Testing a unit in a motor testing laboratory.

Method of testing an engine in the laboratory.

Factory Methods of Testing Automobile Motors

How the Testing Stand or Block is Used

By Stanley Petman, M.E.

FEW in these days of automobiles know of the elaborate manner in which the engines that drive the cars are tested and tried before the purchaser ever hears of them. No engine is considered perfect until it has been run for hours and hours under the watchful eye of an expert mechanic, and none is turned out of the testing rooms until it has passed the final inspector's rigid examination, has had its horse-power "pulled" and has been duly tagged and recorded.

Naturally, lengthy testing of the kind is expensive, and there must be a very excellent reason for doing it. When an engine comes from the assembling rooms it is "rough." Though its mechanical features may be well-nigh perfect, the engine nevertheless is "rough;" it requires "smoothing down," and those last final touches which transform it into a perfectly running machine.

Despite the advances in the perfection of automatic machinery, jigs and templates, no two engines are exactly alike. There are bound to be slight differences of adjustment; some bearings will be smoother than others; some pistons and cylinders "fit" a little better than others. One engine obviously is the best of the lot, and it is in order to bring all the others up to that high standard, or to exceed it if possible, that careful and elaborate testing is necessary.

In factories where many cars are turned out every year, motors are tested on blocks arranged in rows. Generally the rows are scarcely more than a dozen feet apart; for space is always at a premium, where the reduction of overhead expense means much in the ultimate cost of the finished vehicle. The individual test blocks, too, are placed closely together, with just enough room between them for the workmen to attend to their duties.

In all such large factories, efficiency engineering principles play an important part. Ignition apparatus, for instance, and gasoline and water connections, are fastened directly to the testing block. It is necessary merely to drop the motor into place (a small electric crane is used for the purpose), and in a few seconds the "gas" and water leads and the ignition wires are attached. What are known in plumber's parlance as "quick-detachable" connections are generally used for the water and exhaust pipes.

All the motors have to be "cranked," of course. In order to perform this necessary operation some factory superintendents have hit upon a novel scheme, which is the same in all cases except for slight modifications. As the motor testing blocks are placed in rows, with the motors all facing the same way, it is simple enough to lay tracks at the ends of the blocks and to mount a small car upon

A new method of ascertaining power delivered at the rear wheels of a car.

Motor test blocks in a western automobile works.

One of seventeen units in a motor testing department.

the tracks. On the car there may be an electric motor supplied either with suitable gearing and a short countershaft with a clutch device to grip the end of the motor crankshaft, or simply with a large pulley and a flat leather belt. Current for the electric motor is collected from overhead wires and two short trolley poles. Thus it is a simple matter to connect the electric motor with the gasoline engine in order to start it. The system has this advantage: The gasoline engine can be "turned over" for an indefinite time while carburetor or ignition adjustments are made. Inasmuch as few new motors are more easily cranked than started, it must be conceded that such a system is extremely valuable.

Once the motors are on the blocks and running, it is the practice to permit them to run without load for periods which vary in length from four or five hours, where the factory output is large, and to 12 or 15 hours where the factory output is smaller and greater time can be devoted to the "running in" process. Sometimes motors are driven for several hours by a belt placed over their flywheels before they are placed on the blocks to be run under their own power.

When motors are "run in" under their own power "light," they are afterward placed on other blocks and a horse-power test taken by any one of several methods. In other cases, where the output is large and the time per motor for testing is more or less limited, it is the practice to couple them directly to electric dynamometers mounted at the back of the testing blocks. In this way the motors are run in under a load, while at the same time it is a comparatively easy matter to ascertain the horse-power they are developing at any moment merely by reference to a central switchboard to which all the dynamometers are connected. When such is the case, it is easy to obtain horse-power readings with the minimum of computation. Each test block is equipped with a revolution counter, and the figuring of the horse-power resolves itself into a simple problem in arithmetic, the voltage and amperage of the generators being known and 746 watts being recognized as the equivalent of one horse-power.

If the motors are not tested for horse-power directly on the first testing blocks, but are afterward placed on other blocks in order that the horse-power readings may be taken at different speeds, either an electric dynamometer or a fan dynamometer or a water brake or a Prony brake may be used for the purpose. Computations with either the water brake or the Prony brake are slightly more complicated than those necessary with an electric dynamometer, for which reason the latter is preferred. With a fan dynamometer, however, direct readings may

be taken from a dial, which method is the simplest of all—simplest because it is known that with the fan vanes set at certain distances from the center of the carrying arms a certain amount of power will be required to drive the fan at certain speeds. Given fan speeds corresponding with given horse-powers, it is merely necessary to convert the fan speed into horse-power directly by means of a table.

For the taking of even more careful tests, there re-

the indicator with other diagrams known to be theoretically or practically correct. Similarly, incomplete combustion, which is a fault of carburetion or improper scavenging, and also incorrect timing or faulty ignition can be detected readily by means of an indicator diagram. The proper use of such apparatus, particularly on internal combustion motors, requires the greatest of care and considerable experience. Errors are so likely to creep into the results obtained, even where the oper-

taken in conjunction with the horse-power tests.

In a number of factories, testing on the blocks, supplemented by horse-power tests, is considered insufficient, and motors are given a further test after they have been placed in the chassis. There are several ways in which this may be done. Either the motor may be fastened down on its bed in the chassis and coupled up to an electric dynamometer, through the intermediary of the propeller shaft and the transmission gears,

Factory methods of testing automobile motors. Setting an engine on a stand in the testing room.

mains the indicator, an instrument which gives a graphic indication of the conditions within the cylinders during the operation of the engine. With such a device it is possible to ascertain just when the motor is operating at its best, when it could be made to operate at greater efficiency, just what the trouble is and how best to remedy any or all faults. Thus, for instance, sluggish opening or closing of the valves will be made apparent by comparing the diagram taken by

ator is thoroughly qualified to make the tests, that it is rarely used except to "set" a new motor of a new type. Older motors, of course, can be set from the other, reference being made to the timing of the valves and ignition. The indicator also is very valuable in ascertaining the performance of motors which are still in the experimental stage, such as motors in which the stroke to bore ratio is greater than any that has been attempted before. Generally, indicator diagrams are

or, with the rear wheels jacked up, belts may be placed around them leading to fan dynamometers. In this way not only is the motor tested, but all of the transmission elements are tried out at the same time. A test of this kind is nearly, though not quite, equivalent to a road test.

Still another method is to place the completed chassis, tired, on a platform constructed for the purpose, the rear wheels resting on rollers and the front wheels

resting in chocks shaped to fit them. The rollers upon which the rear wheels rest are geared to an electric dynamometer by means of a chain. Under this method, which provides a rigorous and thorough test for the whole of the transmission mechanism as well as the motor, the operator remains seated in the driver's seat of the car with the volt and ampere meters on a standard in front of him. Consequently he is enabled to tell at a glance exactly what setting of spark and throttle levers is productive of the best results and under what condition of carbureter adjustment the motor can be induced to generate its maximum power. The readings taken, of course, represent the actual horse-power delivered at the rear wheels, and as it is this figure which counts most, after all, it may be appreciated that the test is thorough. By it, transmission inefficiencies may be ferreted out, clutch troubles detected and remedied, the cooling and ignition systems given a careful test in the chassis, and, what is even more important, the lubrication of all moving parts except the bearings in the front wheels tested. Finally, brake efficiency can be tested by the very simple expedient of operating the dynamometer as an electric motor, drawing current for the purpose from the lighting mains.

In connection with the method of employing electric dynamometers for measuring horse-power, it is interesting to note that in several factories arrangements have been made to put the current generated to some useful purpose. In one large factory in the West, where production activities are centered in the manufacture of heavy farm tractors, practically all of the current used in running the machinery of the plant is obtained from the dynamometers driven by engines on test. Preparations now are being made to enlarge the testing sheds. One of the principal reasons for the expansion is to permit the use of all current drawn from machines on test. In this way, two birds are killed with one stone, so to speak. The motors are thoroughly tested, the current used is employed in reducing the running cost of the factory, and the net result of the lowered overhead charges is reflected in the lower production cost and the lower selling price of the vehicles.

But to get back to engine testing. All such shop testing of course is merely preliminary to the road test. Regardless of what a shop test may show, no man can tell how that machine is going to operate on the road, probably in the hands of an inexperienced driver. Consequently, they are ultimately mounted in test chassis and sent out over the roads in the hands of a corps of road testers, whose instructions are to abuse them. It is their duty to seek out the weak spots either in design or in construction and to report them to the factory superintendent. Naturally, these road testers are experienced men, perfectly able to cope with very nearly every kind of trouble that may arise short of actual breakage.

The Lexington Avenue Subway Four-track Tunnel Under the Harlem River

THE construction of the Lexington Avenue four-track subway calls for some important sub-aqueous tunneling below the Harlem River. At this crossing it was necessary to maintain a depth of water above the roof of the tunnel of thirty feet at mean high tide, and the tunnel will be constructed to clear this level and will be built with easy grades on each approach.

The method of construction will differ radically from that followed in building the various tunnels beneath the Hudson and the East rivers, where the work was advanced by the use of compressed air and the Great-head shield. At the Harlem crossing the structure will consist of four separate steel tubes, embedded in a

monolithic mass of concrete and heavily lined with concrete on the inside. When it is completed, its cross section will present the appearance shown in the accompanying drawing, and it will have a total depth of 24 feet 6 inches, and a total width of 78 feet.

The first operation will be to dredge a trench across the bed of the river, which will be 34 feet deep, that is to say, the bottom of the trench will be 34 feet below the original bed of the river, and the width of the trench will be 80 feet. The total length of the steel tubes when they are in place will be 1,080 feet. The tubes, four abreast, will be built in five sections, four of which will be 220 feet long and one, 200 feet. They will be constructed of $\frac{3}{8}$ -inch steel plates, the contiguous sides of the tubes being flattened in order to reduce the total width of the four as thus assembled. To preserve the tubes in their relative positions and keep them true to form, transverse diaphragms of $\frac{1}{4}$ -inch steel will be riveted to them at every 15½ feet of their length. Along each side of the structure, these diaphragms will be bolted to vertical side walls, formed of 4-inch by 12-inch planking, backed by 10-inch by 12-inch vertical timbers, one such timber opposite each

lowered away until each end rests on a grillage prepared at the bottom of the trench to receive it.

The top of the grillage platforms upon which the steel structure rests, is about two feet above the bottom of the trench; and the first operation before the buoyancy cylinders are detached is to fill in this space with concrete. The buoyancy cylinders are then completely filled with water and are released from the main structure. It is then necessary only to blow out the central compartment of these cylinders and they come to the surface by their own buoyancy.

The next operation is to fill with concrete the pockets formed by the diaphragms and the side walls. This is done by means of a big scow of the same general type as that shown on our front illustration, which represents the plan adopted in building a two-track tunnel of the same general character beneath the Detroit River. It should be stated here that the method of constructing these tunnels was devised by Olaf Hoff, C.E., who first applied his method in the successful construction of the Detroit River tunnel above referred to. The scow for use in concreting the Harlem River tunnel will be 25 feet in width by 110 feet in length.

At its center will be a two-story structure containing the concrete mixers; and in front of these, erected along the side of the scow, will be five elevator towers of the type shown on our front page engraving. The towers will be so placed that each one, when the scow is in position, will stand immediately over one of the spaces between the adjacent tubes, or between the outside tubes and the side walls above described. Within each tower will be a bucket for hoisting the concrete, and on the outside of each tower will be attached a large pipe which will lead down into the particular pocket which is being concreted up.

The concrete material, broken stone, sand and cement, will be brought to the scow in lighters, loaded into hoppers above the roof of the concrete mixing house, mixed, and then loaded into the buckets in the respective towers. When the buckets are raised to the proper level, opposite the funnel-shaped tops of the concreting tubes, they will be automatically tripped and will discharge their liquid contents into the tube. The bottom of each tube will descend somewhat below the surface of the liquid concrete that has already been deposited, and the concrete will be of such fluid consistency that it will readily flow and find

a fairly uniform level over the whole surface in each pocket. Means are provided for raising the tube as the level of the deposit in concrete rises, and the work goes on uninterruptedly until the whole mass has been completed flush with the top of the diaphragms.

One incidental advantage of this method of concreting is that the concrete sets under a heavy hydraulic pressure, which in the present case ranges from 22 pounds to the square inch at the bottom of the tube to 16 pounds at the top. This heavy pressure serves to thoroughly compact the concrete. We have seen a specimen of the concrete laid by this method in the Detroit River tunnel. It is a core cut from the hardened deposit and polished. It is remarkably compact, and the constituents are well distributed.

The laying and concreting of the cylinders will commence from the center and will be carried toward the ends. When the whole job is completed, the water will be pumped out from the tubes and they will be ready for their interior lining of concrete, which is 12 inches thick on the sides and 16 inches thick on the roof.

The total cost of the tunnel will be \$1,620,000, and the contract time for completion, about three years from the present date. The contractors, however, are confident that it will be finished several months before that time.

Cross-section of Harlem River tunnel, Lexington Avenue subway.

Sinking a length of tunnel tubes during construction of the Detroit River tunnel.

steel diaphragm. The wooden sides will be fastened to the structure by bolts which will pass through the 10-inch by 12-inch timbers and through angles riveted to the outer edges of the diaphragms.

Each four-tube section will be built on staging erected within one of the adjoining dock slips, the staging consisting of four longitudinal rows of piling finished off with longitudinal caps. When the steelwork of a section is completed, a series of scows, each measuring 14 feet by 80 feet, will be floated in between the piles, at low tide, and as the tide rises, the scows will have sufficient buoyancy to lift the tunnel sections clear of the staging. It should be mentioned that the ends of the tunnel tubes will be temporarily closed by wooden bulkheads, as shown in the illustrations. The section will then be towed out into the stream above the position in which it is to rest on the river bottom, the scows will be scuttled and withdrawn, and the structure will be left floating by its own buoyancy.

Before sinking a section, four buoyancy cylinders are strapped across the ends of the tunnel section, two at each end, and water is admitted, first to the tunnel tubes themselves and then to the buoyancy cylinders, until the latter are just awash, at the surface of the water. Two floating derricks will then take hold of the structure, one at each end, the remaining buoyancy will be further reduced, and the whole structure will be