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CIVIL ENGINEERING.

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On the Brooklyn Pumping Engine. By SAMUEL McELROY, C. E.

This engine having been recently tested under its contract, and accepted on the part of the City of Brooklyn, a description of its dimensions and operation will be interesting to the profession.

It is constructed as the first of four eventually to be required in the engine-house now erected, which has an engine-room 84 ft. front by 77 ft. depth, with two boiler-room wings, 66½ ft. front by 45 ft. depth, furnishing ample accommodation to four engines with their appurtenances. The present contract for the works requires two engines.

The *Boilers* now built are three in number, of the drop-return flue variety, cylindrical in form, 8 ft. in diameter, and 30 ft. long. The upper flues are 18 ins. in diameter, the return flues 9 ins. The stop valves, safety valves, feed cocks, and flue dampers are complete for each boiler, so that either may be shut off at any time. They are fed by an independent engine, connected with the hot-well, the pump-well, and the force main by independent pipes, so as to use either for supply. Advantage is taken of the heat in the lower boiler return by a pipe coil, to increase the temperature of the feed-water. For evaporation measurements a tank is provided in connexion with the "donkey."

The *Chimney* is 100 ft. high, built with an annular flue column, 4 ft. in internal diameter.

The *Engine* is double-acting, with a cylinder of 10 ft. stroke and 90 ins. bore, working two lifting pumps of 36 ins. bore and same stroke. The entire piston travel provided for is 10 ft. $3\frac{1}{2}$ ins. The cylinder rests upon the double bed-plate which supports the entire length of the engine, and is directly over the pump-well.

The *Pump-well* is a massive granite structure 37 ft. high, with an inside area of 60 by 10 ft.; the side walls varying from $6\frac{1}{2}$ to 5 ft. thick, the base being a heavy flat-arch, 30 ins. deep, resting on a plank floor, over a solid water gravel bed. Its depth of water way is 7 ft. The cylinder base is above the water-level of the boilers, and it is enclosed as to the cylinder body in a steam jacket case, very carefully felted, and covered with black-walnut lagging. The piston is 18 ins. deep at the centre, and $8\frac{1}{2}$ at the edge, the rods being $8\frac{1}{4}$ ins. diameter for the cylinder and pumps. The steam-pipes and side pipes are 20 ins. diameter. The valves are balanced puppets, 14 and $14\frac{1}{2}$, and 16 and $16\frac{1}{2}$ ins. diameter, and are filled out on the stems so as to reduce the waste of steam.

The cylinder *Valve-gear* is similar to that of a steamboat engine, as to the rock-shaft, lifting toes, and adjustable cut-off, but is not worked by an eccentric. It differs from the Cornish valve-gear, as to the valve-handles, cams, and plug-rods, while it retains the principle of the cataract in an independent water cylinder worked by the force-main, in connexion with a sliding frame attached to the engine beam. The frame operates the valves of the water cylinder, which opens the steam and exhaust valves of the main cylinder, in a quiet and readily adjustable manner, which is a great improvement over the Cornish valve-gear.

The *Beam* is 30 ft. long between end centres, 86 ins. deep at main centre, with a web $5\frac{3}{4}$ ins. thick, and flanches 16 ins. wide. The main journals are 13 ins. diameter by 24 ins. bearing, resting on massive pillow blocks, which are sustained by heavy ornamental cast iron frames. Parallel motions are used for the piston and pump-rod guides at either end.

The *Air-pump* has 36 ins. bore and 60 ins. stroke. It is double-acting, the condenser shower plates being arranged accordingly. The condenser is one-third the size of the cylinder, and takes its injection from the pump-well, or from the force-tube.

The *Pumps* connect with each end of the beam, the lower being placed under the cylinder, and on the floor of the well, and the upper in a chamber of masonry, which also supports the air-chamber. The pump buckets have double beat covers playing on the rods, with wood seats, alternately closing and opening as they work their water charge through each other, and move alternately towards and from each other, having a common connecting pipe of 3 ft. diameter. This feature is one of the leading peculiarities of this engine. Either the lower or upper bucket is constantly sustaining the water column, and keeping up its motion in the same direction, avoiding all losses of momentum and the abrupt change of centres, peculiar to other pumps. To obviate an objection which suggested itself to us at the outset, by the

friction *through* the bucket valves, in sucking by the upper pump or lifting by the lower, annular barrels are placed around each working barrel, 54 ins. in diameter, also provided with double beat covers, giving this additional area of supply and discharge. The small percentage of pumping friction in the engine is, to a great extent, attributable to this arrangement.

The *Air Chamber* connected with the upper pump delivery, is of cast iron, 6.5 ft. in diameter and 25 ft. high. An auxiliary pump is used for its supply, attached to the air pump-rod. A diaphragm plate is fitted in this chamber with valves which can be arranged to throttle the return pressure of the air, and with which some interesting experiments have been made, which demonstrate very forcibly the value of large air chambers in preference to stand-pipes or any similar appendances.

The *Force Tube* connecting the engine with the reservoir, is of cast iron, 3 ft. in diameter, and 3450 ft. long, with but one curve of 800 ft. radius. It has an overfall discharge into the influx chamber. One check-valve is used on it, about midway in its length.

Two *Counterweight Chests* are used: one attached to the upper pump-rod, below the outer end centre, and the other to the lower pump-rod, below the cylinder. A vibrating counterweight is also attached to the lower chest, with a countershaft, of such a form as to load the steam piston during half of its stroke, and lighten it the other half. These weights are of great importance to the smooth and economical working of the engine. Their total amount is 46 tons.

In the ornamental patterns of the castings, the finish of the bright work, the balcony frame, and other parts, and in all the details of construction, the builders have spared no pains or expense to make an engine of great durability and imposing appearance. Placed in a large room of first-class finish, closely connected with, and yet carefully separated from the boiler room and coal shed, the whole arrangement is successfully adapted to convenient and efficient work.

From January 12th to 14th, the trials were made under which the engine was accepted from the principal and sub-contractors by the City. The contracts require that for the test of *duty*, the engine should be capable of lifting 600,000 foot-pounds of water with one pound of coal, allowance being made to the engine for the friction of the pumps and force tube, during a trial of not less than 24 hours, with a delivery of not less than 10,000,000 gallons (N. Y.) into the reservoir. For the test of *capacity* the engine should lift not less than 10,000,000 gallons (N. Y.) into the reservoir in 16 hours. The duty test was made during 26 hours 3 minutes run, and subsequently the capacity test during 16 hours run, after the engine was "hooked on" at full speed. From the following synopsis of the notes it will be observed that the duty trial nearly equaled the capacity requirement of the contract.

ENGINE TRIAL OF JANUARY 12TH TO 14TH, 1860.

DUTY TEST.

Jan. 12. 10 35' A. M. Engine stopped. Fires hauled. Counter 560,647.
 " 10 40' " Steam blown off. Furnaces wooded with 1180 lbs.
 " 10 45' " Started fires.

Jan. 12. 11 6' A. M. Started engine. Steam 15 lbs.

Jan. 13. 1 9' P. M. Engine stopped. Counter 575,612.

Hauled fires. Estimated value of grate contents at 856 pounds coal.

Running Time, 26h 3' = 1563'.

Double Strokes, 14,965; average 9.57 per min.

Quantity Pumped, 2,000,000 cub. ft. measured in reservoir.

Actual Water Lift, 160 ft.

Equivalent " 170 ft. (includes pumping friction.)

Fuel Account, 1180 lbs. wood = 524 lbs. coal. Total fuel, 34,773 lbs.

Duty, 2,000,000 cub. ft. $\times$ 62.5 lbs. $\times$ 170' lift $\div$ 34,773 lbs. = 611.114 pounds raised one foot with one pound of coal.

Delivery of Pumps, 14,418,641 galls. (N. Y.) per 24 hours.

Engine Friction, 7.4 per cent. between cylinder and pumps.

Loss of Action, 1.69 per cent. in pumps.

CAPACITY TEST.

Jan. 13. 7 P. M. Commencement of test.

" 14. 11 A. M. End "

Running Time, 16 hours = 960 minutes.

Double Strokes, 9708; average 10.11 per minute.

Quantity Pumped, 1,325,800 cub. ft. in reservoir.

10,357,812 galls. per 16 hours.

15,536,718 " 24 "

The notes taken for the test of duty were made in the manner described at length in the paper on this subject in the April number of the *Journal of the Franklin Institute* for 1858, and furnish in my opinion the only safe and satisfactory means, in large experiments, of determining the actual quantity of coal used in producing a known result. The engine is taken at work, with the boilers and other parts in their ordinary working condition; it is then stopped, steam is blown off, new fires are lit, all the fuel used is charged to the experiment, and at its end credit is given for the fuel which remains among the contents of the grates and ash-pits, after the fires are hauled and cooled down. It is only in this item of credit that any range whatever is left to the judgment of experts, and a very simple process limits this range to a small chance of error. In the present case the fuel account is thus recorded:

Pine wood, 1180 lbs. =	.	524 lbs. coal.	
Total coal charged,	.	35,105	
		<hr/>	35,629 lbs.
Grate contents after hauling:—			
Ashes,	.	347 lbs.	
Refuse,	.	856 "	
Clinker,	.	375 "	
		<hr/>	1578 lbs.
Coal,	.	.	856 lbs.
		<hr/>	34,773 lbs.
		Total fuel used,	

Notes taken in repeated experiments of this kind, make it a very simple matter to show the impropriety of the usual method of taking the boiler fires in a certain condition, and *trying* to leave them in the same condition, but want of space will not permit it here.

The quantity pumped in all the experiments made with this engine, and in others tested for our information, has been carefully measured in the reservoir, and with gauges of a suitable kind this can be done

very readily and very accurately, even in a water basin of the large surface of the Ridgewood Western Division of about 551,000 sq. ft. The results on the duty trial were as follows:—

Measurement of water prism,	.	.	1,943,810	cub. ft.
“ leakage at gates,	.	.	54,262	“
Estimate of absorption,	.	.	1,928	“
Total,	.	.	2,000,000	cub. ft.

The actual delivery of the pumps per double stroke was 1044·1 gallons. During the duty test, the average travel was determined from repeated observations at 9·875 ft., for which the theoretical discharge is 1062 gallons. The pumps, therefore, worked within 1·69 per cent. of their actual capacity, which shows a remarkably small loss of action. We have found it 6·56, 8, 14·5, and 16·3 per cent. in other engines, and in some cases it has ranged to 30 per cent. The “Leeghwater” engine, which ranks next in power, loses 10 per cent.

The actual water lift from the average level of the pump-well to the force tube discharge was 160 feet. The equivalent lift, as determined by the pump-cards, was 170 feet, showing the pumping friction of the pump and force tube to be 6·25 per cent. In trials of other engines, we find one pumping 3,287,860 gallons per day, with 7·25 per cent. friction; one pumping 1,771,396 gallons, with 17 per cent.; and another pumping 915,510 gallons per day, with 15 per cent. pumping friction; and these cases might be largely multiplied to compare with this engine delivering 14,418,641 gallons in the same time.

Comparing the average cylinder pressure, by the indicator cards taken during the duty test, with the pump-cards, the average pressure on 6375 sq. ins. being 12 lbs., and on 959·31 sq. ins. 73·91 lbs., the actual friction of the engine between the steam and pump pistons is 7·4 per cent. of the steam pressure. This result is remarkable, even when compared with first-class Cornish engines, and is entirely unapproachable by any crank movement in use.

The largest pumping engine in the world is the “Leeghwater” in the Harlaem Meer, and until the completion of the Brooklyn engine it was the most powerful. It has an annular cylinder of 12 and 7 ft. diameter, working 11 pumps of 63 ins. diameter, with 10 ft. stroke; the water lift being 13 ft. Its working speed varies from 5 to 7 strokes per minute, and its capacity of discharge per stroke is 2097 cub. ft. Its duty in foot-pounds per minute at 7 strokes is 11,926,642. The Brooklyn engine at 10 strokes per minute, with the actual discharge of its capacity test, performs a duty of 14,512,900 ft. lbs., and is then 21·6 per cent. more powerful. At 9·5 strokes per minute it has 15·6 per cent. excess of ordinary working power over its larger rival.

In connexion with its superior advantages as to *loss of action* in the pumps, *light pumping friction*, *light engine friction*, and *unequaled power*, the *smoothness of action* with which its work is done is remarkable. Perhaps the best indication of this quality is given in the readings of the pressure-gauge attached to the upper pump-head, which

have ranged for days from 55 to 58 and 59 lbs. pressure. There is no concussion in the valves, although so enormously large, and working at so great a speed under their head, and the quietness with which the cylinder valve motion performs its work, leaves nothing to be desired there as an improvement. In all the qualities named, this engine has fully realized our most sanguine expectations.

This engine was brought to my notice by Mr. Wm. Wright, Superintendent of the "Woodruff and Beach Iron Works," of Hartford, at a time when it was pre-determined by the Board of Water Commissioners, that the Cornish engines adopted by me for the original contract of the Brooklyn works should not be built, and it was necessary to secure if possible the next best style of engine. My observation and study had given me a strong favoritism for the single-acting engine, and in examining the various patterns of engines proposed for our works, the leading principles of that engine were taken as the basis of analysis. These may properly be reduced to two points, viz: the direct and simple character of the motion of the engine, with its durability and lightness of friction; and the use of a large mass of metal in motion, admitting high initial steam pressure and a high rate of expansion. There are minor advantages of the Cornish system, as to steam jackets, careful felting and covering, economy of steam in the passages, &c., which may be generally applied to any other style.

Although the plan of Mr. Wright was in a crude state, it was evident on inspection, that it contained the germ of a valuable engine, with all the leading peculiarities of the Cornish engine, obviating some of its disadvantages, and having obtained Woodruff and Beach's consent to alter the pump-valves from "butterfly" to "double beat," to put counterweight chests on the beam, to increase the size of the air-chamber, and to modify points of less consequence, I advised the adoption of the plan in April, 1857. Two other plans were, however, adopted successively; but in February, 1858, the engine then under construction, which was a fly-wheel engine, working its pumps by spiral cams, was abandoned for that now built.

The question which then presented itself to my mind, and which continued to present itself before the final completion of the engine, was its possible advantage over the Cornish engine, and my recommendation was not made without a careful study of engines in use, and the principles of motion involved.

The Cornish engine is single-acting, and with the exception of the suction lift of its plunger no pumping is done by the steam piston, its main force being expended in raising the counterweighted plunger. In one important sense, therefore, the cylinder is independent of the action of the pumping main.

It follows, then, in a case like that of the supply in question, where the capacity of the engine for a certain amount of work in a fixed time is determined, that the working operation of a Cornish cylinder being limited to one direction, and the speed of the descending plunger being limited by the conditions of water-flow through the valves and force tube, there is an important distinction as to capacity for work between

a single and double-acting engine of the same cylinder. The former pumps in but one direction, and the important water-stroke is not controlled in speed by the cylinder. In order to pump the same quantity of water in a given time, the Cornish engine must be more than twice the size of a double-acting engine.

It is also clear that for the same rate of delivery the Cornish plunger must be more than twice the capacity of a double-acting pump, and that the friction and disturbances of the pump are consequently magnified. This involves an advantage to double-action, in which the pump area need not exceed that of the force tube.

Up to the present time, however, although there are individual cases of double-acting engines more economical and efficient in work than individual cases of the single-acting, the latter as a general rule are entirely in advance of the former in these qualities and in that of durability. And the Cornish engines have the advantage in the friction of their working parts, due to their superior size and simplicity of motion, in their capacity for high initial steam pressure and rate of expansion, and in the superior manner in which they are jacketed, felted, and protected as to the cylinders, boilers, and other appurtenances from losses by radiation, condensation, and otherwise. The testimony of the records of pumping machinery to the date of the trial of the Brooklyn engine is conclusive as to the advantages in practical results of single-acting engines; and if it can be shown that this engine combines within itself all the advantages of the old system with its improvements in capacity for work, we have the whole Cornish testimony endorsing the principles of its success.

It was clear that there were advantages in compactness of arrangement and capacity in Mr. Wright's plan over the single-acting engine. For our work a Cornish engine of not less than 90 inches bore and 15 feet stroke, with a plunger of 50 inches diameter, was required to furnish the supply; and the leading machine shops of the country regarded this as an unwieldy and almost impracticable construction. While there is an advantage in large cylinders for economy over small cylinders, there is at present a practical limit to construction, which must be taken into account in putting work under contract, although the size named is not without precedent in marine engines, and there is also an additional responsibility in daily management. I do not, however, regard the erection and running of such an engine as impracticable, nor have I any doubt as to its economical results; but it is evident that the same results with a smaller engine are much to be preferred.

Conceding then to this plan, the merit of double-action and the disuse of cranks, fly wheels, and other power absorbents of double-acting engines, the question to be determined was, whether the leading features of the Cornish engine could not be embraced in this; or in other words, whether the steam could not be made to lift water instead of cast iron, and with the same economical results.

Starting on the assumption that this was the chief point at issue in this plan, a very careful study was made of the various pumping

engines within observation or placed on record as to those cases where the water was pumped directly by the steam; and the testimony on this point accumulated to many more examples than were at first anticipated. All the mining engines have one water lift at least by steam, and their economy is claimed to be enhanced accordingly; many cases of mining and pumping double-lifting engines occur in Europe and America; the great "Leeghwater" and "Cruquius" engines of the Harlaem Meer lift on their expanded steam, and the climacteric of pumping engines on record, in the Huelgoat Mines, with its vertical lift of 754 feet, belongs to the same class. Two things were clear in practice as in theory: that water could be lifted in this way, and that it could be lifted without injurious disturbance and with great economy. And the conclusion was finally expressed without hesitation, that the steam could be used for the direct water lift without any fear of its disturbing or controlling action on the expansion of the cylinder or the motion of the steam piston. I consider this the vital principle of the Brooklyn engine.

This point determined, the application of a second principle was very simple, and that is the inertia to be given to the working parts to insure a capacity for high initial steam, expansion, and steadiness of action. These points in an engine are determined by the item of *weight in motion*, much more positively than engineers as a general rule are willing to admit, and the success of the Cornish engine is involved herein. This proposition needs no elaborate argument; it is abundantly demonstrated in practice and easily proved in theory. Our own engine has settled this question beyond any controversy, and now lacks some ten tons of the working weight which was estimated for it before construction, and by consequence works with too low a steam gauge and too moderate a cut-off. The experimental weights added from time to time invariably increased the duty and are yet much below the proper standard.

As to the comparative principles of this engine and the Cornish, we claim to have demonstrated that the water can be readily pumped by direct steam lift without any disturbance to the cylinder, and that there is no difficulty in giving the beam and other working parts the same advantages of inertia. These are very important results. The relative capacity, cost, and management are also of great consequence in the comparison.

In connexion with the principle mentioned, that there were no injurious effects to be anticipated from the direct water lift by steam, there are to be considered the peculiar arrangement of the pumps, the areas of delivery, and the size and action of the air chamber, all of which tend to equalize and facilitate the flow.

The pump arrangement, by which each alternately works through the other, has been already described. The Cornish single-acting plungers and double-acting barrels, which put the suction column in motion in one direction, are obliged to reverse it on the return stroke, and thus lose the benefit of its momentum, finding this in fact a force to be overcome. In a number of pump cards taken from various en-

gines, I have found the difference in load between the commencement and end of this suction stroke occasionally to range up to 6 pounds per square inch on the piston. So sensible have hydraulic engineers been of this fact, that numerous ingenious devices have been made to secure a uniformity of motion in the same direction, and the principle is applied on a large scale in the Hartford Water Works engine, and controlled Mr. Wright's arrangement of this plan. There can be no question of its usefulness in retaining every expenditure of power, in preventing any serious loss of action in the pumps and in assisting the quiet opening and closing of the valves.

The facility of delivery through the inner and annular barrels, with their 36 and 54 inch double-beat valves has an important effect on the pumping friction, which as we have shown for the enormous delivery of $14\frac{1}{2}$ millions of gallons per day increases the equivalent lift for both pumps and force tube but 10 feet in 160 or $6\frac{1}{4}$ per cent.; a case without any precedent in pumping experience. The annular barrels were not included in the contract plan, but were adopted at Mr. Wright's suggestion during construction.

Our experiments have also demonstrated the propriety at the outset of making the capacious air-chamber attached to the outboard pump. Various devices are in use for maintaining a continuous motion in force tubes when the plungers are not forcing or the pump pistons are on their centres. The rude and expensive English stand-pipe, which combines an entirely different use in furnishing a fixed head and a small reservoir and whose purpose seems to be much misapplied in our country, has this effect: in some cases, as a device much more rude, a secondary weighted plunger is applied to the tube for this purpose, but no appurtenances of the kind will compare in economy of cost and in softness of reaction with a properly proportioned air-chamber. A proper account of the experiments made on our air-chamber by means of a diaphragm plate fitted across its upper section and provided with adjustable throttle valves, would require much more space than can be taken here. They have all tended to show very clearly the importance of the air chamber to the action of the engine. The effect of the diaphragm when in use was to retard the speed of the engine and to improve the action of the valves, but the oscillation of the pumping column was much increased, affecting the force tube for a long distance and increasing the pump and cylinder load by an important per centage.

It is not claimed for this engine that the result in *duty* equals the highest standard of the best pumping engines, although in advance of any Cornish engine in this country; much better duty than 611,000 foot-pounds is reported in Europe, but in no European or American case are the engines worked with as low boiler pressure and expansion. We have demonstrated by experiments that our only hindrance to these conditions of great economy simply depends on additional weight in motion, while at the same time it is demonstrated that an engine of this class is unprecedented in the items of working friction and smoothness of action. There can be no difficulty, therefore, in fitting the present engine or in building another so as to equal any

result ever actually attained in the venerable history of pumping machinery, and by conditions of experiment rigidly applied to this engine which admit of no contingencies or doubts.

This description of the engine, of its actual results, and of its principles of action, comprises in a general manner all that is requisite to its comprehension. It has been designated an experiment, and there may be a sense in which this is true, as no engine of the same peculiar combination was ever before built; but in those leading features, which clearly follow the well tried paths of known results or natural laws, it is in no sense experimental, and those who assumed the weighty responsibility of its success were fully justified in their undertaking. The engineer who studies carefully the lessons of past experience and the axioms of mechanical laws, will not be disappointed in the results of his combinations; and a demonstration like this, on so important a scale, of hydrodynamic laws, ought to be regarded with interest by the civil engineering profession. By the terms of their contract, Messrs. Woodruff and Beach, in case the engine had failed to perform its specified duty, were bound at their own cost to supply its place by another which would, and there are very few engine builders in this country who would have been willing to assume such a burthen. No small measure of praise is therefore due to them, and their very ingenious superintendent, for the confidence and ability with which their work was undertaken and completed.

Brooklyn, April, 1860.

*Locomotives on Common Roads.**

The plan has been again revived of introducing steam locomotive carriages on common roads, and a committee of the House of Commons during the last session examined witnesses with a view to ascertain its practicability. The experiment of road locomotives had not a fair trial when formerly made, for the formation of railways, and the obstacles that were presented to the running of such carriages, for the time threw the project into the shade, and after several ingenious engineers had been ruined in the endeavor to construct locomotives adapted to the peculiarities of irregular surface traction, the notion was abandoned. The trustees of turnpike roads also, having tried to render the locomotives inoperative by covering the roads with quantities of loose stones, at length adopted the more effectual plan of getting the tolls on such carriages raised to a prohibitive rate. One of the chief objects of the select committee on the Locomotive Bill, which was brought into Parliament late in the session, was to ascertain whether the objections to steam carriages or wagons arising from the injury to the roads, and from the frightening of horses, had been overcome by *Boydell's* traction engine; and whether that method of traveling might not be revived by the application of his invention. The committee appointed to consider the bill met on the 19th of July, Mr. Garnett being appointed chairman. They sat only for three days, and examined the following witnesses: Mr. William M'Adam, Mr.

* From the Lond. Civ. Eng. and Arch. Journal, Sept., 1859.