How Research Guides Railroad Progress

Important Test and Experimentation Projects Initiated by the Pennsylvania in Many Fields

Research is the watchword of progress in this modern and fast moving world. The very word conjures up vistas of romance and adventure, not of the peril-filled kind that accompanied the exploration of unknown lands and seas in the pioneer days, but the quiet and intellectual adventure—none the less absorbing—that comes with quests of discovery into new and ever broadening fields of science and invention. And just as those hardy adventurers of past generations advanced the rails into the golden and fertile West, pushed the frontiers into oblivion and served to unite a great nation, so the modern adventurers of

Streamlined coal burner. The Pennsylvania’s newest type of steam passenger locomotive
This ingeniously devised and complex apparatus is the locomotive test plant at the Pennsylvania Railroad's Altoona Works. It has pointed the way to many important improvements and advances in locomotive design and construction.

applied research are pressing ever forward the frontiers of science and are opening veritable new worlds of progress in all fields of industry.

And the railroads since the earliest days have been in the forefront of this advance, continually adopting scientific discoveries, new inventions and improved technical processes and methods to bring about higher standards of comfort, safety and speed of travel, and greater promptness and convenience in the movement of freight. The objective sought and achieved has been the constant enhancement of the utility and attractiveness of railroad service.

Direct research is carried on by the individual railroads to meet problems peculiar to the various separate lines, and also collectively, through the Association of American Railroads at Washington, to deal with problems common to all. In addition, a vast amount of research is indirectly supported by the railroads through the equipment, supply and fuel industries which conduct continuous experimentation on a very large scale to improve and to adapt to the most
modern uses the locomotives, cars and other equipment and materials produced by them for the railroads.

**Early Pennsylvania Railroad Research**

The Pennsylvania Railroad has engaged extensively in research activities since its inception and has continually broadened their scope as new advances in science and invention have afforded opportunity. As long ago as 1851 the Pennsylvania's motive power department initiated elaborate and exceptionally complete research into the performance of wood, anthracite coal, bituminous coal and coke as locomotive fuels. These experiments and observations continued over several years and yielded a mass of important and valuable information.

Other tests brought about the adoption of steel tires for locomotives in 1861 and of steel axles for passenger and freight cars in 1866. Further research resulted in the pro-

![Specially equipped and fitted dynamometer car which enables Pennsylvania Railroad engineers to determine and check the performance of locomotives operating in actual road service](http://PRR.Railfan.net)
duction in 1868 of the first locomotive having steel boiler tubes, followed by the adoption of steel boilers in the same year to replace iron.

The first practical trial of the air-brake under actual operating conditions was made by the Pennsylvania Railroad in 1868 on the Steubenville accommodation, running from Pittsburgh to the Ohio city of that name.

Altoona Test Laboratories

In 1874 the Pennsylvania Railroad established a department of physical tests at Altoona, followed by a chemical laboratory in 1875 and a bacteriological laboratory in 1889. These were the first test plants of their respective kinds developed by any railroad.

The department of tests at Altoona was further enlarged in 1905 by the addition of a locomotive testing plant. In this plant, though the locomotive itself does not move, it is possible to reproduce actual road conditions and study the effects of various operating factors. The engine under test is carried on supporting wheels instead of rails. The axles of these wheels are extended to receive absorption brakes. The turning of the locomotive driving wheels, under power as on the road, causes the supporting wheels to revolve against the friction of the brakes, and the work done by the locomotive in overcoming this resistance is measured at the draw-bar by a traction dynamometer.

Pressure measuring devices at each end of special steel “recording ties” as used in the electric locomotive track tests at Claymont, Del. The sideways pressures against the rails, exerted by the locomotive wheels at various speeds, were recorded and measured by indentations made in soft steel plates by hardened steel balls.
Observations made in this plant have led to many important improvements in locomotive construction and design. In addition, a completely equipped dynamometer car is operated by the railroad for the purpose of checking and determining the performance of locomotives in actual service.

One of the most important early results of research in the Altoona test laboratories was the development of the first specifications covering the chemical composition of steel for rails and requirements for physical tests and inspections of rail. These specifications and requirements have, of course, been modified many times since, as the result of continued research and experimentation, by both the railroad and the steel companies, and the advances in metallurgical processes. In these laboratories, also, were worked out the first physical and chemical specifications adopted by any railroad for the purchase of important general supplies, such as iron and steel for various purposes, paints, cleaning materials, plush, bearing metal alloys, etc.

These earlier research projects were among those which have become the very foundation of modern railroad transportation, and have been followed by an unbroken series of other projects continuing down to the present and covering substantially the entire field of railroad operation. Among those of great importance recently completed or under way on the Pennsylvania Railroad are included the following:

**Electric Locomotive Track Tests**

Over a section of special track at Claymont, Del., purposely roughened to produce hard riding and equipped with delicate and ingeniously devised instruments to measure pressures and
stresses on the rails at different speeds, trial electric locomotive runs were conducted over a period of many months during the completion of the New York-Philadelphia - Baltimore - Washington electrification. Other tests measured pressures at the hubs and other parts of the engines themselves. The information so gained led to the selection of the types of locomotives used in the high-speed electrified passenger service and to the perfecting of various details of their design. These locomotives also embody many features which are the result of years of research, experimentation and improvements on the part of the railroad and the manufacturers. Improvements in motors have permitted the elimination of side-rods, resulting in smoother performance and less wear and tear on the tracks. Speeds have been increased without sacrificing safety. Power has been increased without sacrificing comfort. Appearance has been improved without sacrificing utility. That so much improvement should have been made in such a relatively short period is in itself an ample demonstration of the results to be obtained by applied research.

Streamlining

The streamlined contours of these new electric locomotives, and also of the recently completed streamlined coal-burning engine which has been on a tour of exhibition covering many cities, were worked out in a series of wind tunnel laboratory tests through the Pennsylvania Railroad's engineering department in cooperation with the railroad's advisory streamlining expert. In these tests, for the first time, clay models capable of immediate alteration in outlines were used. The behavior of the air currents was studied, both in the wind tunnels with
large models and on the road with actual locomotives, by means of silk streamers, which by their movements showed whether the air flow was smooth or interrupted. In the wind tunnel tests the models were constantly reshaped until the most nearly perfect form was obtained for minimizing air resistance, as indicated by the action of the silk streamers, and observation of other effects.

**Electrification**

The research which entered into the design of the electric locomotives was only one phase of the electrification problem. The experience of many years of electric operation and research, beginning with the first steps in 1904 to electrify the Long Island lines, paved the way for the inauguration of the New York-Philadelphia-Baltimore-Washington electrification and led to many outstanding developments. Among them were the designing and building of new and greatly improved types of high voltage circuit breakers, the use of non-corrodible materials in the overhead wire system, improved methods of joining the parts of the overhead system, the adoption of new principles in the construction of the 132,000 volt transmission circuits, the introduction of improved control

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*Clay model of streamlined coal burning locomotive used in wind tunnel tests to develop the most effective contours for reducing air resistance and deflecting smoke up and away from train*
In road tests of the Pennsylvania Railroad's new electric locomotives, instruments attached to various parts registered pressures at driving wheel hubs and elsewhere at all ranges of speed. Operating electrically, these instruments record their findings in curves traced by moving light beams on photographic films, apparatus to permit the elimination of high voltage circuit breakers from the locomotives, and the production of a better and lower cost type of track circuit bond.

**General Track Tests**

To obtain accurate knowledge, not previously available, of just what takes place in track and locomotives under high-speed operation, tests were recently conducted over various sections of the railroad, on both straight and curved track, using electrically operated measuring instruments. These instruments finally record on a photographic film what is literally a picture of the varying forces exerted at the axles and elsewhere on the locomotives, and particularly the effects at switches, guard rails and sharp curvatures. Simultaneously, the stabilization of the track, resulting from various
methods of ditching and draining, was carefully investigated, and studies were conducted of soil conditions and the action of soils of different types under pressure in the roadbed, all making for improved riding qualities for high-speed trains, greater safety and further advances in equipment design.

**Bridge Tests**

Extensive experiments in the action of trains on bridges are now being carried on near New Brunswick, N. J., Chester, Pa., and Elkton, Md. The purpose is to submit to practical test, and revise in the light of the knowledge so gained, certain...
theoretical formulae heretofore used to calculate the effects on structural parts of bridges resulting from the movement over them of locomotives and cars of various weights at different speeds. It is believed that the final results of these tests will show that in practice a more liberal range of train speeds is permissible on bridges, with safety, than had previously been indicated by the purely theoretical formulae. The information obtained will be valuable in the further development of the high-speed electrified passenger service between New York, Philadelphia, Baltimore and Washington, and will also

In this ultra-modern air-conditioned coach of the Pennsylvania Railroad, the cooled, filtered and dehumidified clean air, after being drawn in from the outside and passed through the conditioning apparatus, is distributed evenly through the car by means of improved decorative ducts located in the ceiling on both sides of the continuous lighting system. The coach is one of three which are now in experimental service, and which embody different seating arrangements and many other new features.
be useful in the consideration of train speeds on bridges over the railroad generally.

**Special Air-conditioning Tests**

The Pennsylvania Railroad was one of the pioneers in air-conditioning passenger cars and now operates the largest air-conditioned fleet in the world, numbering, this summer, approximately 1,400 cars, including those in through service. The existing principles of air-conditioning from the viewpoint of maximum health and comfort requirements of the passengers, as well as the details of mechanical and electrical design of the apparatus, have been worked out chiefly by research and experimentation. One of the earliest and most important facts observed was that to maintain a fixed temperature within the car—say 70 degrees—regardless of external temperature, would not produce the best results. An interior temperature which might be comfortable when the

Modern "position light" signals developed by Pennsylvania Railroad research. In these signals, brilliant lights slightly amber tinged show by their position the condition of the track ahead, eliminating the old semaphore arms and the use of colored light signals at night. The vertical position of the lights, as on the third signal to the left, means "Proceed". The 45-degree indication at the extreme right means "Caution, approach next signal prepared to stop". The horizontal indication means "Stop"
air outside was 80 degrees was found to be uncomfortably chilly, and possibly even dangerous to health, with external temperatures ranging from 90 to 100 degrees or more. By actual trial a scale of differentials was worked out covering the entire range of summer temperatures encountered in Pennsylvania Railroad territory and the air-conditioning apparatus in all cars on the Pennsylvania is controlled accordingly. The proper degrees of humidity and the most desirable amount of air motion were also determined by experimental research. In all Pennsylvania Railroad air-conditioned cars the air circulated within the car is constantly renewed by a fresh supply drawn in from the outside and filtered to free it of dust, cinders and pollen. The freedom from pollen gives immediate relief to hay fever sufferers.

**Improved Springs for Freight Cars**

At certain speeds the spiral springs until recently used on all freight cars sometimes cause excessive upward and downward movements of the car bodies. Pennsylvania Railroad engineers, in cooperation with the manufacturers of railroad equipment, by research and experiment have developed and put into practical use a new type of spring arrangement, technically termed “non-harmonic,” which checks the excessive vertical movement. The principal feature of the improved arrangement is the use of elliptical springs in connection with the spiral springs. Since those springs have different rates of vibration, one acts as a check or “snubber” upon the other and reduces the upward and downward movements of the bodies of the cars, keeping them within limits.
Half a century's progress in rail design. At the right is a cross-section of the Pennsylvania's new heavy-duty rail, weighing 152 pounds to the yard and of improved proportions and design. At the left is a section of the rail it replaced. In the center is a 60-pound rail of 50 years ago. Relative sizes may be gauged from the fact that the new rail is 8 inches high which protect the contents of the car from injury from that cause.

The Pennsylvania's 152-lb. Rail

Designed for use on high-speed dense traffic lines, this is the heaviest rail regularly employed by any railroad in the world. Its dimensions were worked out by a joint committee of railroad and steel company engineers, one of the most helpful members of which was a bridge designer whose specialized knowledge of the design of steel bridge parts for maximum strength greatly contributed to the excellent results obtained. Though only 17% heavier than the rail formerly in use, the 152-lb. rail is 80% stronger as a result of the improved design developed by the committee's research.

“Controlled Bearing” Rail Joints

The design of bars which hold the steel rail in place in the track of the modern railway has been the subject of experi-
“Cab signals,” developed on the Pennsylvania Railroad by research and experimentation, are the latest important step ahead in railroad signal science. They bring the indications of the wayside signals into the locomotive cab before the eyes of engineman and fireman so that track conditions ahead are known at all times regardless of outside visibility. The engineman’s side is here shown. Similar apparatus is installed on the fireman’s side of the cab for many years. Pennsylvania Railroad research has brought into extensive use, only within the last year, an improved type of bar, known as “control bearing bar”, for joining the ends of rails. The principal feature of the improved bar is that instead of being straight, it is “waved” in such manner as to touch the rail only at the rail ends and near the ends of the bar. The effect of this change is to reduce wear at the joints and rail ends by a better distribution of the stresses and by always maintaining a tight joint. Not only are track maintenance costs reduced but the smooth riding qualities of the track are enhanced.
Safety-A Triumph of Research

One of the most remarkable fruits of general railroad research has been the unparalleled record created in this country for safety of travel by rail. It is recognized by the great insurance companies that a passenger train on a standard American railroad is probably the safest place in the world for a person to be at any time—far safer than one's home and almost immeasurably safer than the sidewalks of a city street.

The research upon which this achievement has been chiefly based, on the Pennsylvania and other railroads, has covered innumerable tests and studies ranging from passenger car body design to the heat treatment of axles and rails, the chemical analysis of steels, the qualities and preservation of cross-ties, the characteristics of ballast and of the roadbed foundation structure, the strength and life of bridges, and even such an apparently minute thing as the exact curvatures of the top of a rail and of the tread and flange of the car wheel in contact with it.

An "interlocking" plant interior. On busy sections of the railroad, and particularly in great terminal areas, switch movements and signal indications are "interlocked" mechanically and electrically to prevent possibility of error in handling complicated and frequent train movements. Small electric bulbs on boards before the operators diagrammatically show the position and movements of trains over the trackage controlled by the plant.
THE Pennsylvania Railroad has pioneered in developing and adopting many of the fundamental inventions and improvements by which the art of railroading has progressed—among them the following:

The use of steel rails to replace iron.

The practical trial and adoption of the air brake.

The establishment of physical, chemical and bacteriological laboratories for testing materials and equipment and maintaining sanitation.

The development of specifications for the chemical composition of steel rails and requirements for chemical and physical tests of rail, together with the adoption of definite physical and chemical specifications for purchasing materials and supplies generally.

The use of the telephone in railroading, now developed with the telegraph into the world’s largest private system of wire communication.

The protection of trains and control of train movements with block signals.

The installation of mechanical switch and signal interlocking plants.

The adoption of all-steel passenger cars.

The adoption of all-steel freight cars.

The coordination of motor, airplane and rail transport.

The development of “position light” signals, replacing the moving semaphore arms by day and eliminating the necessity for colored light signals at night.

The development of “cab signals” which bring the indications of the wayside signals into the locomotive cab before the eyes of the engineman and fireman.

The creation of the largest fleet of air-conditioned trains in the world.

The electrification and operation of more than one-third of America’s standard railroad electrified trackage.