

tion below this building, having five separate tracks and separate loading and unloading platforms for the passengers. The trains on leaving the station pass into the return tunnel, which is built below Fulton Street and returns underneath the Hudson River to the tunnel station below the Pennsylvania depot in Jersey City. A subway leads from the Cortlandt Street terminal station to the Rapid Transit Subway below Broadway.

The cars are built entirely of steel. They are absolutely fireproof, and are constructed upon a plan differing materially from any others now used in the Metropolitan district. They have large, sliding side doors in the middle, as well as at either end, and the platforms are so arranged at the terminal stations that passengers enter and leave the cars at the same time. Those leaving go out on one side, and those entering the cars come in on the opposite side. This will do away with the congestion and crowding experienced at terminal stations on other Metropolitan railroads. All station platforms throughout the system are built on a tangent, or straight line, so that there is no dangerous space between the cars and the platform, such as is seen where stations are built on a curve. The doors of the cars are operated by compressed air, and no signal bells are used. When the last door in the train is securely closed, the motorman receives an electric flash signal, and starts the train. The automatic adjustment is such that the signal to start cannot be given so long as any door in the train remains open the fraction of an inch. The cars are brilliantly lighted and very comfortable. They have only side seats, and are equipped with steel rods set vertically at frequent intervals, to aid passengers in steadying themselves when trains are crowded.

Throughout the system, which, when completed, will comprise eighteen miles of under-river and underground railroad, the stations are designed with a view to comfort, permanency, and beauty. They are made large enough, not merely to accommodate the Metropolitan traffic of to-day, but to receive comfortably the greatly increased multitudes sure to travel by sub-surface routes in the decades to come. Every part of the stations is constructed either of concrete or metal, so that, like the cars and the tunnel, they are thoroughly fireproof.

To the passengers who descend into the tunnel for the first time, the architecture of the stations is the most striking feature, and particularly so if they have an eye to the general fitness of things. The roof is formed of vaulted arches, which show a pleasant effect of light and shadow produced by the glow of incandescent globes.

The engineering features of the Hudson Companies' tunnels are full of special interest. We have already referred to the early attempts to complete the Morton Street tunnels. The original shaft constructed at the westerly end of the tunnels, is 30 feet in diameter and 65 feet in depth. It is brick-lined and opens into the power house in which the new operating plant is installed. The external diameter of the northern tunnel is 19 feet 5¼ inches and its internal diameter 18 feet 1¼ inches. The southern tunnel is 15 feet 3 inches in internal diameter, and 16 feet 7 inches in external diameter.

Both tunnels were built by the Greathead shield system and lined with a cast-iron shell which is made in segments provided with internal flanges by which the shell is bolted in place.

After the English company abandoned the construction of the northern tunnel in 1891, it was allowed to fill with water. When the work was taken in hand by the present company the tunnel was pumped out, and it was found that with the exception of some 470 feet, the work already done was in good condition. This was in the latter part of 1896, and from that time until 1902, when orders were given to proceed with construction, the tunnel was regularly pumped out and maintained in good condition. A new building was erected at the Jersey shaft, equipped with a very complete power plant, including hydraulic pumps, air compressors, etc. The shield which was used by the English company was overhauled and was used in completing the north tunnel. It was designed for use only in silt, and when the tunnel reached a point where rock and boulders were encountered in the lower half of the excavation, it was found necessary to build a heavy apron, extending 6 feet in advance of the upper half of the cutting edge, and reaching from side to side of the shield. This apron was built of 12-inch I-beams and ¾-inch steel plates, and was strongly braced. Under the shelter of this apron, which was heavily shored up, the workmen were able to pass forward of the shield and drill and blast out the rock below it. This work is unique in horizontal shield excavation, and it was carried forward with complete success.

The method of operating the hydraulic shield is so well known as to need no detailed description here. It was forced forward into the silt by means of hydraulic rams set up between the front edge of the completed iron lining of the tunnel and the rear edge

of the shield. As it moved forward, the silt was squeezed through open inlets into the interior of the shield, where it was broken off, loaded into trucks, and drawn away from the heading by a cable.

On the south tunnel new air-locks were installed, and the necessary machinery built. The shield for this work, which was designed by Jacobs & Davies, engineers of the company, is shown in the accompanying engraving. It will be seen that it is divided by one horizontal and two vertical frames and by transverse diaphragms. The shell is double and the whole construction is calculated to give great stiffness and resistance to distortion. It is provided in front with a movable working platform which, if necessary, may be carried forward of the cutting edge. In the rear it is provided with the necessary hydraulic jacks, valves, etc., for carrying forward the shield and for swinging the erector—a massive arm which moves something like the hands of a clock, and is used for picking up the cast-iron plates and placing them in position ready for bolting up. It is interesting to know that in spite of the difficult nature of the material through which the tunnel was driven, there being, in some places, rock below and soft silt in the upper half of the tunnel, progress was made at the rate of between 4 and 5 feet a day. The work was rendered particularly hazardous by the fact that there was at times a hydraulic head due to 65 feet of water, and that there was only 10 feet of soft silt between this hydraulic pressure and the roof of the tunnel. In driving the Cortlandt Street tunnels the shield was driven bodily forward, forcing the material to give way by displacement. Great credit is due to the chief engineer, Charles M. Jacobs, and his staff for the speed and accuracy with which they have brought this great work to its successful conclusion.

In closing the present article, it is gratifying to be able to state that by the time this issue is in the hands of our readers, the first of the four tubes of the Pennsylvania Railroad below the East River will have been put through, and that all four connections will, judging from present progress, be opened through within three months.

THE TESTING OF A LOCOMOTIVE.

BY FREDERIC BLOUNT WARREN.

Powerful locomotives, no matter how costly, do not matriculate from the builders' shops into the class that draws the sixteen-hour trains to Chicago, or pulls the Lake Shore flyers, without first having demonstrated their capacity by a series of most exacting tests.

Railroad officials must have some better proof of an engine's capacity than the mere indorsement of the men who make the mechanism. So, when locomotives come newly painted and polished from the big Baldwin shops, for instance, the owners send them into testing plants, mount them upon a delicate and compact series of registering instruments, and run them at all speeds, until their weaknesses have been detected and their strong points emphasized almost to a fractional degree of an atom. The testing machinery is, in reality, nothing more than a treadmill, in principle. In outward appearance it seems to be just so many large wheels revolving on axles, so arranged that each wheel of the engine under test meets a corresponding wheel in the tester.

Once in position, an engineer climbs into the locomotive cab, opens the throttle until it has reached its widest point; the steam shoots into her tubes and chests, the great wheels begin to revolve, gain speed and finally become a circling blur, in which the eye is unable to detect the interstices. Deriving the full power from its fuel, the forward or backward movement of the locomotive is nevertheless barely a fraction of an inch.

This is an unromantic testing beside that which Kipling described with characteristic vigor. The "try-out" which he depicted consisted of taking an engine, hitching it on to heavy freight cars and sending it out on the line, on levels and tangents, on curves and grades, until the machinery demonstrated its worthiness to take the speedy runs of its owners. Railroad men to-day are more exacting. Figuratively, their testing plants ask questions of a mass of wonderfully-constructed iron and steel, and the metal answers them in their entirety.

The chief plant of this kind is located in Altoona, Pa., being a part of the extensive shop system of the Pennsylvania Railroad. With a force of sixteen men, it has been in constant operation since November 19, 1906, and, on an average, about three complete tests are made each week.

A separate building of steel and brick has been erected for housing the apparatus. The driving wheels of a locomotive under test rest upon supporting wheels with rims shaped to correspond with the head of a rail. The axles of these supporting wheels carry absorption brakes. The turning of the driving wheels causes the supporting wheels to revolve, but these are retarded to any extent desired. The work actually done by the locomotive consists in overcoming the

friction resistance of the supporting wheels and brakes, the resulting force exerted at the drawbar being measured by a traction dynamometer. The axles of the supporting wheels run in heavy pedestals secured to cast-iron bedplates resting upon a concrete foundation. There are two bedplates running parallel to the track, and in order that the supporting wheels may be directly beneath the locomotive drivers, these bedplates are provided with T-slots, so that the pedestals may be moved along parallel to the track, and secured in any position to suit the particular engine under test. The only wheels of the locomotive which move during a test are the drivers. The wheels of the leading truck rest upon rails secured to I-beams and supported upon the same bed-plates that carry the pedestals. The wheels of the trailing truck rest upon supporting wheels—which remain stationary during the test—and are carried by pedestals secured to longitudinal bedplates.

Preparation of the testing plant to receive a locomotive consists of bolting the pedestals to the bedplates, so spacing them that there will be a pair of supporting wheels directly beneath each pair of drivers of the locomotive. A section of special rail is bolted to the inside faces of the supporting wheels. This rail is composed of a heavy I-beam, to the top of which is secured a grooved head in which the flanges of the drivers run. The top of the supporting wheels are in line with the track entering the testing plant building, so that a locomotive can be backed in and the drivers will run on their flanges until in position directly over their supporting wheels. After a locomotive has been secured in place and its drawbar attached to a dynamometer, these grooved rails upon which it ran in are removed, leaving the drivers resting upon the supporting wheels.

The axle for each pair of supporting wheels carries upon each of its overhung ends an Alden absorption brake. Each of these brakes consists of two smooth circular cast-iron disks, keyed to the supporting-wheel axle. On each side of each one of these disks is a thin copper diaphragm secured at its periphery, and also at its inner edge to a housing which does not revolve and has its bearings upon the hubs of circular revolving disks. The stationary housing is so designed that when it is filled with water under pressure the copper disks are forced against the revolving disks, creating friction. Provision is made for securing continuous and uniform lubrication of the surfaces of these revolving disks, and the water is caused to flow through the housing in order to carry away the heat generated. Thus the water performs two functions: it supplies pressure to cause the friction, and it carries away the heat generated by the friction.

Connection between each brake and the source of water supply is made by a flexible hose. Discharge pipes for all the brakes empty into an iron trough, and each pipe is provided with a valve located adjacent to the valve in the supply pipe for the same brake. When placing a load upon the locomotive under test, these valves are adjusted until the individual brakes each absorb their share of the work. When this preliminary adjustment has been made, the power absorbed by all of the brakes may be increased or decreased by operating a large valve in the supply main.

A special system has been installed for the purpose of supplying water under uniform pressure for use in the brakes.

An adjustable drawbar is used to connect the locomotive with a dynamometer and, in addition, the dynamometer housing is provided with a means for raising and lowering the dynamometer proper to bring this drawbar truly horizontal. Two safety bars are provided between the locomotive and the dynamometer frame, to decrease the vibration transmitted to the dynamometer through the drawbar. At their ends these bars have universal joints to insure perfect freedom of adjustment, and each bar is provided with an oil dashpot near the dynamometer end.

The Pennsylvania Railroad's traction dynamometer, which measures the drawbar pull of the locomotive, is of the lever type. The weighing mechanism is supported by a frame, which slides up and down in ways formed by the housings. These housings are very massive, rigidly secured together, and anchored to a heavy foundation. The lever system is constructed upon the Emery principle, in which flexible steel fulcrum plates take the place of knife edges used in ordinary scales. As the levers are vertical instead of horizontal, their weight would not come upon the flexible fulcrum plates in the direction in which they transmit pressure. In certain cases it has therefore been necessary to supply two fulcrum plates with their axles at right angles, one for carrying the weight of the levers, and the other for transmitting the thrust.

The mechanical and mathematical detail entering into this phase of locomotive testing is so delicate and complicated that it would be, in an article of this kind, almost wholly unintelligible to the lay machinist, though of course easily understood by trained engineering minds.

Of very great interest, however, are the records obtained on a recording table, over which an endless strip of paper eighteen inches wide is mechanically drawn, and upon which a continuous story of the test and its results is told. The paper is driven by direct connection with one of the supporting wheels of the testing mechanism, upon which the locomotive drivers rest. The speed reduction is so arranged that when the locomotive under test travels one mile on the supporting wheels, the paper moves 52.8 inches, giving a scale of 100 feet to the inch upon the diagram. In order to obtain an accurate movement of the paper, it passes between a finely corrugated brass roller and another roller covered with rubber. The winding drum to which the paper is finally delivered is arranged to slip upon its shaft, in order to accommodate its constantly increasing diameter as the test progresses.

A datum pen marks a continuous straight line upon this paper. A traction recording pen moves across the paper perpendicular to the datum line, being dependent upon the force transmitted by the drawbar from the locomotive. The maximum travel of this pen away from the datum line is eight inches. Two sets of springs are provided. With the heaviest set the eight-inch movement of the traction pen corresponds to a load of 80,000 pounds upon the drawbar, which represents the maximum capacity of the dynamometer. With the other set of springs the eight-inch motion of the traction pen corresponds to a pull of 40,000 pounds upon the drawbar, and with all the flat springs removed the eight-inch motion corresponds to a 16,000-pound load. The total motion of the drawbar to give the eight-inch movement to the recording mechanism is about 0.04 of an inch. The multiplication of the recording and weighing mechanism is therefore 200 to 1.

An integrator is provided and attached to the traction recording mechanism, so that the foot-pounds of work performed by the locomotive is automatically summed up. Five additional electrically-operated pens are provided. They normally draw continuous straight lines. One of them is electrically connected to a clock, so that each second is indicated by a jog in the straight line which the pen normally draws. Another pen is electrically connected to a roller, which is rotated by the recording paper, causing the pen to make a jog in the line for every thousand feet which the locomotive travels. Another pen is electrically connected to the integrator, and makes a jog in its line every time the integrator measures one square inch. The remaining electrically-operated pens are used for recording such features of the test as taking indicator cards.

For handling coal used by the locomotives under test, a very complete plant has been installed. Bottom-dumping railroad coal cars are run in on a track beside the test building. They are dumped into a large hopper, and from this the coal is carried by a bucket conveyor to two elevated reinforced concrete pockets, each of which has a capacity of about fifty tons. Each coal pocket is provided with a hopper cut-off gate at a convenient height above the main floor of the test building. Coal from the bins, as needed, is discharged through the gates into wagons holding about 1,000 pounds each, which are run over weighing scales, pushed out to the locomotive, raised by hydraulic elevator to the firing platform, and then dumped.

Ashes from the locomotive are discharged at the pit level, placed in wagons, and removed.

A supply tank located in the corner of the laboratory supplies the water used in the locomotive boiler. This water first passes through a meter, the reading of which is used as a check upon the weighing tanks. A small motor-driven centrifugal pump returns to the supply tank the overflow from the injectors used on the locomotive.

So unique and complete is this big testing plant of the Pennsylvania Railroad, that rarely is there a week that passes when engines of other railroads are not tested because the owners of the locomotives lack the facilities in their shops to determine the road value and capacity of their own transportation haulers.

For the completeness of this plant and the highly-maintained state of perfection the Pennsylvania officials attribute much credit to Mr. Theodore N. Ely, Chief of Motive Power of the Lines East.

According to L'Eclairage Electrique, traction by steam locomotives fitted with smoke consuming apparatus is to be temporarily re-established in the Simplon Tunnel, owing to the fact that the locomotives lent by the Valtellina Railway have given rise to difficulties in working. Their dimensions cause them to act as pistons, and thereby a great deal of energy is absorbed. Further, on account of the condensation, arising from the difference of temperature inside and outside the tunnel, the insulators deteriorate, and several motors have been damaged. Modifications which have been introduced in the motor insulation will, it is hoped, satisfy these special operating conditions.

Correspondence.

Energy of Recoil of Guns.

To the Editor of the SCIENTIFIC AMERICAN:

In looking through an article on "Guns and Armor" in your issue of December 7, 1907, I happened to notice an erroneous statement which seems worth correction. The author of that article says: "At the instant that a 12-inch projectile is driven from the muzzle of the gun with an energy of over 44,000 foot-tons, the gun itself is driven in the opposite direction, backwardly, with exactly the same energy."

It is lucky for the designers of our gun carriages that this is not true. Of course it is the *momentum* of the parts moving backward which exactly equals the momentum of the parts moving forward. The *energy* of the projectile is vastly greater than the energy of the gun, for the simple reason that the former moves very much farther than the latter under the action of the effective force, the powder pressure.

PHILIP B. ALGER, Professor U. S. N.
Annapolis, Md., January 3, 1908.

Effect of the Manhattan Terminal on the Manhattan and Williamsburg Bridges.

To the Editor of the SCIENTIFIC AMERICAN:

In the issue of the 8th instant you published a very interesting article on the permanent Manhattan terminal of the Brooklyn Bridge, and I would like to call your attention to the effect of this improvement, not only on the Brooklyn Bridge, but on the Manhattan and Williamsburg bridges.

In the first place, the plans of the Bridge Department for this permanent double-deck Manhattan elevated terminal at the Brooklyn Bridge will cut off any possibility of an elevated connection between the Brooklyn, the Manhattan, and the Williamsburg bridges, and, further than this, elevated trains are to operate through the Center Street subway, interfering seriously with future extensions of the several Brooklyn subways, which must connect with and depend for efficiency throughout upon quick transit through this Center Street subway as the main objective of all Brooklyn subway service.

At the present time, construction is being carried on by which the elevated railroad tracks at the Manhattan end of the Brooklyn Bridge may be spread, allowing two central tracks to descend at a sharp grade, which terminates on a curve at a station to be located under and north of the old Staats-Zeitung building, while plans are rapidly progressing by which a great municipal building will occupy the site above, shutting off any possibility of extending the elevated tracks from either of the two upper-deck terminals, which are to be built under the plans of the Bridge Department.

At the Manhattan Bridge the four tracks on the upper level are to be at such an elevation that no feasible approach can be arranged at the New York end; and while notification was sent by the Board of Estimate some time ago to all transportation companies, inviting applications for the right to operate over the Manhattan Bridge, no use of these four upper tracks is to-day physically possible, except by constructing an unsightly elevated incline on the newly-acquired Flatbush Avenue extension, so as to allow the Brooklyn trolley lines to get to the upper tracks and then run to New York, and terminate at such an elevation above the street as would seem to preclude any chance of the tracks extending to the street surface there.

Without any elevated railroad connection from the upper tracks of the Manhattan Bridge at the New York end, it has appeared necessary to the authorities to turn over two of the lower tracks on the bridge for the Brooklyn elevated railroad, which is now designed to run through Flatbush Avenue from Fulton Street, and to descend near the bridge approach to the street level, so as to connect with these lower tracks of the Manhattan Bridge.

Even with this peculiar arrangement proposed, by which the trolley lines in Flatbush Avenue extension pass up an inclined plane, and the elevated lines there are to run down an inclined plane on the Bridge Plaza in going to New York, the grade for the elevated trains from the lower deck of the bridge to the Center Street subway is so steep as to be considered by the Brooklyn Rapid Transit Company prohibitive, requiring the equipment of every car with high-power motors, and the proposed grades for the elevated tracks into the Center Street subway at all three of the bridges are practically the same.

Such arrangements on the Manhattan Bridge are inconsistent with its design and purposes, with its four upper-level tracks originally intended for elevated service by an elevated connection in Manhattan.

At the Williamsburg Bridge a long-delayed contract, providing for elevated connection with the Broadway line, has been carried out, and nearly a year ago the Department of Bridges made a contract providing for tearing down about half a mile of the elevated structure at the Manhattan end of the Williamsburg Bridge,

by which these Brooklyn elevated trains will now run down to a station in Delancey Street, and ultimately through the Center Street subway to the other two bridges.

Looking for a moment at our Brooklyn Subway Loop Line, which is being built by the city as a part of the Broadway-Lafayette Avenue subway, of the Fourth Avenue subway, with the Coney Island extension, and properly of the Flatbush extension, which it could also serve, it must be admitted that the four tracks in the Center Street subway will be necessary for these lines extending over the three bridges and for the Pineapple Street tunnels, which are now proposed by the Public Service Commission as connections of the Center Street subway. To load this Center Street subway with all the through elevated service as well, in the short Manhattan run, where stations are at short intervals, must result in congestion, which will reduce the capacity of both systems, and especially prevent efficiency throughout the subway extension in Brooklyn. This Center Street subway was to be the nucleus of future subway extensions, as provided in the resolution of the Board of Estimate providing for spurs and further connections from the Broadway-Lafayette Avenue line, and it seems evident that the Center Street subway will be fully loaded, and that independent provision should be made for the elevated service of Brooklyn.

The history of the Stevenson elevated loop scheme through the Bowery line and the older proposition of Engineer Martin for the Center Street elevated loop is all pertinent to the question to-day, and immediate action should be taken leading to a rational treatment of this elevated service connection in Manhattan for the Brooklyn lines. Objections to the double-deck elevated line proposed through the Bowery were principally in the great distance off Broadway, through which a large part of the traffic would reach the bridges, and from the fact that the proposition was so tied up with demands of the Interborough Company, that the Brooklyn interests could not be separated and treated on their merits. A Center Street elevated road seems to be out of the question, and it is for this reason that we have for the past year urged the construction of the Baxter Street Elevated Bridge Loop, which was incorporated at our suggestion in the amended Dowling Bill last year. It is a plan which is thoroughly practical as to line and grade, and running through a street where the improvements are generally unimportant, and where the grade of the elevated structure through Baxter Street and private property may readily be carried through to the subway on Delancey Street or to an elevated structure through this very wide bridge approach, provided for this purpose by the city.

There is no more important Brooklyn proposition to-day than this elevated connection in Manhattan, from the fact that it affects the utility of both the present elevated service and the future subway service for Brooklyn. The Brooklyn Rapid Transit Company were ready a year ago to pay a fair rental on the cost of this Baxter Street elevated loop, with its favorable grades and alignment, and proposed furthermore to utilize the available space under the structure for trolley connection between the bridges. Without the elevated loop in Manhattan the city cannot use the upper tracks of the Manhattan Bridge for elevated service, and the utility of the Brooklyn subways is reduced to such an extent as to delight the opponents of city control of city utilities. Opposed to us are the Interborough and other private interests working for the crippling and permanent defeat of what is being attempted by the city at this critical time in transit extensions for the city, and the public should understand these definite issues.

R. WALTER CREUZBAUR,
Consulting Engineer of Public Works,
Borough of Brooklyn.

Brooklyn, February 13, 1908.

The Growth of Modern Steamships.

The maximum size of ocean-going steamships has doubled within the last ten years, and prophecies are frequently heard of continuous growth, alike in size and speed. It seems probable, however, that in the immediate future there will be little increase in the size or speed of steamships. Speed does not pay, and some regard must be paid to the depth of harbor channels and the capacity of drydocks. Before vessels larger than the "Lusitania" are designed, there must be some assurance that they can get in and out of the ports which they are likely to visit. Any demands created by expanding commerce can easily be met by increasing the number of vessels to be devoted to it and by increasing the frequency of sailing dates.

Every knot of speed added beyond a certain point means a more than proportionate expense. And speed is not everything. More than one of the transatlantic lines are noted for the roomy comfort of their steady, slow-traveling boats, which neither pitch unduly in rough seas nor transmit a constant vibration from the engines.

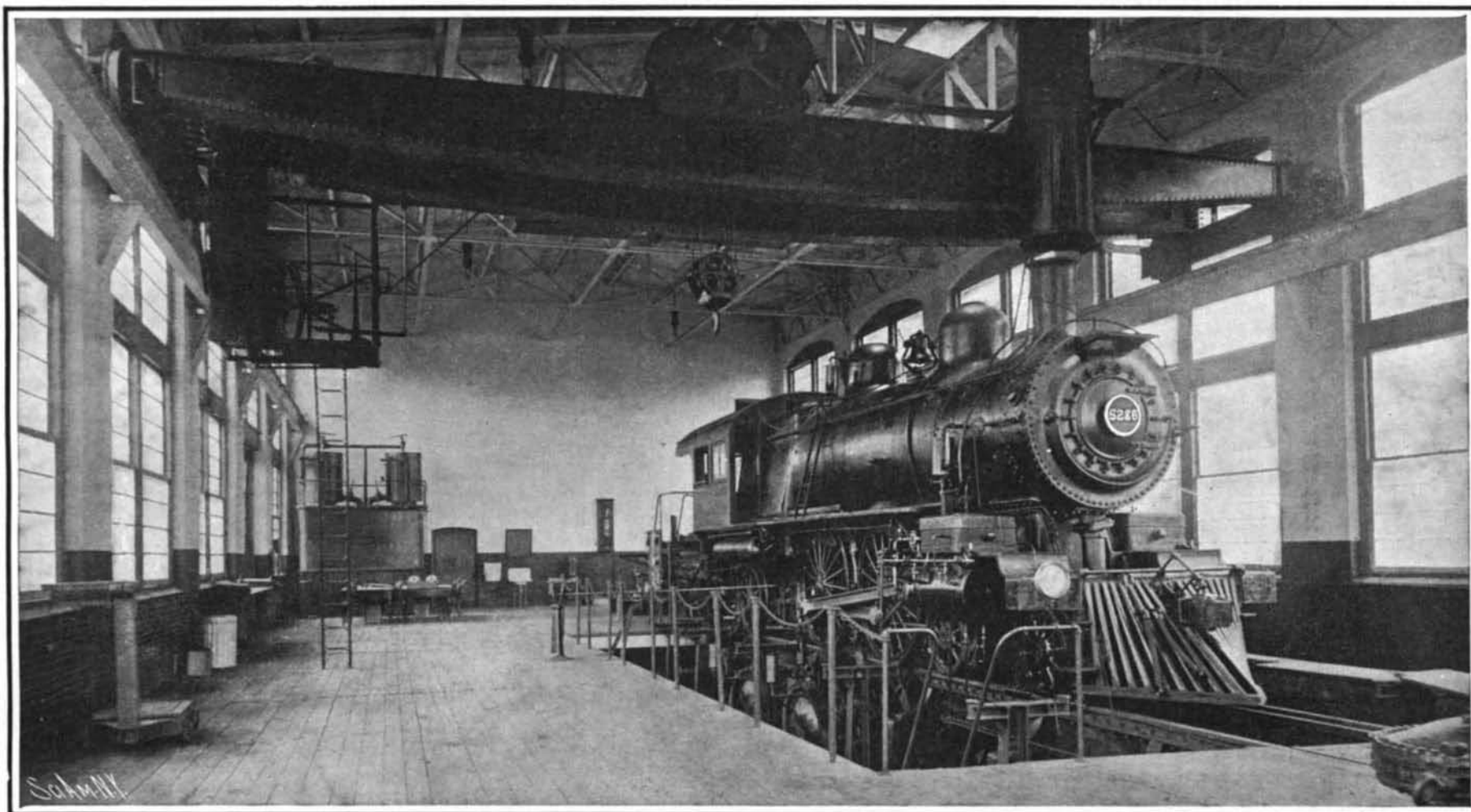
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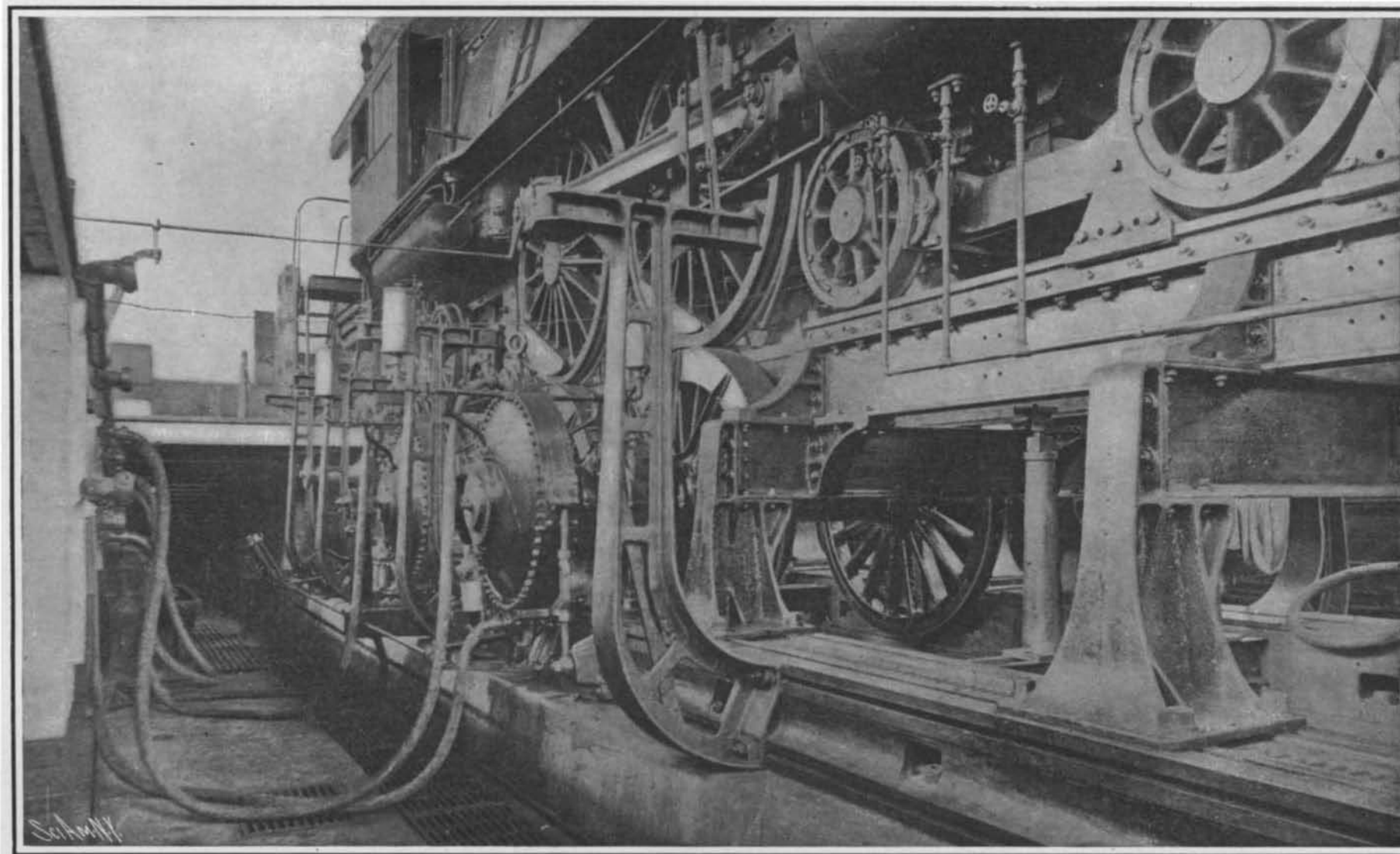
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Interior of Main Laboratory of the Locomotive Testing Plant.



Pit Floor With Foundation Apparatus.
THE TESTING OF A LOCOMOTIVE.—[See page 126.]