The Test Department of the Pennsylvania Railroad*

Brief History and Outline of Its Present Scope; Description of the New Physical and Chemical Laboratory

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Endeavoring to promote the safety of passengers and employees on its lines by minimizing or eliminating, if possible, all accidents traceable to defective or unsuitable material, the Pennsylvania Railroad has found that the quality of the material purchased for use in rails, bridges, cars and locomotives must be carefully scrutinized. Control over the quality of supplies is secured by the aid of specifications, which are based upon careful consideration of the materials available for the various uses of the railway, and by research work tending toward the development of new materials and devices, or improving those which are in general use. Neither the reputation of the manufacturer nor a superficial inspection of the materials offered has been found to be a sufficient safeguard in the purchase of supplies, since frequently the manufacturer himself has no positive knowledge of the strength or other physical properties of the iron, steel or other metals, nor the purity of many of the articles offered for sale.

An organization with laboratories at a central point is an essential in promoting the work of thorough inspection, the importance of which is unquestioned. With this inspection, accidents to the traveling public and the employee have been reduced, and efforts in the future will be towards their further reduction. It is desirable, therefore, that the public be fully informed as to the facilities provided by one of the largest railroad companies for making tests of all its supplies and conducting investigations with a view of obtaining the best materials which can be commercially furnished.

The Department of Tests of the Pennsylvania Railroad—the first of an American railroad—has grown in the following way:

In 1874 there was established at Altoona a department of physical tests, the organization of which was placed under the direction of Theodore N. Ely, then superintendent of motive power. The first testing machine was purchased during the early part of the year. It was of 50,000 lb. capacity and was furnished by Fairbanks and Ewing. The first test was made on April 2. 1874.

In the beginning, the testing work was conducted by the master mechanic of the Altoona shops, but in August, 1874, the department of physical tests was placed in charge of John W. Cloud, who became the first engineer of tests. A chemical laboratory, under the direction of the late Dr. Charles B. Dudley, was added in the autumn of 1875. Research work for the improvement of rails was begun, and the investigations and accumulation of experience, which later made possible the preparation of a series of "Standard Specifications," had their start.

It was not until 1879, or five years after the beginning of the testing of materials, that the physical and chemical departments were provided with a separate building. This building was a one-story frame structure, 25 ft. by 45 ft. These quarters were soon abandoned, however, and until 1914 space was made

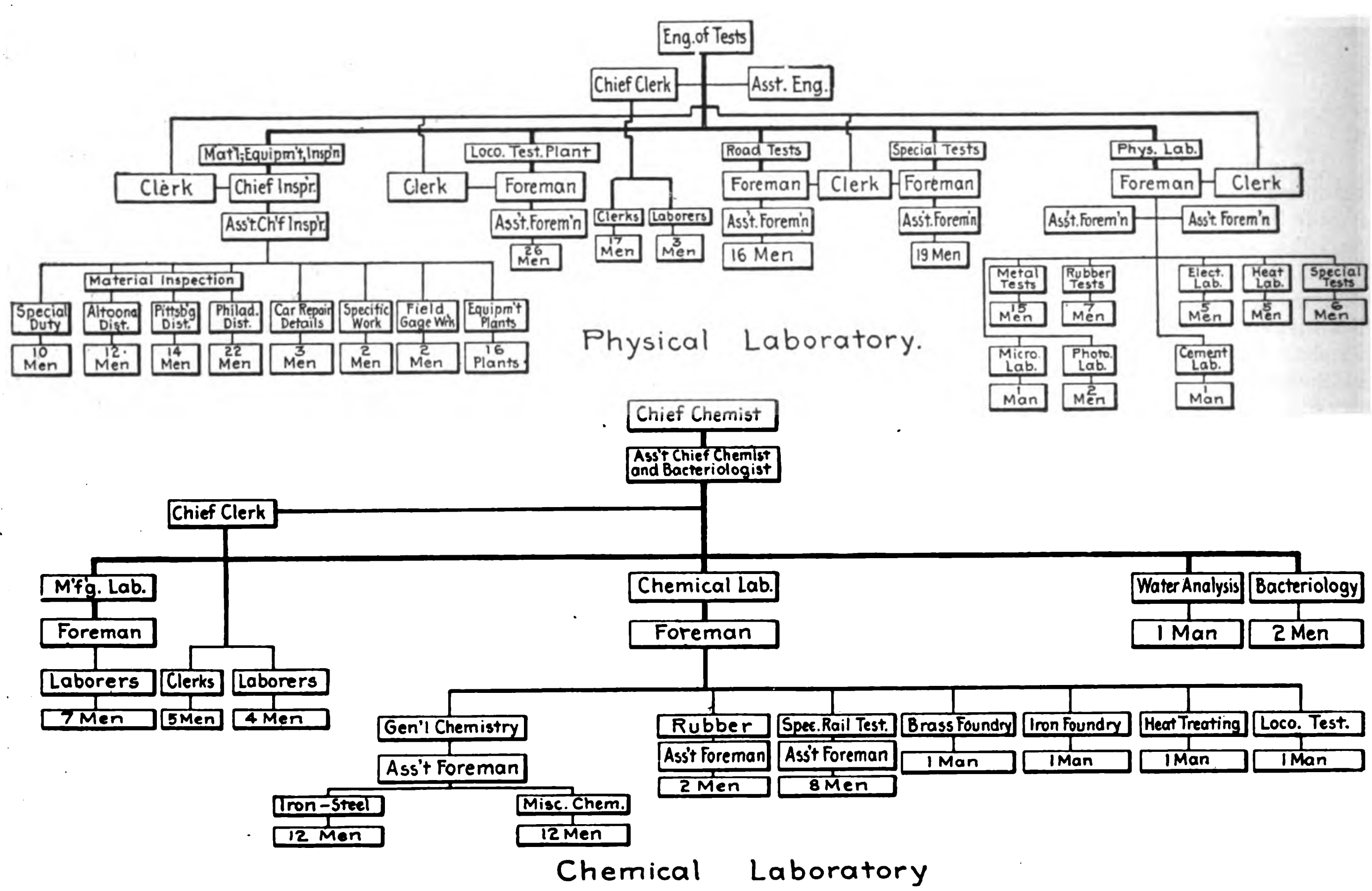

Chart Showing the Organization of the Department of Inspection and Tests

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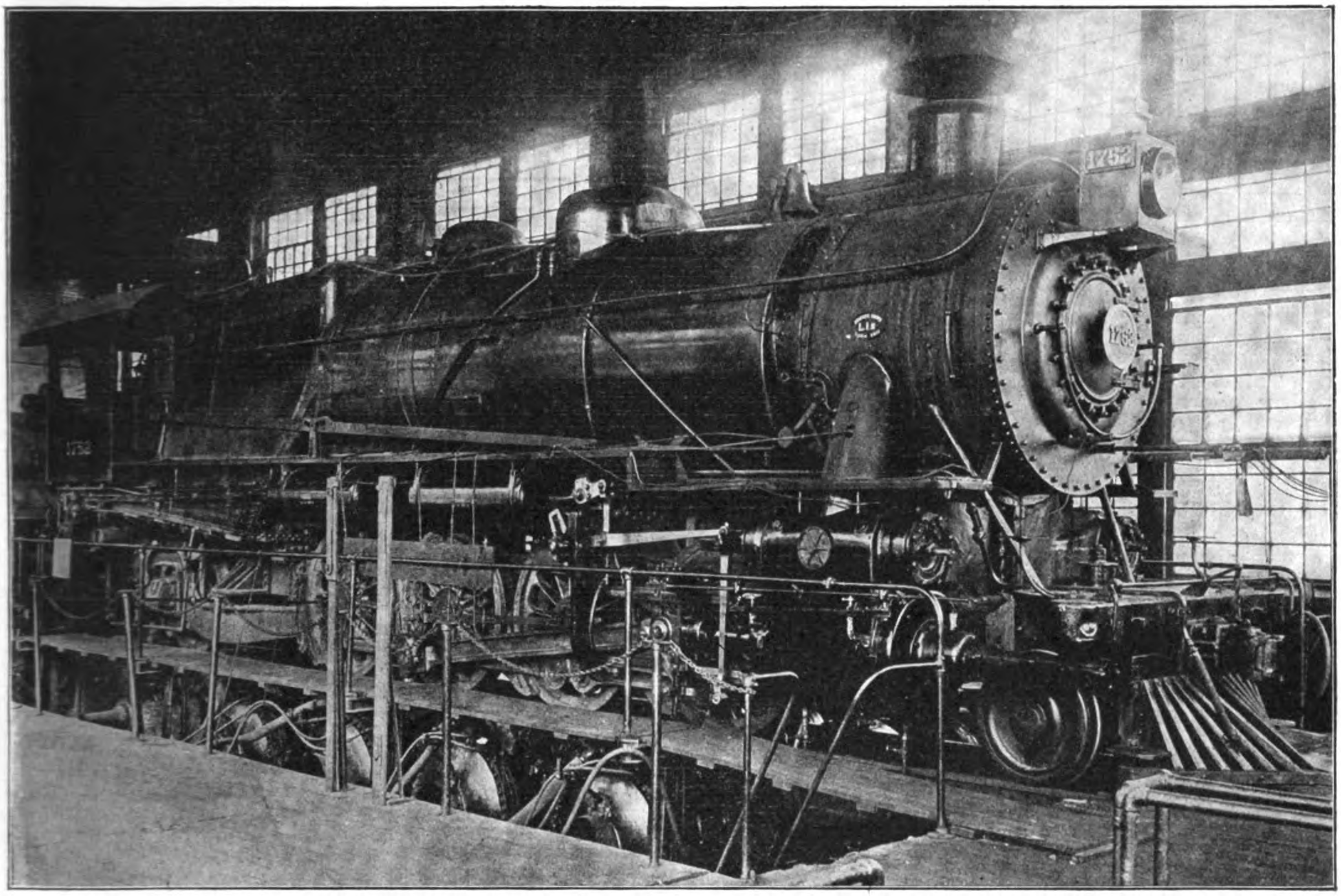
available in a part of the shop office and storehouse building, where the departments finally occupied 15,476 sq. ft. of floor area on four floors. That the growth of the departments has been rapid is also evidenced by the diagram, which shows the number of employees, the number of routine physical tests, and the number of standard specifications in force for each year from 1874 to 1914. The quarters having become congested in the past few years, a new building with a floor area of 41,000 sq. ft. was begun in 1913 and completed in 1914. Thus, in 35 years the requirements of the departments, as shown alone by the floor space occupied, have increased more than 35 times; or, there has been an average increase of over 100 per cent for each year since the work began. The growth of the test department and laboratory has been very much more rapid than the increase in tonnage hauled, or the extension of the general business of the railroad. The reason for this is that there was almost as wide a field for the application of specifications, and the inspection and testing of materials, in the beginning as at the present time.



The Locomotive Testing Plant, with a Mikado Type Locomotive in Position for Testing

THE NEW BUILDING

The new building at Altoona which has just been occupied is constructed of reinforced concrete, the reinforcement being of twisted bars. Structural steel cores are used in the concrete columns. The whole exterior is finished in red brick and red terra-cotta. It is arranged with a central service portion consisting of the middle bay which contains a stairway and an electric elevator, giving access to all parts. On the basement floor of the service section there is a receiving room for materials. This room communicates with the elevator for the distribution of small samples to the different sections of the building, while large pieces may be lifted to the physical-test section by means of a ten-ton traveling crane with a hatchway in the main floor. There is a machine room in the basement and in this all of the metal test specimens are prepared. On this floor there are two large fireproof vaults for the storage of letter files and the like, and a room for chemical stores.

The first or street floor is devoted to physical tests. It contains a physical laboratory with five universal tension and compression testing machines, the largest of which has a capacity of 1,000,000 lb., and all are served by the traveling crane. On this floor are separate sections for oil, cement and lagging, hose, rail, miscellaneous and heat-treatment tests.

The second floor is used for office, locker and toilet rooms, the south end being occupied by the office force of the engineer of tests and the north end by that of the chief chemist.

The third floor is divided into laboratory rooms for bacteriology, rubber, water and gas analyses, photometry and lamp tests, and the calibration of electric instruments.

The whole fourth floor is used as a general chemical laboratory with a separate chemical balance room. The central bay is extended up to form a fifth floor, which comprises a photographic studio and dark room, while the roof of the remaining portion of the building is used for experimental work and tests where exposure to the atmosphere is required.

Direct lighting with tungsten lamps is the system of illumination. "Abolite" metal reflectors are used in the basement and on the first floor, with "Pyro" glass reflectors on the second or office floor. In the chemical laboratory, where metal would be injuriously acted upon by gases, "Holophane" glass reflectors are in use. All of the lighting and power conduits were placed in the floors before pouring the concrete. Telephone, dictaphone and buzzer systems are installed in the floor conduits, and in addition great flexibility is possible in the location of these fixtures by the use of a chair rail around the walls of each room, the chair rail having three separate grooves for wires.

The building is heated by direct steam radiators with a single pipe system, and the radiators are placed under the windows. A hot water service, with a heating and circulating tank in the basement is provided. The gas, steam, air, water and hydraulic lines are of open work, and all pipe risers are in a common conduit which is located in the central service bay of the building.

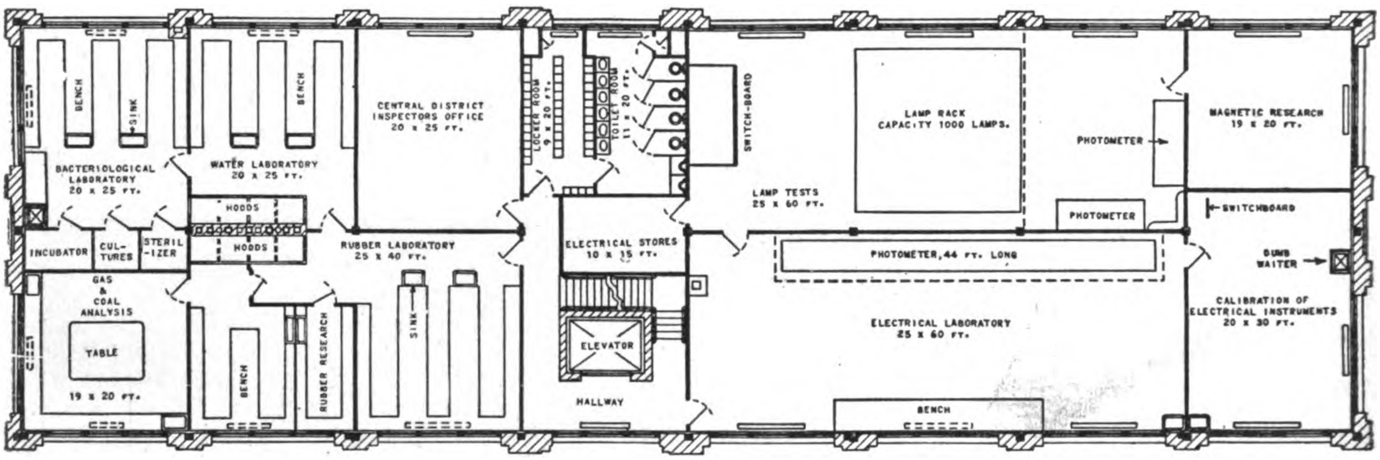
The interior of the building is finished in natural chestnut throughout, with the exception of the office rooms, which are finished in imitation mahogany. All interior doors and partitions are glazed. The floors, with the exception of the basement where the floor is of concrete and the physical laboratory where it is of wood on concrete, are of magnesium-cement composition.

It is noteworthy that the building was constructed and equipped complete within the original estimates and appropriation. The building itself cost about $150,000. An estimate of the value of the contents is, for the physical laboratory, $100,000; and for the chemical laboratory, $25,000. With equipment complete, the investment for the laboratories is about $275,000.

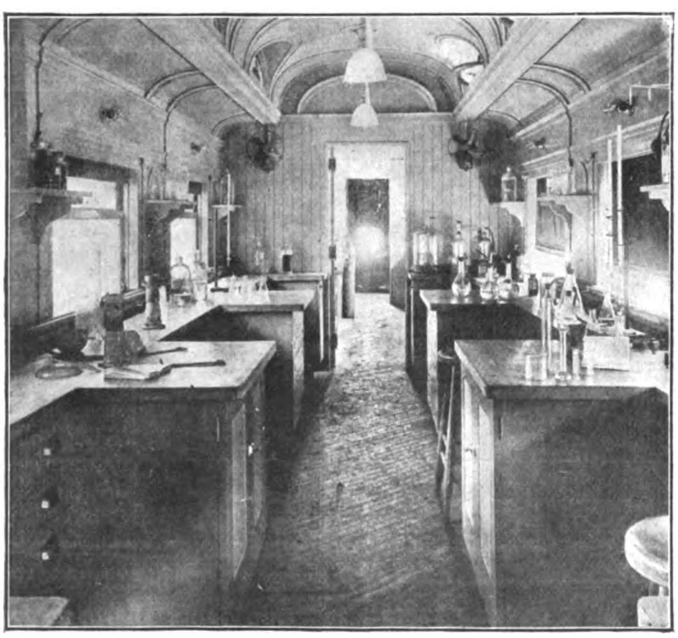
PHYSICAL LABORATORY

Among the machines and apparatus that compose the equipment of the physical laboratory, there are the following:

Five universal tension and compression testing machines, one of 1,000,000, two of 300,000, two of 100,000-lb. capacity;
One vibratory endurance spring testing machine of 75,000-lb. capacity.
One 43-ft. drop-testing machine;
Two vibrating staybolt testing machines;
One Brinell hardness testing machine;
One 2,000-lb. cement testing machine;
One horizontal microscope, with camera for metalographic work;
One grinding, buffing and etching outfit for the preparation of samples for microscopic work.



Plan of the Third Floor, Giving an Idea of the Floor Layout in the New Building



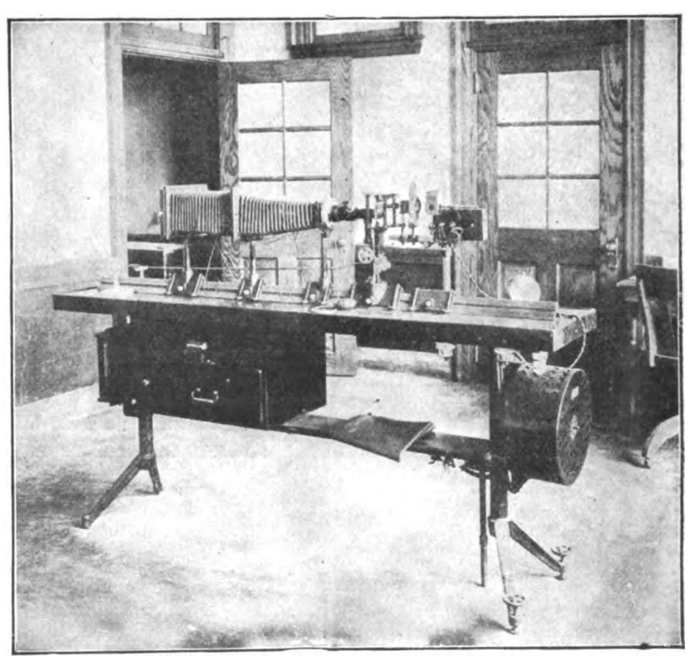
The General Laboratory in the Laboratory Car

In the machine room, where the sample test specimens are prepared, the following tools are used:

Two 14-in. engine lathes;
One 12-in. drilling lathe;
One 24-in. shaper;
One 24-in. radial drill;
Two milling machines for specimens;
One 30-in. cold saw;
Two motor hack saws;
Two tool grinders.

For the work in testing air brake, signal and tank hose and other miscellaneous tests including steam and hydraulic gages, there are:

Six rubber stretching machines;
One friction test rack for rubber;
One hose mounting machine;



Metalographic Laboratory

One vibrating test rack for hose;
One continuous test rack for rubber;
Four tension testing machines for rubber;
One stretching machine for rubber insulation;
One spring micrometer machine;
One vacuum gage testing machine;
One arbor press specimen cutter;
One hydraulic gage testing machine, capacity 25,000 lb. per sq. in;

One dead-weight gage testing machine, capacity six gages;
One wiggling testing machine for hose;
One bumping testing machine for gages;
One whipping testing machine for gages;
One hydraulic machine for testing gage glasses.

The materials for test, including samples which have been obtained by the inspectors at outlying points and those sent to the department by the shops, are brought into the building through the receiving room. They are distributed throughout the building from that point, the metal specimens going to the machine room in the basement for preparation, then to the physical laboratory for tension, compression, vibratory or other tests, and to the chemical laboratory for analysis.

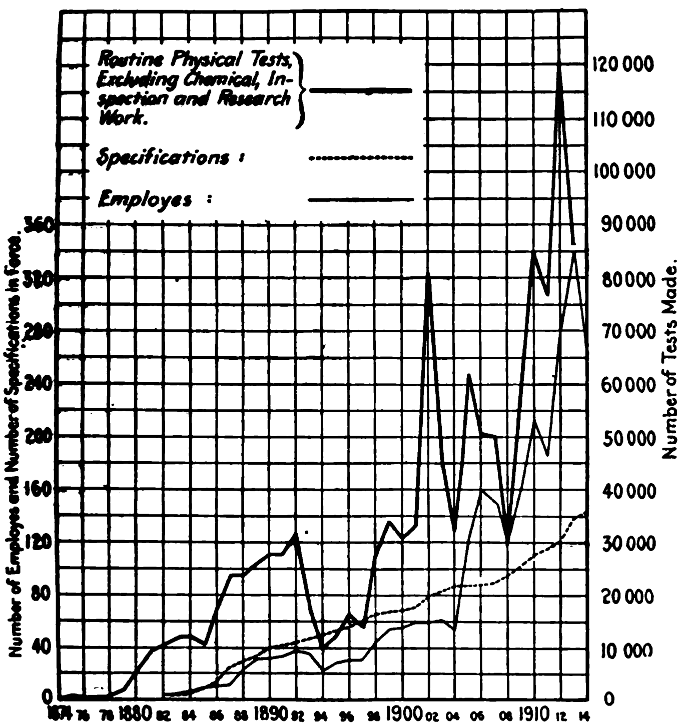


Diagram Showing the Growth of the Department of Inspection and Tests of the Pennsylvania Railroad

Rubber, Air Brake Hose and Miscellaneous Laboratory.—The extent of the work of this department is indicated by the fact that the needs of the railroad are about 635,000 pieces of air brake hose per year. There are now being installed machines for air brake, signal and tank hose, and other miscellaneous tests, including steam and hydraulic gages, and gage glasses for boilers and lubricators.

Heat-Treatment Laboratory.—This department, on the first floor, is for the development of standards in the heat-treatment of metals during the process of their manufacture for use in railway equipment. Investigations are carried out to study the effect of various heat treatments on a large variety of carbon and alloy steels. They are also made to determine the properties of non-ferrous alloys, including the co-efficient of expansion. Shop-manufactured locomotive and car springs, involving as they do a form of heat-treatment, are sampled and tested regularly to determine their acceptability for service.

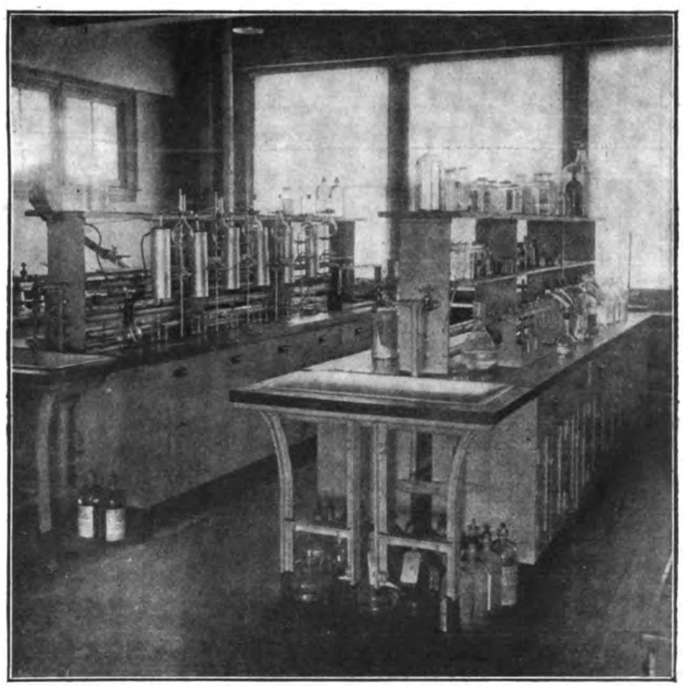
Large castings of various kinds have been heat-treated by this department with the aid of outside facilities with a gratifying degree of success. The effect of chemistry and heat-treatment upon the endurance of materials to repeated stresses is tested out by revolution and vibration tests, including vibration tests on complete springs. Rails, splice bars and tie plates are heat-treated to study the increased service it is possible to secure. The effects of heat-treatment are noted and a wide range of working conditions are applied on a variety of the high speed tool steels to ascertain the best chemical characteristics.

Investigations are made on various types of fireproof material for the purpose of maintaining a high standard. The testing of felt and insulating papers used for lining refrigerator cars has been made necessary by the large variety of materials of this kind on the market, the keen competition among manufacturers, and the ease with which the highest grade and best material can be closely imitated by cheap and inferior products. This laboratory is equipped with an insulated room and electrical heating arrangements for this work, the tests being designed to represent as nearly as possible the service conditions to which these materials would be subjected. Temperature measurements are made of various types of refrigerator-car construction by means of resistance thermometers. Aside from the measurements of high temperatures in the laboratory, periodic calibrations are made of the various pyrometers. The heat-treatment department in general carries on a large variety of special work, and there is but little that falls without its range of possibilities even to the extent of heat treating glassware.

ELECTRICAL LABORATORY

Lamp Tests.—On the third floor the equipment for lamp tests consists of three photometers, a lamp test rack of 1,000 lamps capacity, with switchboard, transformers and potential regulator equipment. This work was taken up in 1902, with a view of obtaining data for the preparation of specifications to secure uniformity in the ordering of incandescent lamps, and the maintaining of sufficiently high standards. It consists mainly of life tests of lamps at abnormal voltages and tests for the efficiency of illumination, as well as the investigation of new developments in the general field of illumination as applied to railway work.

Standardization of Instruments.—A division of the electrical laboratory is employed in investigations and development work along electrical lines, and the standardization of electrical instruments. Part of this work is done at the laboratory, and part of it, when necessary, at other points, by laboratory men. The character of the work may be judged from the following examples upon which comprehensive reports have been made:



The Water Testing Laboratory

An investigation of electrolysis in systems of underground metallic structures;
Tests and investigations of the construction of various makes of transformers;
Tests of various makes of primary and secondary battery cells;

Oscillographic tests for linear and angular velocity, wave forms, etc.;
Investigations of special cases of electrical troubles;
The devolopment of an electrical method of measuring the hardness and homogeneity of steel.

Matters such as these are reported on and recommendations made. Electrical instruments are sent in from all points on the Pennsylvania system to this department for calibration and repair, and men from the laboratory are sent out to inspect and check electrical instruments on switchboards at the various power plants, and at other points.

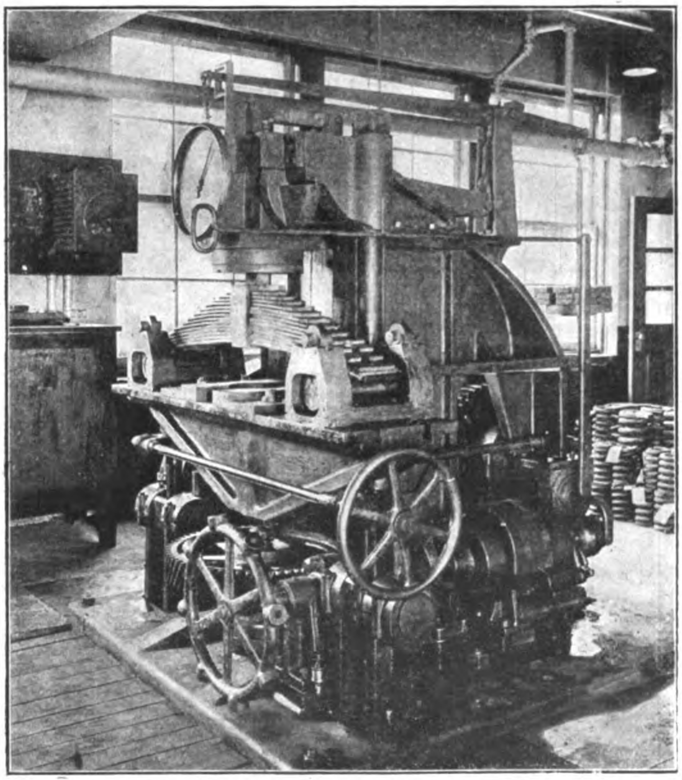
LABORATORY AND ROAD ASSISTANTS

The large room on the second floor is provided for the force of laboratory and road assistants coming under the direction of the foreman of road tests and special tests. The duties of these men are varied, and include tests of locomotives on the road or tests of equipment with special devices; the tonnage rating of trains and the following up of all experimental appliances which are put into service for test purposes.

The fifth floor has been arranged for photographic work, consisting largely in making prints of metal sections, photomicrographs of steel rails forming a large part of these. Photographs of parts which have failed in service are also made for convenient preservation and study. The photographic work requires the services of two men and about 25,000 prints per year are made.

CHEMICAL LABORATORY

Metallurgical Work.—The main chemical laboratory on the fourth floor is divided by the central balance room, into two

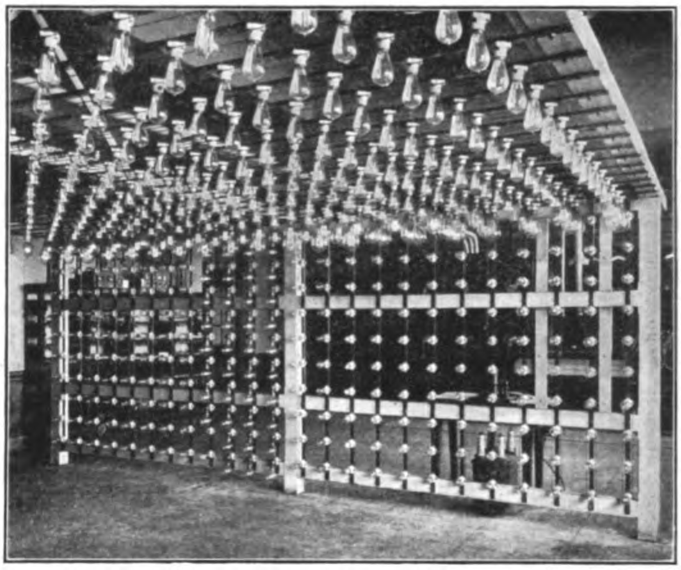


Vibratory Endurance Testing Machine for Springs

departments, the larger one of these being devoted exclusively to metallurgical chemistry. In this department methods are developed for the determination of the elements in plain-carbon steels, alloy steels, and non-ferrous alloys used for bearing backs and linings, packing-ring metal for different purposes, etc. Data are obtained leading to the development of specifications for this class of products, and samples of shipments are analyzed to determine whether they are acceptable under the specifications adopted. This steel laboratory has facilities for analyzing 100,000 samples per year.

Miscellaneous Work.—The smaller of these two laboratories is for work of a more general character, being used for the examination of fuels, the development of specifications for paint products, lubricating and burning oils, boiler compounds, lacquers, plush, car cleaners, cutting compounds, belt dressing, polishing compounds, hydraulic-jack liquids, fuses, track caps, fire-extinguishing preparations, the recovery of used or wasted products, etc.

In both of these laboratories much time has been spent in the examination of broken or "failed" parts of equipment, in an effort to determine the cause and with a view to the preven-



Lamp Test Rack with a Capacity for Making Efficiency and Life Tests of 1000 Lamps

tion of accidents which aside from the money losses, might result in injuries or loss of life.

Certain food products used in the dining car service are also examined here at times; many other miscellaneous investigations are made, as of conditions which may have led to loss from the damage of freight in transit, and to so establish methods for preventing such loss. During the past year a considerable amount of work has been devoted to the chemistry of tunnel air in connection with the installation of ventilating systems. The total list of activities touched upon would be too long for enumeration in an article of this character.

The chemical analysis of rubber compounds has been studied and much experimental work done in perfecting a method whereby material of this kind can be bought on specifications which define and limit its chemical properties. At present there is in force a specification for high-grade rubber insulation. Samples from all shipments are analyzed as well as some other rubber compounds. At the same time experimental work is being carried on to improve the method of analysis, and to devise others so that specifications may be drawn covering the chemical properties of other grades of rubber materials.

Manufacturing Laboratory.—A manufacturing laboratory, which might be called a small factory, is maintained in a separate building which is under the direct supervision of the chief chemist, and new products are manufactured in this until such time as it is found advisable to purchase them from "outside" manufacturers.

Laboratory Car.—In addition to the steel-rail work at Altoona a laboratory car has been built to be moved, as required, to that point where steel rails in process of manufacture are to be inspected. The object in equipping this car is to make chemical analyses of the finished rails at the mills by a force of chemists under the chief chemist. This, it is expected, will avoid delays which at times occur in the operation of the mills, and are impossible to avoid without the facility of a suitable force at hand at the time and when the rolling is taking place, in order to keep up with the chemistry requirements of the company's specifications. The car is equipped with furnaces for combustion and all other necessary apparatus for general chemical work in connection with the inspection of steel rails.

Bacteriological Laboratory.—When the department of chemistry was established, problems were frequently presented which applied chemistry could not solve satisfactorily. It was found, for example, that a chemical examination of water might show the presence of organic constituents, but it was impossible to tell the source of these. A water might contain a large amount of organic material of vegetable origin and yet not carry any infectious material which would likely give rise to disease, while other samples low in organic constituents were believed to carry infectious germs which might render their use very dangerous to employees or patrons of the road.

It was also found necessary to supervise certain sanitary matters and to disinfect cars, offices and waiting rooms under certain conditions, but it was not known what disinfectants were destructive to specific disease-producing bacteria. Manufacturing concerns were offering various disinfecting preparations, but the officers of the company had no means of determining which ones were efficient and the problem could not be solved by chemistry alone. These questions were considered so important that it was decided that a division of bacteriological chemistry was necessary, and on November 1, 1899, such a laboratory was established.

The work in bacteriology and water analysis has increased constantly, and at the present time four men are employed in the laboratory. The department co-operates with the surgeon general of the United States in the enforcement of the quarantine regulations of 1913, which require that railroad companies shall furnish wholesome drinking water and proper ice supply to passengers using their cars. Water which contains anything indicative of injurious contamination is not permitted to be introduced into the drinking containers of a Pennsylvania coach.

The department regulates the standardization of disinfectants and issues instructions concerning their application for the protection of passengers and employees, as well as the disinfection of stock cars. Special care is taken to prevent any infected employees from coming in contact with the public.

In 1914 bacteriological and chemical examinations were made of 609 samples of drinking water. There were 3,112 bacteriological examinations of pathological specimens, submitted by the relief association physicians. The total number of bacteriological examinations was 3,621, or an average of more than ten per day.

In addition, this department has under its care the examination of boiler feed waters and the formulation of methods for their treatment. In 1913, examinations of 287 boiler feed waters were made, while in 1914 the number was 282.

OTHER EQUIPMENT

As part of the equipment of the test department there is a dynamometer car which was built in 1906, and is the fifth of a series of such cars which have been in use on the Pennsylvania Railroad. There is also the locomotive testing plant which is located adjacent to the test department building. This plant was erected in 1905, after having been in use at the St. Louis Exposition in 1904, and is operated by a force of 26 men.

There is being installed in a separate building a brake shoe testing machine which will be the first of its kind, in that it will have two dynamometers of 4,000 lb. capacity, which will make it possible to obtain the co-efficient of friction of brake shoes when two shoes are applied to a single wheel (clasp brake conditions). The car wheel will run upon an idler wheel, representing the action of a rail upon the wheel.

EXTENT AND VARIETY OF MATERIALS TESTED

The scope of the work now embraced by these departments coming under the jurisdiction of J. T. Wallis, general superintendent of motive power, at Altoona, can be better appreciated when it is understood that the cost of the materials covered by the inspection and tests, and entering into the construction of the railroad rolling stock and track, in 1913 amounted to $82,119,480, while the cost of operating the test department and chemical laboratory for the same year was $534,060. For an approximation and using these figures, it is interesting to observe that the total cost of operating the departments, including all additional work and inspection, is about 0.6 per cent of the cost.

The year 1913 was perhaps a record one for the test department and laboratory, and the extent and variety of the work of the departments can be shown by a few examples for that year. There were 61,148 separate reports of material tests issued by the test department. In the physical laboratory, while no record was kept of the number of samples examined, 138,886 tests were made. These tests represented quantities such as the following:

Of bar iron 149,863,693 lb. were tested and 6,246,611 lb. rejected; of staybolt iron, 15,385 tests representing 8,301,960 lb. were made; of cement, 29,231 tests were made, representing 587,900 bbl., of which 13,600 bbl. were rejected; of wheels, 310,381 were inspected, and 1,213 were rejected; of axles, 164,810 were tested and 8,035 were rejected; 290 samples, representing 56,322 yd. of plush, were tested; of air brake hose, samples representing 634,807 were tested and 84,826 rejected.

In the chemical laboratory, during 1913, a total of 57,309 samples were analyzed, involving about 286,545 determinations.

There are 85 items, ranging from asphaltum to zinc, which are now bought under specifications and which must be passed upon by the test department or the chemical laboratory.

During 1913 there were inspected, while building at manufacturers' works, 24,966 freight cars, 343 steel passenger cars, and 190 locomotives. The value of the materials rejected through the test department in 1913 was for the physical laboratory, $776,928; and for the chemical laboratory, $65,767.

ORGANIZATION OF DEPARTMENTS

As outlined in the diagram of the organization, the inspection at the manufacturers' works and the collection and forwarding of samples to Altoona is carried out under the direction of the chief inspector, with permanent resident inspectors and forces for the central district at Altoona, the western district at Pittsburgh and the eastern district at Philadelphia. In addition, when equipment is being built at outlying points, temporary inspection forces are maintained at these places during the progress of the work.

As previously stated, the work of the department began under the direction of John W. Cloud. In May, 1879, he was appointed the first engineer of tests and continued under that title until July, 1886, when he succeeded to the office of mechanical engineer, retaining control of the test department. Axel S. Vogt, the present mechanical engineer, succeeded Mr. Cloud in March, 1887. The work of the department under the mechanical engineer was in direct charge of W. O. Dunbar from July, 1886, to July, 1893. From the latter date to July, 1903, the assistant mechanical engineer had direct charge of all the work of the department. During this latter period the assistant mechanical engineers were A. W. Gibbs, from July, 1893, to August, 1902, and W. F. Kiesel, from the latter date until July, 1903. In August, 1903, E. D. Nelson was appointed engineer of tests, and in September, 1911, was succeeded by the writer.

Two men have been in charge of the chemical laboratory, Dr. Charles B. Dudley from November, 1875, until his death, December 10, 1909. Since December, 1909, Dr. F. N. Pease has held the position.

That the information collected and the developments which have been made in the chemical laboratory and the test department have been freely given to the public, is well exemplified by papers and addresses which have been presented by the late Doctor Dudley. In addition to the works of Doctor Dudley, there have been published by the test department, 27 printed bulletins covering field tests and the work of the locomotive testing plant.