturers that they were at all safe in the presence of explosive mixtures of gas or coal dust. It was evident that, without systematic tests, very little knowledge of the safety or lack of safety of any particular explosive could ever be gained, and, consequently, the user of explosives was apt to regard with incredulity any claim by the manufacturer in regard to the qualities of safety. Owing to lack of proof, this was most natural; and it was also evident that the very slow process of testing, which was offered by a study of mine explosions during past years, was sufficient only to prove the danger of black powder, and not in any way to indicate the safety of any of the brands of mining powder for which this property was claimed. Indeed, one of the few explosives to which the name, “safety,” was attached, at the time the Government experiments were first undertaken, was found to be anything but safe when tested in the gallery, although there is no reason to believe that the makers of this and other explosives claiming “safety” for their product, did not have the fullest confidence in their safety.

The Testing Station offered the first opportunity in the United States to obtain facts in regard to the danger of any particular explosive in the presence of explosive mixtures of gas or coal dust. With most commendable energy, the manufacturers of explosives, noting the early failures of their powders in the testing gallery, began at once to modify them in such ways as suggested by the behavior of the explosives when under test, and, in a short time, returned to the Testing Station with improved products, able to stand the severe tests required. In this way 311
the Testing Station has been a most active agent in increasing the general safety of explosives, and the manufacturers have shown clearly that it never was their desire to offer inferior explosives to the public, but that their failures in the past were due solely to lack of information in regard to the action of explosives under the conditions which exist before a mine disaster. The chance being offered to duplicate, at the Testing Station, the conditions represented in a mine in the presence of gas, they showed an eagerness to modify and improve their explosives so as to enable them to answer severe mining conditions, which is most commendable to American industry.

In regard to the unfavorable conditions existing in mines in the past, the same arguments may be used. In spite of the frequency of mine accidents in the United States, and in spite of the high death rate in coal mining as compared with that in other countries, it must be said in fairness that this has been the result of ignorance of the actual conditions which produce mine explosions, rather than any willful disregard of the known laws of safety by mine owners. Conditions in American mines are far different from those obtaining in mines abroad, and, as a result, the rules which years of experience had taught to foreign colliery managers were not quickly applied to conditions existing in American mines; but, as soon as the work at the Pittsburg Station had demonstrated the explosibility of the coal dust from adjoining mines, and had shown the very great safety of some explosives as compared with others, there was at once a readiness on the part of mine owners throughout the country to improve conditions in their mines, and to take advantage of all the studies made by the Government, thus showing clearly that the disasters of the past had been due to lack of sufficient information rather that to any willful disregard of the value of human lives.

Another of the indirect benefits of the work of the Station has resulted from its examination of explosives for the Panama Canal. For several years the Isthmian Canal Commission has been one of the largest users of explosives in the world, and, in the purchase of the enormous quantities required, it was found necessary to establish a system of careful examination and inspection. This was done in order to insure the safety of the explosives delivered on the Isthmus, and also to make certain that the standards named in the contract were being maintained at all times. With its established corps of chemists and engineers, it was natural that this important work should be taken up by the Technologic Branch of the United States Geological Survey, and, during the past three years, many millions of pounds of dynamite have been inspected and samples analyzed by the chemists connected with the Pittsburg Testing Station, thus insuring the high standard of these materials.

One of the many ways in which this work for the Canal Commission has proved of advantage is 312
shown by the fact that, as a result of studies at the Testing Station, electric detonators are being made to-day which, in water-proof qualities, are greatly superior to any similar product. As the improvements of these detonators were made by a member of the testing staff, all the pecuniary advantages arising from them have gone directly to the Government, which to-day is obtaining superior electric detonators, and at a cost of about one-third of the price of the former materials.

All the work of the Technologic Branch is being carried out along eminently practical lines, and is far removed from such work as can be taken up advantageously by private or by State agencies. The work of the Mine Accidents Division was taken up primarily to reduce the number of mine accidents, and to increase the general conditions of safety in mining. As the work of this Division has progressed, it has been found to be of great advantage to the miner and the mine owner, while the ultimate results of the studies will be of still greater value to every consumer of coal, as they will insure a continued supply of this valuable product, and at a lower cost than if the present methods, wasteful alike in lives and in coal, had been allowed to continue for another decade.

Mr. Bartoccini.

A. Bartoccini, Assoc. M. Am. Soc. C. E. (by letter).—The writer made a personal investigation of the mine disaster of Cherry, Ill. He interviewed the men who escaped on the day of the accident, and also several of those who were rescued one week later. He also interrogated the superintendent and the engineer of the mine, and obtained all the information asked for and also the plans of the mine showing the progress of the work.

After a careful investigation the writer found that the following conditions existed at the mine at the time of the disaster:

First.—There were no means for extinguishing fires in the mine.

Second.—There were no signal systems of any kind. Had the mine been provided with electric signals and telephones, like some of the most modern mines in the United

States, the majority of the men could have been saved, by getting into communication with the outside and working in conjunction with the rescuers.

Third.—The miners had never received instructions of how to behave in case of fire.

Fourth.—The main entries and stables were lighted with open torches.

Fifth.—The organization of the mine was defective in some way, for at the time of the disaster orders came from every direction.

Sixth.—The air shaft was used also as a hoisting shaft. 313

Seventh.—The main shaft practically reached only to the second vein; its extension to the third and deepest vein was not used.

Eighth.—Plans of the workings of the second and third veins were not up to date. The last survey recorded on them was that of June, 1909. This would have made rescue work almost impossible to men not familiar with the mine.

Ninth.—The inside survey of the mine was not connected with the outside survey.

Would it not be possible for the United States Geological Survey to enforce rules which would prevent the existence of conditions such as those mentioned? The Survey is doing wonderful work, as shown by the rescue of twenty miners at Cherry one week after the conflagration; but there is no doubt that perhaps all the men could have been saved if telephone communications with the outside had been established. Telephone lines to resist any kind of a fire, can easily be installed, and the expense is small, almost negligible when one considers the enormous losses suffered by the mine owners and by the families of the victims.

Mr. Stott. H. G. Stott, M. Am. Soc. C. E.—The curves shown by Mr. Wilson give a clear general idea of the relative efficiencies of steam and gas engines when treated from a purely theoretical thermodynamic point of view. This point of view, however, is only justified when small units having a maximum brake horse-power not exceeding 1,000 are considered.

The steam engine or turbine operating under a gauge pressure of 200 lb. per sq. in., and with 150° superheat, has a maximum temperature of 538° Fahr. in its cylinder, while that of the gas engine varies between 2,000° and 3,000° Fahr.

The lubrication of a surface continually subjected to the latter temperature would be impossible, so that water jackets on the cylinders and, in the larger units, in the pistons become absolutely necessary. As the cylinders increase in diameter, it is necessary, of course, to increase their strength in proportion to their area, which, in turn, is proportional to the square of the diameter. The cooling surface, however, is only proportional to the circumference, or a single function of the diameter. Increasing the strength in proportion to the square of the diameter soon leads to difficulties, because of the fact that the flow of heat through a metal is a comparatively slow process; the thick walls of the cylinders on large engines cannot conduct the heat away fast enough, and all sorts of strains are set up in the metal, due to the enormous difference in temperature between the inside and the jacket lining of the cylinder.

These conditions produce cut and cracked cylinders, with a natural resultant of high 314
maintenance and depreciation costs. These costs, in some cases, have been so great, not only in the United States, but in Europe and Africa, as to cause the complete abandonment of large gas engine plants after a few years of attempted operation.

The first consideration in any power plant is that it shall be thoroughly reliable in operation, and the second is that it shall be economical, not only in operation, but in maintenance and depreciation. Therefore, in using the comparative efficiency curves shown in Mr. Wilson's paper it should be kept in mind that the cost of power is not only the fuel cost, but the fuel plus the maintenance and depreciation charges, and that the latter items should not be taken from the first year's account, but as an average of at least five years.

The small gas engine is a very satisfactory apparatus when supplied with good, clean gas, and when given proper attention, but great caution should be used before investing in large units, until further developments in the art take place, as conservation of capital is just as important as conservation of coal.

Mr. Dunn. B. W. Dunn, Esq.[31] (by letter.)—The growing importance of investigations of explosives, with a view to increasing the consumer's knowledge of proper methods for handling and using them, is evident when it is noted that the total production of explosives in the United States has grown from less than 9,000,000 lb. in 1840 to about 215,000,000 lb. in 1905. Table 5 has been compiled by the Bureau of Explosives of the American Railway Association.

TABLE 5.—Manufacture of Explosives in the United States, 1909.

Kind of explosives.	Number of factories.	Maximum Capacity, in Pounds.	
		Daily.	Annual.
Black powder	49	1,220,150	366,135,000
High explosives	37	1,203,935	361,180,500
Smokeless powders	5	75,686	22,705,800

The first problem presented by this phenomenal increase relates to the safe transportation of this material from the factories to points of consumption. A package of explosives may make many journeys through densely populated centers, and rest temporarily in many widely separated storehouses before it reaches its final destination. A comprehensive view of the entire railway mileage of the United States would show at any instant about 5,000 cars partially or completely loaded with explosives. More than 1,200 storage magazines are listed by the Bureau of Explosives as sources of shipments of explosives by rail.

The increase in the demand for explosives has not been due entirely to the increase in mining 315
operations. The civil engineer has been expanding his use of them until now carloads of dynamite, used on the Isthmus of Panama in a single blast, bring to the steam shovels as much as 75,000 cu. yd. of material, the dislodgment of which by manual labor would have required days of time and hundreds of men. Without the assistance of explosives, the construction of subways and the driving of tunnels would be impracticable. Even the farmer has awakened to the value of this concentrated source of power, and he uses it for the cheap and effective uprooting of large stumps over extended areas in Oregon, while an entire acre of subsoil in South Carolina, too refractory for the plow, is broken up and made available for successful cultivation by one explosion of a series of well-placed charges of dynamite. It has also been found by experience that a few cents' worth of explosive will be as effective as a dollar's worth of manual labor in preparing holes for transplanting trees.

The use of explosives in war and in preparation for war is now almost a negligible quantity when compared with the general demand from peaceful industries. With the completion of the Panama Canal, it is estimated that the Government will have used in that work alone more explosives than have been expended in all the battles of history.

Until a few years ago little interest was manifested by the public in safeguarding the manufacture, transportation, storage, and use of explosives. Anyone possessing the necessary degree of ignorance, or rashness, was free to engage in their manufacture with incomplete equipment; they were transported by many railroads without any special precautions; the location of magazines in the immediate vicinity of dwellings, railways, and public highways, was criticized only after some disastrous explosion; and the often inexperienced consumer was without access to a competent and disinterested source of information such as he now has in the testing plant at Pittsburg so well described by Mr. Wilson.

The first general move to improve these conditions is believed to have been made by the American Railway Association in April, 1905. It resulted in the organization of a Bureau of Explosives which, through its inspectors, now exercises supervision over the transportation of all kinds of dangerous articles on 223,630 of the 245,000 miles of railways in the United States and Canada. A general idea of the kind and volume of inspection work is shown by the following extracts from the Annual Report of the Chief Inspector, dated February, 1910:

	1909.	*1908.*	
"Total number of railway lines members of Bureau December 31st	172	158	
Total mileage of Bureau lines December 31st	209,984	202,186	
Total number of inspections of stations for explosives	6,953	5,603	
Number of stations receiving two or more inspections for explosives	1,839	1,309	
Total number of inspections of stations for inflammables	6,950	1,098	316
Number of stations receiving two or more inspections for inflammables	1,886	....	
Total number of inspections of factories	278	270	
Number of factories receiving two or more inspections	75	69	
Total number of inspections of magazines	1,293	1,540	
Number of magazines receiving two or more inspections	349	361	
Total number of boxes of high explosives condemned as unsafe for transportation	10,029	4,852	
Total number of kegs of black powder condemned as unsafe for transportation	1,468	531	
Total number of cars in transit containing explosives inspected	475	448	
Total number of cars in transit showing serious violations of the regulations	168	197	
Total number of inspections of steamship companies' piers (inflammable, 75; explosive, 63)	138	....	
Total number of inspections made by Bureau	16,087	8,959	
Total number of lectures to railway officials and employes and meetings addressed on the subject of safe transportation of explosives and other dangerous articles	215	171	

	1909.	*1908.*	*1907.*
"Total number of accidents resulting in explosions or fires in transportation of explosives by rail	12	22	79
Total known property loss account explosions or accidents in transporting explosives by rail	$2,673	$114,629	$496,820
Total number of persons injured by explosions in transit	7	53	80
Total number of persons killed by explosions in transit	6	26	52

"During the same period reports have been rendered to the Chief Inspector by the Chemical Laboratory of the Bureau on 734 samples, as follows:

Explosives	211
Fireworks	186
Inflammables	304
Paper for lining high explosive boxes	31
Ammunition	2
Total	734

"As a means of ensuring the uniform enforcement of the regulations, by a well grounded appreciation of their significance and application, the lectures delivered by representatives of the Bureau have proved most successful. The promulgation of the regulations is not of itself 317
sufficient to ensure uniformity or efficiency in their observance, and so these lectures form a valuable supplement to the inspection service. They have been successfully continued throughout the year, and the requests for the delivery of them by the managements of so many of the membership lines, is a convincing testimonial of the high esteem in which they are held.

"While the lectures are primarily intended for the instruction and information of the officials and employes of the railway companies, and especially of those whose duties bring them into immediate contact with the dangerous articles handled in transportation, the manufacturers and shippers are invited, and they have attended them in considerable numbers. Many of this class have voluntarily expressed their commendation of the lectures as a medium of education, and signified their approval of them in flattering terms.

"The scope of these lectures embraces elementary instruction in the characteristics of explosives and inflammables and the hazards encountered in their transportation and in what respects the regulations afford protection against them. The requirements of the law, and the attendant penalties for violation, are fully described. Methods of preparation, packing, marking, receiving, handling and delivering, are explained by stereopticon lantern slides. These are interesting of themselves, and are the best means of stamping the impression they are intended to convey upon the minds of the audiences, and are always an acceptable feature of the lectures. The reception generally given to the lectures by those who have attended them, often at the voluntary surrender of time intended for rest while off duty, may be stated as an indication that the subject matter is one in which they are interested.

"The facilities of the Young Men's Christian Association, in halls, lanterns and skilled lantern operators, have been generously accorded and made use of to great advantage, in connection with the lectures at many places. The co-operation of this Association affords a convenient and economical method of securing the above facilities, and the Association has expressed its satisfaction with the arrangement as in line with the educational features which they provide for their members.

"During the year 1909, 215 lectures were delivered at various points throughout the United States."

The Bureau of Explosives, of the American Railway Association, and the Bureau of Mines, of the United States Geological Survey, were independent products of a general agitation due to the appreciation by a limited number of public-spirited citizens of the gravity of the "explosive" problem. It is the plain duty of the average citizen to become familiar with work of this kind prosecuted in his behalf. He may be able to help the work by assisting to overcome misguided opposition to it. Evidences of this opposition may be noted in the efforts of some shippers to avoid the expense of providing suitable shipping containers for explosives and inflammable articles, and in the threats of miners' labor unions to strike rather than use permissible explosives instead of black powder in mining coal in gaseous or dusty mines.

Too much credit cannot be given Messrs. Holmes and Wilson, and other officials of the 318
Technologic Branch of the United States Geological Survey, for the investigations described in this paper. They are establishing reasonable standards for many structural materials; they are teaching the manufacturer what he can and should produce, and the consumer what he has a right to demand; with scientific accuracy they are pointing the way to a conservation of our natural resources and to a saving of life which will repay the nation many times for the cost of their work.

When these facts become thoroughly appreciated and digested by the average citizen, these gentlemen and their able assistants will have no further cause to fear the withdrawal of financial or moral support for their work.

Mr. Wilson.

Herbert M. Wilson, M. Am. Soc. C. E. (by letter).—The Fuel Division of the United States Geological Survey has given considerable attention to the use of peat as a fuel for combustion under boiler furnaces, in gas producers, and for other purposes. It is doubtless to this material that Mr. Allen refers in speaking of utilizing "marsh mud for fuel," since he refers to an address by Mr. Edward Atkinson on the subject of "Bog Fuel" in which he characterized peat by the more popular term "marsh mud."

In Europe, where fuel is expensive, 10,000,000 tons of peat are used annually for fuel purposes. A preliminary and incomplete examination, made by Mr. C. A. Davis, of the Fuel Division of the Geological Survey, indicates that the peat beds of the United States extend throughout an area of more than 11,000 sq. miles. The larger part of this is in New England, New York, Minnesota, Wisconsin, New Jersey, Virginia, and other Coastal States which contain little or no coal. It has been estimated that this area will produce 13,000,000,000 tons of air-dried peat.

At present peat production is in its infancy in the United States, though there are in operation several commercial plants which find a ready market for their product and are being operated at a profit. A test was made at the Pittsburg plant on North Carolina peat operated in a gas producer—the resulting producer gas being used to run a gas engine of 150 h.p.—the load on which was measured on a switch-board. Peat containing nearly 30% of ash and 15% of water gave 1 commercial horse-power-hour for each 4 lb. of peat fired in the producer. Had the peat cost $2 per ton to dig and prepare for the producer, each horse-power-hour developed would have cost 0.4 of a cent. The fuel cost of running an electric plant properly equipped for using peat fuel, of even this low grade, in the gas producer would be about $4 per 100 h.p. developed per 10-hour day.

Equally good results were procured in tests of Florida and Michigan peat operated in the gas
producer. The investigations of peat under Mr. Davis include studies of simple commercial
methods of drying, the chemical and fuel value, analyses of the peat, studies of the mechanical 319
methods of digging and disintegrating the peat, and physical tests to determine the strength of
air-dried peat to support a load.

The calorific value of peat, as shown by numerous analyses made by the United States Geological Survey, runs from about 7,500 to nearly 11,000 B.t.u., moisture free, including the ash, which varies from less than 2% to 20%, the latter being considered in Europe the limit of commercial use for fuel. Analyses of 25 samples of peat from Florida, within these limits as to ash, show a range of from 8,269 to 10,865 B.t.u., only four of the series being below 9,000 B.t.u., and four exceeding 10,500 B.t.u., moisture free. Such fuel in Florida is likely to be utilized soon, since it only needs to be dug and dried in order to render it fit for the furnace or gas producer. Many bituminous coals now used commercially have fuel value as low as 11,000 B.t.u., moisture free, and with maximum ash content of 20%; buckwheat anthracite averages near the same figures, often running as high as 24% ash.

One bulletin concerning the peats of Maine has been published, and another, concerning the peat industries of the United States, is in course of publication.

Mr. Bartoccini asks whether it would not be possible for the United States Geological Survey to enforce rules which would prevent the existence of conditions such as occurred at the mine disaster of Cherry, Ill.

The United States Government has no police power within the States, and it is not within its province to enact or enforce rules or laws, or even to make police inspection regarding the methods of operating mining properties. The province of the mine accidents investigations and that of its successor, the Bureau of Mines, is, within the States, like that of other and similar Government bureaus in the Interior Department, the Department of Agriculture, and other Federal departments, merely to investigate and disseminate information. It remains for the States to enact laws and rules applying the remedies which may be indicated as a result of Federal investigation.

Investigations are now in progress and tests are being conducted with a view to issuing circulars concerning the methods of fighting mine fires, the installation of telephones and other means of signaling, and other subjects of the kind to which Mr. Bartoccini refers.

Much as the writer appreciates the kindly and sympathetic spirit of the discussion of Messrs. Allen and Bartoccini, he appreciates even more that of Colonel Dunn and Mr. Stott, who are recognized authorities regarding the subjects they discuss, and of Messrs. Kreisinger and Snelling, who have added materially to the details presented in the paper relative to the particular investigations of which they have charge in Pittsburg.

Mr. Snelling’s reference to the use of explosives in blasting operations should be of interest to 320
all civil engineers, as well as to mining engineers, as should Colonel Dunn’s discussion
concerning the means adopted to safeguard the transportation of explosives.

Since the presentation of the paper, Congress has enacted a law establishing, in the Department of the Interior, a United States Bureau of Mines. To this Bureau have been transferred from the Geological Survey the fuel-testing and the mine accidents investigations described in this paper. To the writer it seems a matter for deep regret that the investigations of the structural materials belonging to and for the use of the United States, were not also transferred to the same Bureau. On the last day of the session of Congress, a conference report transferred these from the Geological Survey to the Bureau of Standards. It is doubtful whether the continuation of these investigations in that Bureau, presided over as it is by physicists and chemists of high scientific attainments, will be of as immediate value to engineers and to those engaged in building and engineering construction as they would in the Bureau of Mines, charged as it is with the investigations pertinent to the mining and quarrying industries, and having in its employ mining, mechanical, and civil engineers.

Footnotes

1. Presented at the meeting of April 20th, 1910.

2. “Coal Mine Accidents,” by Clarence Hall and Walter O. Snelling. Bulletin No. 333, U. S. Geological Survey, Washington, D. C.

3. “The Explosibility of Coal Dust,” by George S. Rice and others. Bulletin No. * * *, U. S. Geological Survey.

4. “Notes on Explosives, Mine Gases and Dusts,” by Rollin Thomas Chamberlin. Bulletin No. 383, U. S. Geological Survey, 1909.

5. “Prevention of Mine Explosions,” by Victor Watteyne, Carl Meissner, and Arthur Desborough. Bulletin No. 369, U. S. Geological Survey.

6. With a view to obtaining a dust of uniform purity and inflammability.

7. “The Primer of Explosives,” by C. E. Munroe and Clarence Hall. Bulletin No. 423, U. S. Geological Survey, 1909.

8. “Tests of Permissible Explosives,” by Clarence Hall, W. O. Snelling, S. P. Howell, and J. J. Rutledge. Bulletin No. * * *, U. S. Geological Survey.

9. “Structural Materials Testing Laboratories,” by Richard L. Humphrey, Bulletin No. 329. U. S. Geological Survey, 1908; “Portland Cement Mortars and their Constituent Materials,” by Richard L. Humphrey and William Jordan, Jr., Bulletin No. 331, U. S. Geological Survey, 1908; “Strength of Concrete Beams,” by Richard L. Humphrey, Bulletin No. 344, U. S. Geological Survey, 1908.

10. “Fire Resistive Properties of Various Building Materials,” by Richard L. Humphrey, Bulletin No. 370, U. S. Geological Survey, 1909.

11. “Purchasing Coal Under Government Specifications,” by J. S. Burrows, Bulletin No. 378, U. S. Geological Survey, 1909.

12. “Experimental Work in the Chemical Laboratory,” by N. W. Lord, Bulletin No. 323, U. S. Geological Survey, 1907: “Operations of the Coal Testing Plant, St. Louis, Mo.” Professional Paper No. 48, U. S. Geological Survey, 1906.

13. Also Bulletins Nos. 290, 332, 334, 363, 366, 367, 373, 402, 403, and 412, U. S. Geological Survey.

14. “Tests of Coal for House Heating Boilers,” by D. T. Randall, Bulletin No. 336, U. S. Geological Survey, 1908.

15. “The Smokeless Combustion of Coal,” by D. T. Randall and H. W. Weeks, Bulletin No. 373, U. S. Geological Survey, 1909.

16. “The Flow of Heat through Furnace Walls,” by W. T. Ray and H. Kreisinger. Bulletin (in press), U. S. Geological Survey.

17. The assumption is made that a metal tube free from scale will remain almost as cool as the water; actual measurements with thermo-couples have indicated the correctness of this assumption in the majority of cases.

18. “Heat Transmission into Steam Boilers,” by W. T. Ray and H. Kreisinger, Bulletin (in press), U. S. Geological Survey.

19. “The Producer Gas Power Plant,” by R. H. Fernald, Bulletin No. 416, U. S. Geological Survey, 1909; also Professional Paper No. 48 and Bulletins Nos. 290, 316, 332, and 416.

20. A Taylor up-draft pressure producer, made by R. D. Wood and Company, Philadelphia, Pa.

21. “Coal Testing Plant, St. Louis, Mo.,” by R. H. Fernald, Professional Paper No. 48, Vol. III, U. S. Geological Survey, 1906.

22. A report of these tests may be found in Bulletin No. * * *, U. S. Geological Survey.

23. “Illuminating Gas Coals,” by A. H. White and Perry Barker, U. S. Geological Survey.

24. “Gasoline and Alcohol Tests,” by R. M. Strong, Bulletin No. 392, U. S. Geological Survey, 1909.

25. “Washing and Coking Tests,” by Richard Moldenke, A. W. Belden and G. R. Delamater, Bulletin No. 336, U. S. Geological Survey, 1908; also, “Washing and Coking Tests at Denver, Colo.,” by A. W. Belden and G. R. Delamater, Bulletin No. 368, U. S. Geological Survey, 1909.

26. U. S. Geological Survey, Professional Paper No. 48, Pt. III, and Bulletins Nos. 290, 332, 336, 368, 385, and 403.

27. Professional Paper No. 48, and Bulletins Nos. 290, 316, 332, 343, 363, 366, 385, 402, 403, and 412, U. S. Geological Survey.

28. “Peat Deposits of Maine,” by E. D. Bastin and C. A. Davis. Bulletin No. 376, U. S. Geological Survey, 1909.

29. U. S. Geological Survey, Pittsburg, Pa.

30. Chief Explosives Chemist, U. S. Geological Survey.

31. Lieutenant-Colonel, Ordnance Dept., U. S. A.

Fractions (Expanded)

Ellipses (...) represent omitted text at beginning or end of a paragraph. For consistency, common fractions such as ½ have also been expanded.

Gas and Dust Gallery No. 1.—Gallery No. 1 is cylindrical in form, 100 ft. long, and has a minimum internal diameter of 6 1/3 ft. It consists of fifteen similar sections, each 6 2/3 ft. long and built up in in-and-out courses. The first three sections, those nearest the concrete head, are of 1/2-in. boiler-plate steel, the remaining twelve sections are of 3/8-in. boiler-plate steel, and have a tensile strength of, at least, 55,000 lb. per sq. in....

...The beam, from which the mortar is suspended, rests on concrete walls, 51 by 120 in. at the base and 139 in. high. On top of each wall is a 1-in. base-plate, 7 by 48 in., anchored to the wall by 5/8-in. bolts, 28 in. long....

This apparatus is in the southeast corner of Building No. 17. The cylinder is 31 1/2 in. long, 19 1/4 in. in diameter, and is anchored to a solid concrete footing at a convenient height for handling. The explosion chamber is 19 in. long and 7 7/8 in. in diameter, with a capacity of exactly 15 liters....

The inner receiver is made of 1/16-in. sheet copper, 30 7/8 in. deep, and with an inner diameter of 17 7/8 in. It is nickel-plated, and strengthened on the outside with bands of copper wire, and its capacity is about 70 liters....

...In the front of the box are two plate-glass observing windows, 2 5/8 by 5 1/2 in. In the side of the box, between the two windows, is a 3/8-in. hole, which can be closed by a tap-screw, through which samples for chemical analysis are drawn.

There is some variety in the cupboards and tables provided in the various laboratories, but, in general, they follow the design shown in Fig. 13. The table tops, 12 ft. long, are of clear maple in full-length pieces, 7/8 in. thick and 2 5/8 in. wide, laid on edge and drilled at 18-in. intervals for bolts. These pieces are glued and drawn together by the bolts, the heads of which are countersunk. The tops, planed off, sanded, and rounded, are supported on pipe legs and frames of 1 1/4 by 1 1/2-in. galvanized-iron pipe with screw flanges fitting to the floor and top. Under the tops are drawers and above them re-agent shelves. Halfway between the table top and the floor is a wire shelf of a frame-work of No. 2 wire interlaced with No. 12 weave of 5/8-in. square mesh.

...The fineness of the coals put through the hammer crusher varies somewhat, but the average, taken from a large number of samples, is as follows: Through 1/8-in. mesh, 100%; over 10-mesh, 31.43%; over 20-mesh, 24.29%; over 40-mesh, 22.86%; over 60-mesh, 10 per cent....

Section 5. General Information About Project Gutenberg™ electronic works