needed is the educated man, who not only knows how to build a costly, ideal road, but one who can economically construct an eight foot country road—a man who knows both the theoretical and practical end of road construction. This is the style of graduate which the Rhode Island institution aims to turn out. . . . At the end of the course they will have graduated a man who can plan the highway, draw the contracts and who is able to run the machinery to build the road; a man who knows the business from the hoe handle to the tripod, from shoveling coal under the boiler of the steam roller to drawing the plans—a road engineer.

"There are a number of openings which a practical road builder may fill. He may become a road expert for the United States government. By passing the civil service examinations of the Road Division, Department of Agriculture, he will be put on the list of eligibles, and as soon as a vacancy occurs will receive an appointment from the government. Then the builders of road machinery have a constant call for men to set up their plants in the various towns and cities which are constantly acquiring such equipments. They have to send with the machinery men who know all about operating it. As a rule, the men they send out are shop hands, and beyond the rule-of-thumb experience with these identical machines, they know but little. The builders say there is a constant demand for road builders with these plants, and that they consider that this is a good field for young men.

"But the largest field for men educated as road builders will probably be found as highway superintendents among the various counties and towns. There are few first class men in this line and, with the spread of the good roads movement, the demand for such experts is growing."

A HYDRAULIC ENGINE.

By Mr. ARTHUR RIGG.

ALL users of hydraulic power are aware that its cost is greatly enhanced by the wasteful manner in which pressure water is applied. Indeed, the hydraulic engine has been in much the same condition as regards

its economical working as the steam engine was before expansion was introduced. Water pressure obtained artificially from steam power by pumping, and then distributed through many miles of high pressure mains, must necessarily be more costly than steam used direct. This would be the case were it applied in an economical manner, and its duty performance maintained at a proportion of say 80 per cent. Such, however, is very far from being the case, not that hydraulic engines working under their full load are in themselves extravagant motors, but because they are handicapped through having to use the full quantity that their cylinders contain, whether working at full power, at half power, or driving themselves alone.

The diameters of their cylinders, like their stroke and revolution, are constants; and such governing as exists simply means throttling the supply, that is, reducing the working head and wasting all such balance of power as cannot be employed in performing useful work.

Such exaggerated extravagance cannot be found in even the worst steam engine, with steam entering during an entire stroke—for steam, after passing a throttle valve, does retain some force, owing to incomplete expansion; but nothing of this kind favors an incompressible fluid such as water.

The cost of pumping water to a pressure of 700 lb. per square inch varies but little, while the charge by hydraulic supply companies varies from 1s. per 1,000 gallons to 2s. per 1,000 gallons for hydraulic motors, under a sliding scale of rates. Indeed, the cost of working such hydraulic engines as are now in the market very much restricts the use of this convenient and serviceable source of power.

One thousand gallons of water per hour, falling 1,600 feet, or having its equivalent pressure of 700 lb. per square inch, may be taken as giving 8 horse power gross; and this, at a duty of 75 per cent., gives 6 horse power net. Taking the cost of pressure water at 1s. per 1,000 gallons, the cost of 1 horse power per hour is 2d., a figure which agrees with that given by Mr. El-

lington in his paper on "Hydraulic Supply," read before the Institution of Civil Engineers in 1888, and he continues, "In no case would it be profitable in London to supply power at less than 2d. per horse power hour. . . . At current rates . . . the cost of working is too high for continuous driving, and the hydraulic engine is itself not a sufficiently economical machine to induce a large use. What is required is a good durable engine, with an automatic regulation of the consumption of power water, at a constant speed according to the varying demands on the engine." If, therefore, 20 horse power be obtained at this rate by a hydraulic engine working always at full power for 1,800 hours, the cost of pressure water becomes £300. But as very few hydraulic engines are required to give out their full power continuously, although always consuming the full value of an equivalent water expenditure, this condition of things further exaggerates the cost of power obtained through water at high pressure artificially produced.

Assuming an engine that is required to give out 20 horse power at starting its load, but working, as many do, for the remainder of their time at an average of 10 horse power. This at once doubles the rated cost of 10 horse power by making it equal to the expenditure for 20 horse power; or taking a continuous value for 1,800 hours and 20 horse power at £300—the cost of 10 horse power, comes out the same, £300, which would be reduced to £150 in a properly governed engine.

It can be no wonder, then, that ever since 1848—fifty years ago—when Lord Armstrong first introduced his hydraulic rotative engine, attempts innumerable have been made to invent one that shall alter its piston displacement in proportion to variations in the demand for power.

In the whole range of commercial enterprise connected with engineering it would be hard to find anything to beat the record for extravagance now held by un-

governed hydraulic engines. This is not due so much to any defect in the principles of their construction as to the want of proper governing, aggravated by the way in which such engines are expected to run without any kind of lubrication for their internal parts. Nobody ever expects a steam engine to work well under such adverse conditions, and the engine driver who neglected to use his sight feed lubricators would soon be dismissed his post. Yet the same kind of neglect attracts no attention with hydraulic engines now in general use. Such engines when working at full power, and capable of performing a duty of say 80 per cent., are worked under conditions so barbarous that 60 per cent. becomes a good average, and the engines themselves receive no more attention than sailors bestow upon steam capstans. Considering, too, that such engines frequently draw their supply from unfiltered river water, or from the impure contents of a dock, it is almost surprising that so good a duty as 60 per cent. can be obtained under any circumstances. The proper system for working any hydraulic installation is to return all exhaust water to a tank, where it can be warmed if necessary, and supplied with a lubricant; also enough fresh water to compensate for leakages and evaporation. This can readily be arranged for all new systems, but it is not so easy with those already at work, and filtration of the water remains about all that can be done under most circumstances.

Experiments made to ascertain the haulage necessary to start a load, and then to keep such load moving, seem to show that for such examples as capstans, cranes, drawbridges, grain elevators, etc., about double the strain is needed to start such loads moving as afterward suffices to keep them going. Judging from this rough rule, it becomes necessary to provide an engine twice as powerful as would otherwise be necessary in order that there be no failure in starting. This proportion would mean no loss in the case of an engine governed so as to reduce the stroke by one-half after the load

begins to move; but it leads to incomparable extravagance with such engines as are now in general use, not governed at all. This extravagance means a very great deal in connection with capital expenditure upon boilers, engines, and accumulators, for all of which covered space has to be found and interest earned. As the ordinary type of hydraulic crane possesses the same kind of defect that accompanies the rotative engines, and as the first opening of lock gates absorbs more power than their future movement, it may very well be taken that half the power now supplied is absolutely thrown away. This, in a large dock, means the loss of many thousands a year from preventable causes, and means a pitch of wasteful extravagance of which makers of the very cheapest type of steam engines would be thoroughly ashamed.

In the good old times, when income was plentiful, matters of economy received only scant attention, but such neglect can now no longer be tolerated in these days of competition. No accountant is needed to prove that a saving of 50 per cent. annual expenditure would justify the entire renewal of any plant, just as they would certainly do in America for considerably less gain. The adoption of compound pumping engines has cheapened the cost of pressure water, to the advantage of shareholders in any hydraulic supply company, but what concerns the consumer most is the economical production of power from water delivered to him.

It will be interesting at this stage to trace the progress of several inventions that have had for their object the economical regulation of power by hydraulic motors. The earliest idea seems to have been that patented by Messrs. Knowlton and Edwards in 1858. Three cylinders, set at 120° apart, were all arranged to drive the same crank, which was on a stroke that could be altered as to radius by two hydraulic rams. These were moved by pressure conveyed through pipes in the

FIG. 1.—RIGG'S HYDRAULIC CAPSTAN.

middle of the engine shaft, and thus the stroke could be regulated while the engine was running. The same idea has occurred to other inventors, but the system does not seem to have made any headway.

Another type of variable power engine was that patented by Mr. Percy S. B. Westmacott, a member of the Elswick firm, in 1863. In this, a somewhat complex valve arrangement was adopted for using a selection from three rams and pistons. If, for example, an engine have rams $2\frac{1}{4}$ inches in diameter and pistons 4 inches in diameter, then by admitting pressure under the 4-inch pistons, while the opposing annulus is open to the atmosphere, the engine works to its full power. Again, if a constant pressure be upon the annulus, and the 4-inch pistons are working as before, then only half power is given out.

In 1874 Mr. Andrew Brown, of Edinburgh, described his three-cylinder hydraulic engine, which was regulated in a somewhat intermittent manner, by moving the crank pin into holes of different radii; but this arrangement was quite unsuitable for automatic governing.

Mr. Hoppé, of Berlin, governs his hydraulic engines on a different system, whereby low-pressure water in varying quantity, as determined by a governor, is admitted to the cylinder, and all remaining space becomes filled with water of the higher working pressure.

In all these cases, except the last, regulation is intended to be done by hand, and therefore it is unreliable, or practically useless.

One of the earliest engines possessing an automatic governor to regulate the quantity of water used in relation to load was that of the late Mr. Hastie, of Greenock. It was specially designed for hoists—to run light loads up quickly, with a shortened stroke, and to move heavier loads more slowly. His crank pin, set in a slide, could be moved radially by cams attached to the winding drum, which turned round in relation to the engine shaft as the resistance varied. The drum

was held forward by springs, like those of a dynamometer pulley, and it was arranged for the crank pin to move in its slide and give an increased stroke whenever resistance became greater. This engine, however, possessed no timing arrangement, and can hardly be considered complete as a governed engine. The same remark applies to all the other systems described, for none of them comes up to the ideal of perfect governing; that is, maintaining an approximately uniform number of revolutions, however much the load may change. Of all methods for regulating the quantity of water expended, none is simpler than altering the ra-

levers, not shown in the figure, having also its valves carried upon the moving head, like the valves of a steering gear are carried. This simple arrangement gets rid of any tendency toward hunting; because as the governor balls extend or contract so does the stroke diminish or increase, just as if they caused the movement directly. The main driving engine consists of three cylinders, revolving round a stud, which is carried by the relay, and of three rams which are carried by three crank pins projecting from the face of the fly wheel, and always, therefore, turning round upon its center; which is that of the main shaft. As

extend, and act upon one of the two valves of the relay, which at once responds to this direction, and shortens the stroke, perhaps to about one-eighth of the full amount, thus saving about 85 per cent. The bollard, moreover, can never "run away," and directly that it feels the rope the governor balls close together, and subsequently keep altering the stroke all the time that haulage proceeds, using just so much pressure water as may be required for the present load, and saving, on an average, at least one-half of the pressure water demanded for similar work by any ungoverned hydraulic engine. The handle alongside the bollard is only intended for occasional use, reversing the engine, if, for example, a new rope develops a kink, and cannot be cleared without a reversal. Some engineers prefer to avoid the use of gearing, and in such case there is no difficulty whatever in the application of larger sized engines, working direct upon the main shaft. One of these variable stroke hydraulic engines has been at work for seven years working wagons up inclines, another nine years driving chain pumps, etc., without requiring any renewals, except packing rings, and although to anyone unfamiliar with the arrangement it may appear complex by comparison with an ordinary hydraulic engine, yet nobody can expect to effect a saving of 50 per cent. without some extra machinery to do it with, and it must be recollected that every detail of this mechanism serves a very definite purpose.

As with all other machines, it is only necessary to be sure that each part has been properly proportioned to guarantee that the whole shall fulfill the purposes of the inventor, who designed all these machines, and of Messrs. Hughes & Lancaster, who made them.—We are indebted to The London Engineer for the cuts and particulars.

THE NEW PALACES OF THE CHAMPS ELYSEES.

THE construction of two new palaces designed to replace the Palace of Industry and the Pavilion of the City of Paris, at the Champs Elysees, is going to give rise to a curious experiment.

As well known, the Great Palace did not rise all of a piece from the competition of 1896, the various leading projects having, after a manner, been blended. The final structure will therefore be due to the collaboration of several reputable architects, each of whom, moreover, will have had an opportunity of exercising his own peculiar talent in that part of the edifice assigned to him.

It is none the less true that, while the Great Palace will not be the Louvet Palace, nor the Deglane Palace, nor the Thomas Palace, the Small Palace will be called the Girault. In fact, M. Girault's project, which obtained the first prize, is in course of execution without any appreciable change.

To the right of Avenue Nicolas II we shall therefore have a great composite palace, the result of a skillful collaboration, and, to the left, a small palace conceived and constructed by one and the same artist. Experience will tell which of the two systems is the better.

The Small Palace covers a quadrilateral in the form of a regular trapezium, the longest base being parallel with the new avenue. A plaster model which has just been finished will show how well M. Girault has succeeded in turning the configuration of the ground to account. At the center of the principal façade there will be a large bay of 15 meters opening, which will be reached through twenty steps and which will be surmounted by a cupola. To the right and left there will be two series of Ionic columns, and at each extremity there will be a wing. The central cupola will cover a vast vestibule of slightly elliptical form, flanked by two large exhibition halls lighted by windows that occupy the spaces between the columns.

The two lateral façades will be connected by a sharp angle with the main façade, which will make an obtuse angle with the posterior one. The three secondary parts of the building will comprise a series of galleries lighted by windows looking out upon the groups of trees of the Champs Elysees. In the center of the structure there will be laid out a garden bordered with a semicircular peristyle, the level of which will be raised four meters above the mean level of the external earth. Between the peristyle and the main buildings upon three sides of the edifice internal galleries that

FIG. 2.—RIGG'S HYDRAULIC ENGINE.

dus of one crank, around which are fixed any convenient number of cylinders. Varying the radius of an ordinary crank while the engine is running, although it can be done by means of hydraulic rams, according to the system of Messrs. Knowlden and Edwards, is so uncertain and cumbersome as to be practically unworkable with engines of the usual type.

There is, however, an inversion of the ordinary type of engine, where the crank does not turn round, and the cylinders revolve around it. Thus the crank radius can be altered as desired while the engine is running, and up to the present it is only engines of this type which can be governed to use pressure water in due proportion to work done, and to make approximately the same number of revolutions, however much the load may change. Two examples of this class of engine, the invention of the writer, are shown by illustrations, Figs. 1 and 2. Fig. 2 shows the front elevation, with cover removed, of an engine driving a large grain elevator, which requires considerably more power to start than to keep going. This elevator can be driven by its original motor, an Armstrong engine of the usual three-cylinder type, or by Rigg's engine, so the performances of both can easily be compared. At starting either engine provides about 20 horse power, and the older type uses pressure water up to this value all the time that it is running.

Very different, however, is the result obtained by the newer type, for, as speed increases, the governor begins to act, and reduces the stroke to such an extent that while raising oats 8 horse power only is required, thus effecting a saving of 60 per cent. in the amount of pres-

therefore the relay engine answers all movements of the governor ball, so does the stud, which carries the cylinders, approach or recede from the main center, and so this distance, which corresponds with the crank of an ordinary engine, alters accordingly. An oil pump is supplied with all these engines to lubricate the stud around which the cylinders revolve, and there are many minor details which go to perfect this construction, and to enable it to endure the hardships of ordinary work.

In reference to the amount of power required to start a load, and thenceforth to keep it moving, a very interesting experiment was made with a drawbridge, which is now moved over and back from a dock entrance 72 feet wide by one of these engines similar to Fig. 1. But it has no governor, and is arranged to reverse, varying the power in either direction, according to the control of the attendant. It was found that a pull upon the steel rope of three tons was required to start this bridge, but that a pull of from 30 to 35 hundredweight sufficed to keep it moving; so this case would indicate that an engine with variable stroke would be in a position to economize half the water required for any hydraulic engine with a fixed stroke doing this work. It is not easy to ascertain such data as this very often, but a proportion of 50 per cent. seems generally applicable to capstans and hydraulic power generally, wherever an automatically governed engine is used, instead of one that consumes the full value of water always.

Figs. 1 and 3 illustrate by a plan and photograph one of Rigg's governed hydraulic engines driving a

PRINCIPAL FAÇADE OF THE SMALL PALACE OF FINE ARTS.

POSTERIOR FAÇADE OF THE SAME PALACE.

M. GIRAULT, ARCHITECT.

sure water that would be required to drive any ungoverned engine. In the event of an insufficient feed to the elevator, then the governor balls extend and shorten the stroke, so reducing the expenditure of pressure water to 4 horse power, while the attenuated exhaust water emphasizes the value of the mechanical contrivances that can and do effect a clear saving of 60 per cent. to 80 per cent. of the water power.

This hydraulic motor actually comprises two separate and distinct engines; one of these drives the load, while the other engine serves as a "relay," having its valves worked by the governor through rods and

three-ton capstan recently erected in London. The bollard, of cast steel, has been designed after examining many and noting their defects and good features. Gearing permits the use of an engine of comparatively small size, and allows the main shaft to take its bearing in a strong bedplate, while the engine becomes open, and most easily accessible. The governor is carried lower down upon the crank shaft, and it acts through levers and rods upon the relay engine valves, which are clearly seen in the plan. Whenever water pressure is admitted to the engine—which stands at full stroke—movement increases until the governor balls

receive their light from above will line the external ones. The foundation, despite the difficulty met with in the search for good ground on the side of the Seine, was finished in less than three months, and the first courses have already appeared above ground. The masonry should be finished before the end of October, 1898. Even if the heavy work is finished within this time, it is certain that the sculpture of the Girault Palace will not, any more than will that of its great neighbor, be completed for 1900. Mouldings in staff will provisionally supply this want.

Let us recall the fact that the Small Palace will be