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“The Distribution of Hydraulic Power in London.”

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THERE is generally a long interval between the conception of an idea and its realization. Water power is no new force, but water power, as formerly understood, was limited in its application to systems of mechanism suitable for the low pressures found in Nature. The effects that have been obtained by the use of high pressure are so different in degree, if not in kind, from all previous experience, that a new name was needed and has been found in the term “Hydraulic Power.”

The reputed father of the system was Bramah. The ideas which he first crystallized into practicable and useful shape had no doubt occupied the minds of inventors before him; but it was his genius that produced the hydraulic press, and he clearly foresaw the future development and great capabilities of the system. Mr. E. A. Cowper, M. Inst. C.E., read to the Institution in 1876 a letter of Bramah's, which is remarkable as indicating his foresight.¹

But Bramah had probably little notion of all that was required to make his brilliant idea a practical success, and he did not live to see anything approaching it accomplished. It was reserved for Lord Armstrong to work out and superintend all those intricate details, which had to be slowly developed, before the system could be made fully serviceable. The effect of his work, and of that of his coadjutors, is visible all over the world. The number of workers at present engaged in this field of enterprise,

¹ Minutes of Proceedings Inst. C.E. vol. xlix. p. 30.

the varied nature of the apparatus in which Hydraulic Power is the motive force, and the general use of the system for all sorts of purposes, are among the most remarkable facts of recent industry. In the Author's opinion this advance has been due entirely to the use of high pressures, and is a striking illustration of the great effects which can be produced by changes apparently most insignificant. At first sight the use of 700 lbs. per square inch pressure of water in place of 60 or 70 lbs. does not appear a very vital change, but it has given "Hydraulic Power" to the world.

The public supply of Hydraulic Power in London constitutes the latest development of this system, and more nearly realizes Bramah's happy thought than any previously executed.

CENTRAL PUMPING STATION.

The first and largest pumping station has been erected on a site known as Falcon Wharf, about 200 yards east of Blackfriars Bridge (Plates 1 and 2). The house is a very old one, and is said to have been occupied by Sir Christopher Wren during the building of St. Paul's Cathedral. A few alterations enabled it to be used for the offices of the Company and a dwelling for one of the staff. The rest of the site was cleared, but the retaining-walls next the creek and the river-wall, being in fairly good condition, were not rebuilt.

The engine-house at present contains four sets of pumping-engines, each set being capable of exerting 200 indicated HP. The engines are vertical-compound, of a type combining the advantages of a three-throw pump with direct connection between the pump-plungers and the steam-pistons. The centre cylinder (Plate 3, Fig. 2) is high pressure, 19 inches in diameter, 24 inches stroke. The two outer cylinders are low pressure, 25 inches in diameter. The pump-plungers are single-acting, 5 inches in diameter. The engines are fitted with surface-condensers. The air-, circulating-, and feed-pumps are worked from beams connected to the high-pressure piston-rod cross-head, in accordance with the usual practice in marine engines. The floor-space occupied by the engines is very small, 14 feet by 10 feet.

Each set of engines will deliver 240 gallons of water per minute into the accumulators at 750 lbs. pressure per square inch, at a piston speed of 200 feet per minute. This is the normal speed of working, but they can be worked when required at 250 feet per minute, the maximum delivery being 300 gallons per minute.

The condensing water is obtained from storage-tanks over the engine-house, and is returned by the circulating-pumps to one or

other of those tanks. The quantity of water required for condensing is, approximately, the same as the quantity of power-water delivered into the mains; but the arrangements adopted for taking water from the river, and for storage and filtering, do not admit of the supply being delivered to the tanks synchronously with the delivery to the mains. The amount of fresh water entering the unfiltered water-tanks is, however, sufficient, unless under very exceptional circumstances, to prevent the temperature in these tanks rising above 90° Fahrenheit. Should it rise above this, water is raised from and returned to the river by the circulating-pumps.

The unfiltered water from the tanks is lowered in temperature during its passage through the filters, and further cooling takes place during the interval of rest in the filtered-water storage-tanks. When required during the winter months the filtered water is used for condensing so as to raise its temperature. These arrangements allow of the water delivered into the mains being maintained all the year round at temperatures varying between 60° and 85° Fahrenheit.

The details of a trial made with one of the engines on the 10th of March, 1887, are given in Appendix I. The engine ran continuously for nine hours at an almost constant speed of 55·35 revolutions per minute; in other respects the trial took place under the ordinary conditions of working. There is also given a statement of the coal burnt under the usual condition of varying demand for power. As there are certain times in the day when the engines are running at full speed, this result approaches the maximum attainable in practice.

The coal (rough small) consumed during the nine-hours run amounted to 2·19 lbs. per indicated HP. per hour. In ordinary work the rate is 2·93 lbs. per indicated HP., an increase of one-third, owing entirely to the varying speed of the engines. The economy of engines working under such conditions cannot be reasonably compared with that of ordinary waterworks engines, but must be treated *sui generis*. As the engine during the trial consumed 19·79 lbs. of steam per indicated HP., it will be seen how small a saving in coal-consumption remains to be effected by reduction in the weight of steam used.

BOILERS.

The boilers are of the double-flued Lancashire type, with Galloway tubes, and are made of steel. They are four in number, three being 7 feet in diameter by 28 feet long, and the fourth 7 feet 6 inches by 28 feet. All are fitted with Vicars' mechanical

stokers; the hoppers are kept full by means of an elevator and a horizontal trough and worm. Sliding doors admit the slack to the different hoppers (Plate 2). These stokers convert the fire-grates of the boilers into a kind of gas-furnace, and with a good coking-coal and careful handling are effectual smoke-consumers. Boilers with this apparatus cannot be unduly forced in the firing, and require a good deal of attention under the irregular demands for steam which the installation has to meet. Their working under the somewhat peculiar conditions has given very good results. At the back of the boilers is a Green's economizer, consisting of ninety-six tubes. The economizer and the stoker-gear and worm are driven by a Brotherhood three-cylinder hydraulic-engine, the pistons being 3 inches in diameter, and their length of stroke 3 inches. The engine is bolted to the engine-house wall, and is a good illustration of the use of the hydraulic supply for rotary-driving with a variable demand for power. The engine, having no dead point and no expansion, runs equally well at 4 or 5 or 100 revolutions per minute. The supply of coal to the hoppers and to the furnaces is regulated by adjusting the speed of this engine. With steam at 82·5 lbs. per square inch, 3,120 gallons of water have been evaporated with 3,460 lbs. of coal in eight hours and fifty minutes. The temperature of the feed-water averaged 76°·2, and the coal used was sea-borne rough small.

The results agree substantially with those obtained in some trials made about the same time by Professor Kennedy and Mr. Bryan Donkin, jun., when the evaporative efficiency of the Lancashire boiler and economizer was 10·65 lbs. of water at the temperature of the feed-water, or 12·4 lbs. of water from and at 212°, per lb. of Nixon's navigation ordinary coal, fired with mechanical stokers.

ACCUMULATORS.

The accumulators at the pumping-station are two in number, each having a ram 20 inches in diameter and 23 feet stroke. The weight-cases are of wrought-iron, and are filled with iron slag. The total weight of the case and load on each ram is approximately 106 tons, corresponding to a pressure of 750 lbs. per square inch. There is capacity in the accumulator casings for increasing this load to 800 lbs. per square inch. Each accumulator is fitted with an electric bell, which comes into action when the accumulators are half down, as a signal to the engineer-in-charge to stand by, and, if necessary start an additional set of engines, and

thus keep the supply up to the demand. The accumulators and load, weighing 250 tons, are carried by a bed of concrete, supported on 12-inch piles driven well into the London Clay, which is met with at a depth of about 30 feet below Trinity high-water mark. In old times a creek at this spot entered the River Thames, and during the excavations for the foundations, 22 feet below the engine-house floor, a quantity of oak timber was met with, which appeared to have been used as a kind of grid for vessels to lie on.

STORAGE-TANKS AND FILTERING APPARATUS.

The storage-tanks form the roofs for the engine- and boiler-houses. The water for the power-supply is obtained from the River Thames, and is pumped into the tank over the engines (Plates 2 and 3, Fig. 1). This tank is 50 feet by 45 feet by 8 feet deep, and is divided into three compartments. The three compartments when full contain 105,500 gallons. A considerable quantity of the mud in suspension settles in these tanks, and the water is conveyed to the filters through swivel-pipes provided with floats, so that the intake is always from the surface. Each compartment has its own swivel-pipe, and the one appertaining to the compartment into which the river-water is being pumped is thrown out of use. The water passes through the filtering apparatus by gravity, into the filtered-water tank over the boiler-house, which is 7 feet below the level of the unfiltered-water tank. This tank is divided into two compartments, but a portion of one of the compartments is partitioned off to form two charcoal filter-beds.

The filtered-water tank is 66 feet by 30 feet by 8 feet deep, and has a capacity of 92,800 gallons. Each charcoal filter-bed is 15 feet by $12\frac{1}{2}$ feet (Plate 3, Fig. 1), and is fitted with pipes and valves, so arranged that either or both beds may be used to supply either or both of the compartments of the filtered-water tank. The filter-bed is constructed with cast-iron perforated plates, covered with sheets of brass gauze, the sheets being held in position with wood strips, secured by Muntz metal studs. A layer of animal charcoal is laid upon the gauze, and troughs and valves are provided for washing out. The charcoal beds are intended only to remove the fine particles which may pass the mechanical filters about to be described.

These filters (Plate 3, Fig. 1) are on a novel principle, designed by Mr. Perrett and constructed (apart from the hydraulic arrangements) by the Pulsometer Engineering Company. They consist of cast-iron cylinders 5 feet in diameter, in groups. Each group

contains two filters, one over the other. Each cylinder contains a movable perforated piston and a perforated diaphragm; between the movable piston and the diaphragm is introduced a quantity of broken sponge. The sponge is compressed by means of a hydraulic ram, which gives a pressure of $10\frac{1}{2}$ tons on the area of the piston, or about 4 lbs. per square inch on the sponge. While filtering, this condition is constantly maintained by hydraulic pressure from the mains. After the lapse of four to six hours, varying according to the state of the unfiltered water in the storage-tanks, the sponge becomes so clogged that the flow is seriously diminished in quantity, when the filter has to be cleansed.

Cleansing is accomplished by reversing the flow of water through the filters, and by opening communication to the wash-out pipes; at the same time, by means of the controlling valve in the hydraulic cylinder, the perforated pistons are caused to move up and down in the cylinders, alternately compressing and releasing the sponge, which, in the course of fifteen minutes or so, becomes thoroughly clean. The operation is comparable with that of rinsing a dirty sponge by hand. The filter is then set as at first, and filtering recommences. The filtering capacity of each group of two is 5,000 gallons per hour. There are five groups at present in use; the total capacity is 25,000 gallons per hour. Filtering is continued during the night.

As a reserve a supply of water can be obtained from the mains of the Southwark and Vauxhall Water Company.

PUMPING FROM THE RIVER.

Several ways are provided for pumping from the river. Centrifugal pumps, driven by Brotherhood's three-cylinder steam-engines, were first put down (Plate 2) in duplicate, each pump being capable of delivering 60,000 gallons per hour; but with a length of suction of 260 feet, and a total head of 45 feet, the conditions were too severe to allow them to be thoroughly depended on (though they are still used occasionally), and pulsometers were added. With these it is possible to take the water at any state of the tide except at dead low-water. Neither form of pump is economical in steam, but their incidental advantages, when dealing with such muddy water as that in the Thames at Blackfriars Bridge, are considerable.

As before explained, the circulating-pumps of the engines can also be used to pump from the river; but the constantly varying speed of the main engines, and the great length of the suction-

pipe, are not favourable to good results being obtained with them.

The method of intake from the river is shown on Plate 2. One suction-pipe draws from a sump in the foreshore, and the other from a cast-iron box provided with a grating containing the clack-box and perforated nozzle of the suction-pipe. There is also a hydraulic perforated pipe laid round inside the box. This pipe is connected to a 2-inch hydraulic main, and is used to clear the box from any deposit which may collect in it. The box is placed 185 feet from the quay, and is only exposed at low spring-tides.

PHILIP LANE PUMPING-STATION.

About the same time that Hydraulic Power was first being supplied in the City, a large fire occurred in Wood Street and destroyed the whole block of premises bounded by Wood Street on the west, Addle Street on the south, Philip Lane on the east, and London Wall on the north. Hydraulic Power was wanted for the new buildings, but the area was outside the very circumscribed district of the "Wharves and Warehouses Steam Power and Hydraulic Pressure Company."¹ A small pumping-station was therefore erected in Philip Lane, for supplying the warehouses in the neighbourhood.

This district now forms part of the general system of supply, being included in the area defined by the "London Hydraulic Power Company's Act" of 1884. The Philip Lane pumping-station is only occasionally used, but the accumulator is in constant connection with the mains.

This accumulator is loaded to 710 lbs. on the square inch, and is 13 feet above those at Falcon Wharf. The estimated difference of pressure between the central accumulators at Falcon Wharf and that at Philip Lane is therefore only 34 lbs.; but the Philip Lane accumulator has never been observed to fall more than a few feet. Indeed, the regularity with which the pressure is maintained throughout the system, with only the accumulators at Falcon Wharf and the supplementary one at Philip Lane, is very remarkable. As the supply of power increases, further accumulators will be required; but experience, so far, tends to prove that these supplementary accumulators need not be of any great size for the

¹ This Act was obtained in the year 1871, Messrs. Burrell and Valpy, MM. Inst. C.E., being at the time the engineers. The powers remained dormant until resuscitated by the Author in 1882.

purpose of maintaining a constant pressure, and their influence as storage is small, as they can never contain more than a few minutes' supply. During the busiest time of the day the Author has frequently observed the main engines running at a good regular speed, for a quarter of an hour together, without any material movement in the accumulators.

MAINS AND VALVES.

The delivery of power-water from the Falcon Wharf pumping-station is through four 6-inch mains (Plate 1). Two are used for the City service, and two for Southwark. The two City mains are carried across Southwark Bridge. At the junction of Holland Street with Southwark Street, one of the Southwark mains is continued along Stamford Street and over Waterloo Bridge. Except, therefore, for 200 yards from the pumping-station, the supply is carried through five 6-inch mains.

The delivery from four sets of engines is 1,040 gallons per minute, and, with equal flow in each of the five pipes, the velocity would be 2.83 feet per second. The loss of head corresponding to this velocity is 22.896 feet per 1,000 yards, using the formula—

$$\frac{(\text{Gallons per minute})^2 \times \text{length of pipe in yards}}{(3 \times \text{diameter of pipe in inches})^5}.$$

The most distant point of the main from the accumulators is at the west end of Victoria Street, and is 5,320 yards, or just over 3 miles. There is a further loss due to the valve-passages and bends in the pipes. To provide for all frictional loss in the pipes and valves, the accumulators have been loaded to 750 lbs., the stated pressure supplied being 700 lbs. per square inch.

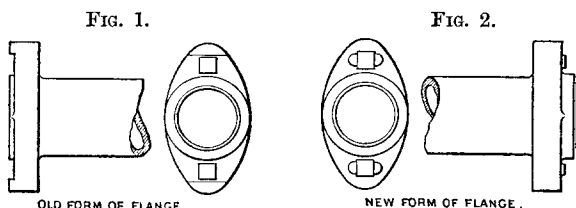
On one occasion the main valves were so set that the accumulator with the greatest load was at one end of a circuit of 5 miles, and the accumulator with the lighter load at the other end. The lighter accumulator was lowered and shut off, the heavier remaining at the top of its stroke. Communication was opened between the light accumulator and the main, and the accumulator was raised by the other through the 5-mile circuit, the normal difference of pressure in the two accumulators being 20 feet head.

It would appear, from certain observations that have been made, that the pressure is better maintained at all parts of the system when there is a considerable demand upon the mains for power. Some further observations are required to elucidate this point, but it is probably to be accounted for partly by the effect of the inertia

of the column of water in the long length of main, and partly by the slight increase of pressure at the pumping-station when the engines are running with a stationary or rising accumulator.

The 6-inch mains were first constructed as shown in Fig. 1. With the form of flange there depicted, it was found that whenever a fracture in a pipe occurred it was invariably one of the lugs that broke off. The Author was thus led to design the flange shown in Fig. 2, and the result of a number of tests with pipes made of similar metal, and cast in the same foundry, but with the different forms of flanges, showed that the pipes with the new flanges were increased in strength at least 35 per cent. The most reliable of these experiments are given in Appendix II. There has so far been no failure of pipes made on the Author's system. The total length of the mains, laid to the end of the year 1887, was nearly 27 miles.

The mains are laid in circuit, and there are stop-valves at about every 400 yards, so that any such section of main can be isolated.



The sub-mains are usually connected to the circuit at two points with valves at each junction; then the supply to the sub-mains can be given from either 6-inch main.

Where even an occasional stoppage of supply for a few hours is of great importance, two distinct service-pipes can usually be given. There have been only four breaks in the mains during the last two years. There is good reason for believing that they were due either to settlement in the ground or to an excessive initial strain having been put upon the flanges in screwing up.

For the purpose of rapid repair, the importance of all the pipes used being of standard lengths cannot be overrated.

The difficulties encountered in laying mains in many of the streets, especially in the City, are very great. Figs. 3 and 4 show sections of portions of the mains as laid. Notwithstanding the very irregular lines, each pipe in those sections is a standard size, and can be replaced from stock in a few hours.

The main stop-valves are of the mushroom type, but balanced

in such a way that they can be opened by one man with an ordinary socket-spanner and bar, and equally well whether the pressure is on one side of the valve or on the other (Fig. 5). With the mains laid in circuit this is of importance. The mode of action is as follows. Assuming, first, the valve to be closed with the pressure on the right hand, or on the top of the valve, the pressure will get past the leather A, through the

FIG. 3.

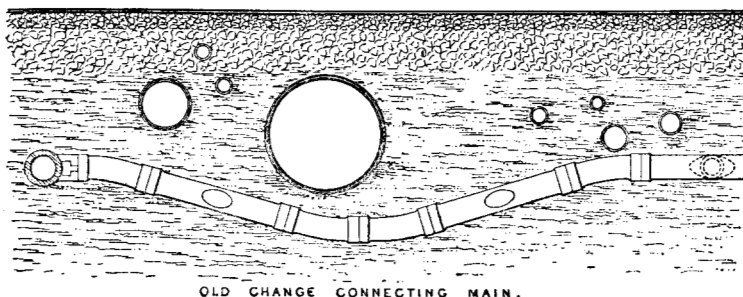
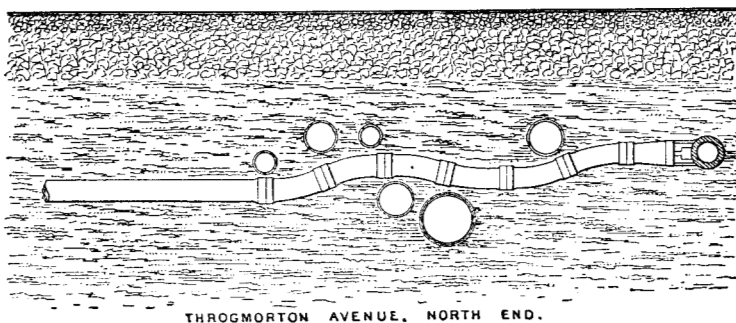


FIG. 4.

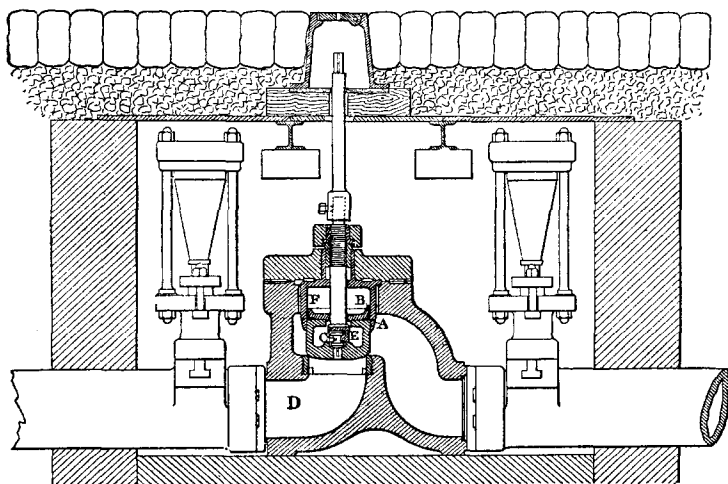


passage B, and keep the small controlling-valve C closed. On giving the valve-spindle a few turns, the valve C is raised, when the pressure-water will pass into the pipe D, filling it. When full the main valve E is balanced, and by continuing to turn the spindle it is opened, its weight only having to be raised.

If the pressure, when the valve is closed, is underneath the valve, *i.e.*, in the pipe D, it keeps the valve C open, and the pressure is maintained in the space F, closing the leather A, and thus

balancing the main-valve E. Each main stop-valve is protected by spring momentum-valves on each side.

FIG. 5.



METHOD OF DETECTING LEAKAGE.

The method employed for detecting leakage is based upon an automatic record of the number of gallons delivered into the mains. In cases of abnormal increase during any night, if found to arise during the early hours of the morning, the mains are tested. For this purpose, at Falcon Wharf pressure-gauges of considerable range are connected to each of the four mains radiating from the station. The valves in the middle of each circuit are kept closed. Each main is then shut off in succession at Falcon Wharf, and the behaviour of the hands of the gauge will indicate the condition of the mains. If the pressure falls rapidly and continuously a leakage is indicated. By closing the valves in succession along the main indicated as leaking by the gauge, and using a sounding-rod to transmit the sound of the passing water to the ear, nearly the exact spot of the leakage is determined. Should a considerable leak or break occur, the water will generally reach the surface of the street, though not always, and once there was a good deal of difficulty in fixing the exact spot. It was eventually found by hearing the water running by a street gully into the sewer.

The method of gauging the pressure at different points, and of using the divining-rod, is very effective. On one occasion, from the record of the pumping, a leak was supposed to exist. The following night the valves at the Wharf were set for observation, and a singular action of the gauge could only be accounted for by a main stop-valve in the City, about 2 miles away, supposed to be closed, passing a small quantity of water, and at the same time by a machine on a line of main near this valve having been left working by the attendant. The same curious result was obtained on repeating the experiment, the condition of things at the spot indicated was examined—the valve was found leaking as expected, and the machine could be distinctly heard at work. It was a hydraulic pump, and each stroke of the pump was indicated by the gauge. As this pump was only taking 0·09 gallon of water per stroke, the perfect condition of the mains was incidentally proved by the experiment.

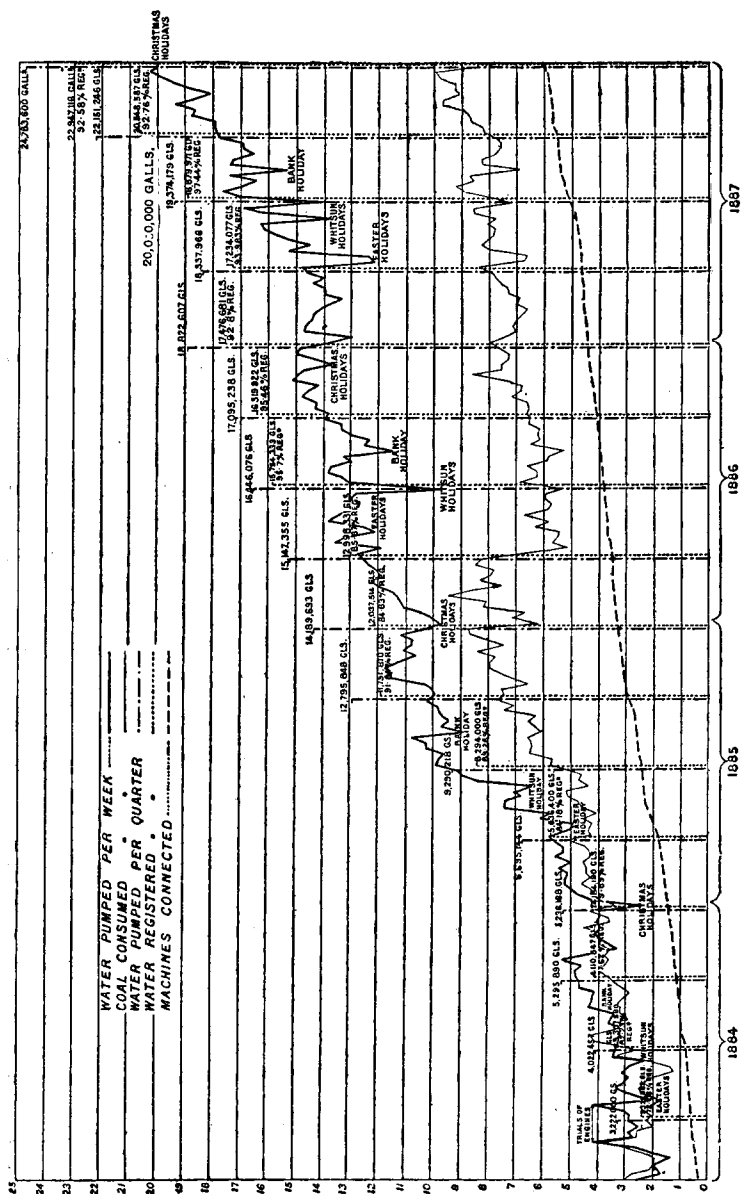
Sound will travel along these mains a great distance. On the same occasion, with the sounding-rod on the valve referred to as being 2 miles from the pumping-station, each beat of the engine, hardly noticeable in the engine-house, could be distinctly heard, and also each stroke of the small hydraulic pump as the water was drawn from the main.

METERS.

The power-water used is invariably registered through meters on the exhaust-pipes from the machines, and from the meters passes to the drains. The meters most in use are Parkinson's. Siemens' meters under some circumstances are adopted, but they are very inaccurate under the sudden fluctuations in discharge which occur with hydraulic machines. Kent's positive meter has been also used to a limited extent, and so far has given good results.

The final test of efficiency of the meters, and of the whole plant, is supplied by the registration of the quantity of water passed into the mains. This is obtained by the revolutions of the engines, registered by counters, multiplied by a constant representing the capacity of the pumps of the engines less 5 per cent. for slip. Fig. 6, p. 13, represents the quantities pumped into the mains each week since the commencement of regular supply. The vertical columns at intervals are the quantities during each quarter, pumped and registered; the difference is the quantity not accounted for, and is made up of the water used for washing-out and leakage. The thick dotted horizontal line shows the number of machines at work from the mains each week. The comparatively

FIG. 6



large loss, shown in the quarter ending December 1885, was mainly due to one leak through a small hole in a pipe in Cannon Street, not more than $\frac{1}{8}$ inch in diameter, which had been gradually forced through a soft place in the metal of the pipe, and which had not developed a leak when the pipe was laid. The velocity of water at 700 lbs. pressure through a free orifice being 320 feet per second, a hole only $\frac{1}{8}$ inch diameter will pass between 30,000 and 40,000 gallons in twenty-four hours.

The diagram demonstrates:—

First, The necessity for the complete integrity of the main, and the greatest watchfulness to maintain efficiency;

Secondly, The possibility of laying great lengths of such mains in a perfectly sound and good condition for long periods without repairs.

CONDITIONS OF SUPPLY.

The scale of charges is given in Appendix IV, and was designed to meet, as nearly as possible, the variable conditions and requirements of consumers. The more continuous the use the lower the charges. The scale is intended chiefly for intermittently-acting machinery, and experience has fully proved that these rates are sufficiently low to effect a large saving to the consumer in almost all cases, whether for a large or a small plant.

ECONOMY TO BE DERIVED FROM AVERAGING THE REQUIREMENTS OF INDIVIDUAL CONSUMERS.

The averaging effect of a number of consumers on the maximum demand for power is one of the most interesting problems connected with the system, and has more influence on the rates at which the power can be supplied than any other consideration. Even with a general distribution of power, the cost of supplying the power must be greater where the use is intermittent than where it is constant. In December 1887 there were about six hundred machines of various kinds working from the mains in London, and the largest amount of power delivered in one week was then a little over 2,000,000 gallons.

The effect of working six hundred machines from one centre, is, of course, to reduce to a great extent the consumption of each to a common average; but there is still a very great variation in the demand for power at different times of the day and on different

days of the year. The maximum quantity in any twenty-four hours during the quarter ending December 24th, 1887, was approximately 350,000 gallons, and the minimum 75,000. Taking, however, one hour as the standard, the maximum was 35,000 gallons, and the minimum 1,500.

Fig. 7 (p. 16) shows the maximum and minimum daily curves for the half quarter ending November 13th, 1887. The line A shows the average delivery for the half quarter per hour. It is obvious that the use of power for machinery working intermittently, even when the number of machines at work is very large, will bring down the average line A much lower than the same number of hydraulic engines running pretty continuously for ten or twelve hours a day. Supposing there were three hundred engines working twelve hours a day, and on the average developing only 1 HP. each, the consumption during the night making up for the deficiency below the maximum delivery during the day, the average line would be at B. The revenue at equal rates, and from the same plant, would be increased 50 per cent., or the same revenue would be derived from a reduction in the scale of charge of 33 per cent.

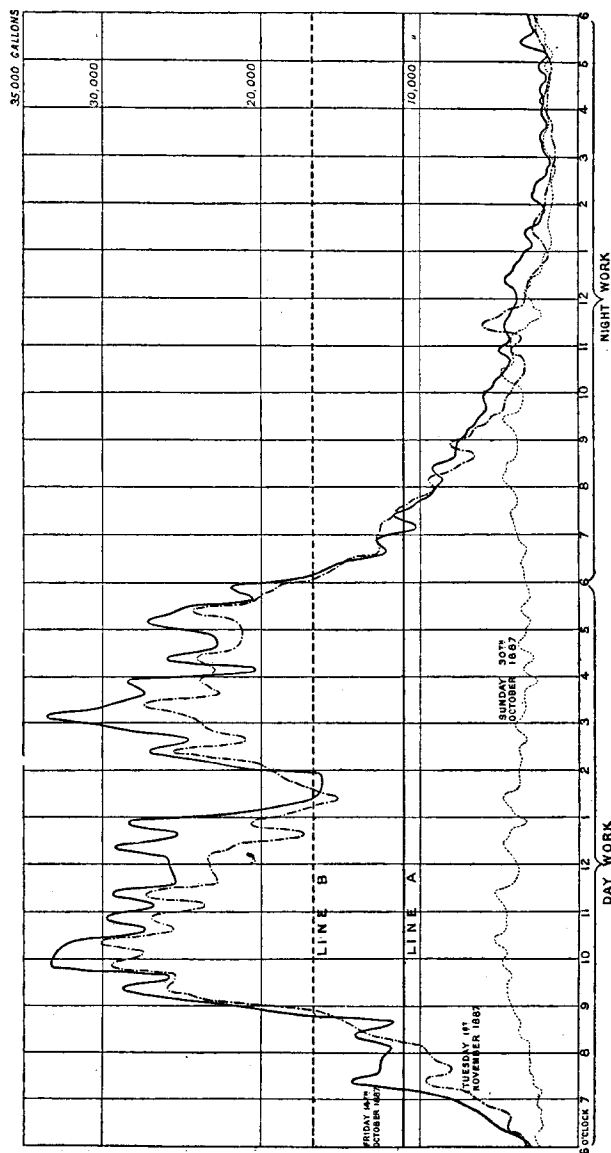
An individual requiring power has, if dependent on his own plant, to provide for the maximum demand for power whether the machinery is worked continuously at that point or not. A Power Supply Company must do the same. If the public supply is taken for driving engines which may be supposed to be running all day, the Supply Company will have to provide plant of a power approaching the total power of all the engines working from the central source. In such a case there would be comparatively little saving by averaging the consumers' requirements. The profit of the Company would be limited by the difference in the cost of working the small plant of the individual consumers, and the reduced working cost per unit of power of the central station. But with intermittently acting machinery, such as lifts, cranes, and presses, the conditions of comparative cost are entirely changed. Here the averaging effect of the intermittent demands of a very large number of consumers during any short period of time, say one hour, would be complete within a small percentage, and the margin of profit to the Supply Company has two elements—first, the direct reduced cost of working a central station; and secondly, the reduction of the large but occasional demands of individuals to a common average.

Expressed in figures the case may be said to stand thus:—

Assume that two hundred engines of 5 HP. are each working

ten hours a day, and up to, say, 80 per cent. of the total as a

Fig. 7



maximum. Then 800 HP. is required at the central station.

Assume two hundred lifts and cranes consuming, when in motion, 5 HP. each, but averaging only 1 HP. at the time of greatest demand. The HP. required at the pumping-station is 200.

In each case the consumer would have to provide for himself 5 HP., but the saving of the public supply is four times greater in the latter case than in the former.

The maximum delivery during any one hour has been stated to be 35,000 gallons, and the income would be, at 3s. per 1,000 gallons, 105s., or, approximately, 4d. per HP. per hour = £1 per HP. per week of sixty hours' work. Few consumers would pay such a rate for a continuously driven engine. It is the intermittent character of the demand that makes it profitable to the consumer to pay considerably higher rates, because, though he is paying at the rate of 4d. per HP. per hour for what he uses, he is only paying at the rate of, say, 1d. per HP. per hour for the power he requires to have at command, and for this only during the time the machinery is at work.

As a large use of power for continuously-driven engines from central stations would greatly increase the total quantity used, the cost of the supply per 1,000 gallons of water would no doubt be reduced, but not in direct proportion. There would also be necessary a larger amount of reserve power.

Taking all the circumstances into account, it can hardly be a profitable operation to supply public power under conditions similar to those which exist in London at less than 2d. per indicated HP. per hour. This would be from £20 to £25 per HP. per annum, working fifty to sixty hours per week.

The Author believes any idea of supplying power from a central source at rates much below this to be chimerical. The practical efficiency (brake HP. of hydraulic motors) of the hydraulic system may be fixed at from 50 to 60 per cent. of the power developed (indicated HP.) at the central station. No other method of transmission, to say the least, would show a better result.

For small powers continuously working, the cost of £20 per HP. per annum would compare very favourably with the cost of steam. At first sight it perhaps may not appear so favourable as compared with the cost of working a gas-engine when at its best, where the gas-engine can be used without creating a nuisance, and the gas itself is cheap. But when the oil, water, attendance, &c., required for gas-engines are taken into account, the total cost of gas power is probably quite as much.

Directly, however, the gas-engine is set to do intermittent work the advantage is largely on the side of Hydraulic Power,

while for such purposes as lifting and pressing, the general convenience and simplicity of the hydraulic system are such that its use would hardly be affected even if there were no direct economy in the cost of working.

KENSINGTON COURT.

In addition to the general supply of Hydraulic Power in the City and adjoining districts to the six hundred and fifty machines at present worked, a new departure has been taken by the application of Hydraulic Power to an estate at Kensington Court. Seventy houses and dwellings are to be built on this estate, of which thirty have been already erected. Each house is fitted with a hydraulic lift, taking the place of a back staircase, and the power-supply is provided on the estate expressly for working these lifts. There are subways in the streets, in which the pressure and return pipes are laid.

MACHINERY USED BY CONSUMERS.

The driven machinery is of as great importance to an economical and satisfactory result as the distributing plant, but this obvious fact is not always understood.

General regulations were prepared by the Author, defining the conditions to be observed by manufacturers in fitting up machinery for connection to the power-mains. These regulations are given in Appendix III. They are intended to secure safety, and an efficient registration of the quantity of power used; but they leave the question of economy and efficiency of the machines to be settled between the consumers and the makers.

HYDRAULIC LIFTS.

In London more lifts are working from the mains, and more power is used by them than by any other description of machinery. The number at present at work of all classes is over four hundred.

The principal types in use are illustrated by Plate 4.

Plate 4, Fig. 1, shows the hydraulic balance as used at the Hotel Métropole. The height of the passenger lifts at this hotel is 90 feet. The working load is 20 cwt., the diameter of ram is 6 inches, of steel, and the working speed has been fixed at a maximum of 180 feet per minute. The quantity of power-water

used per journey of 90 feet is $24\frac{1}{2}$ gallons. The hydraulic balance reduces the consumption of power-water from 109 gallons (which it would take if worked by direct pressure of the power-water under the ram) to $24\frac{1}{2}$ gallons.

In another type of hydraulic balance, Plate 4, Fig. 2, the large ram A, subjected to the constant pressure of water from a small tank in the roof, balances the weight of the ram and cage, and as the net downward pressure on this ram increases as it descends, the balance is maintained with approximate accuracy in all positions of the lift-ram. It will be understood that the pressure on the end of the lift-ram diminishes as it comes up out of the water. The load is 7 cwt. The height of lift is 70 feet. The diameter of lift-ram is $4\frac{1}{4}$ inches, and the quantity of water used per journey is $10\frac{1}{2}$ gallons, represented by the displacement of the ram A. Worked by direct pressure the quantity used is 43 gallons.

In the hydraulic balance-lift, Plate 4, Fig. 3, the power-water is used for balancing, the contents of the annulus being returned to the main during the descent of the cage. The height of lift is $55\frac{1}{2}$ feet, the load is 8 cwt., the ram is 4 inches in diameter, and the net consumption of power-water is $7\frac{3}{4}$ gallons. If worked by the pressure direct into the lift-cylinder the consumption would be $30\frac{1}{4}$ gallons.

The hydraulic balances are sometimes placed horizontally alongside the lift proper. Existing direct-acting chain-balanced ram-lifts, working from special pumping-plants at 200 lbs. per square inch (a pressure which previously to the introduction of the hydraulic balance had given the best results in ram-lifts) have been converted to work from the power-mains at 700 lbs., through a system of differential rams, which act in the same way as the hydraulic balance-cylinders, except that the chains and weights are retained.

The lift working in Palace Chambers, Bridge Street, Westminster, has been converted on this plan. The height of this lift is 80 feet, the load 16 cwt., the diameter of ram is $4\frac{1}{4}$ inches, and the consumption of power-water is 18 gallons per journey, as against 49 gallons if worked by direct pressure from the main on the lift-rams.

This lift makes between four hundred and five hundred journeys per day, more than any other single lift with which the Author is acquainted. The maximum speed is 250 feet per minute. It is working day and night and Sundays, the property being partly residential. The consumption of power-water is from 300,000 gallons to 400,000 gallons per quarter. There has been a saving in the cost of working by adopting the public supply of about

30 per cent., as compared with the steam pumping-plant previously in use. This is without taking into account the interest on outlay on plant. If the lift had been erected in the first instance to work from the power-mains, the saving in cost would have amounted to about 50 per cent.

The foregoing represent the highest class of passenger lifts, but from their construction, and the cost of the bore-hole for the lift-cylinders, they are necessarily expensive, and, in some cases, it is impossible to put a bore-hole in the required position. Recourse must then be had to the suspended principle of construction, in which the cage is pulled up instead of being pushed up. There is great variety in the arrangements adopted for suspended lifts; but they are all more or less modifications of the original hydraulic crane or jigger of Lord Armstrong, in which the motion of a ram or piston, produced by the pressure of water acting on it, is multiplied by pulley-blocks as required to give the height of lift.

Suspended lifts depend on the sound condition of the ropes or chains from which the cages hang. As they become worn and unreliable after a short period, it is usual to add safety appliances to stop the fall of the cage in case of breakage of the suspending ropes. These safety appliances are of a very varied character, and most of them fail in practice. The Author has no knowledge of any appliances which can be expected to act under all circumstances. Simplicity and the absence of tricky details are of the greatest importance in this class of apparatus. With careful supervision it is, of course, possible to make such lifts reasonably secure; but even the best examples are, in the Author's opinion, inferior in safety, simplicity and durability to the ram type.

There has been occasionally some controversy as to whether the ram-lift is the simplest and safest type; but, as a matter of theory, there appears to be no room for any reasonable difference of opinion. The superiority of the ram-lift would have been universally recognized if it had not been for the practical difficulties that arise in lifts of great elevations. These practical difficulties are:—

1. The increased sectional area of the ram required for stability as the height increases.
2. The concurrently-increased depth of the bore-hole.
3. The loss of power arising from the unbalanced weight and displacement of the ram, which increases in a higher ratio than the height of lift.
4. The greatly-increased cost of ram-lifts of great height arising from these considerations.

Until within the last few years it was the custom to make all ram-lifts of considerable height with counterweights and chains or wire-ropes for balancing the weight of the ram and its displacement, and the cage. Their use introduced, to a great extent, all the risks and impediments due to the principle of suspended construction.

The Author has no doubt that, even when so used, the ram is the best possible safety appliance; but the greatest safety in lifts is to be obtained by the general adoption of the simple ram without any balance-chains or counterweights. Lifts are now becoming so general, and the number of persons who use them is so great, that the Author considers it necessary to urge with emphasis the importance of securing the greatest possible safety in their construction.

Suspended passenger-lifts will, however, continue to be used. Plate 4, Fig. 4, illustrates the Author's design for a suspended lift worked from the power-mains. There are four main ropes coupled in pairs; for this height of lift (115 feet) the multiplying gear is 4 to 1. The chief peculiarity is in the safety wedges, of which there are two. The wedges are not in any way connected to the cage, and their action does not depend on springs or weights. The wedges are attached to wire-ropes, driven by a second and independent pulley-gear on the main ram at its lower extremity. It will be seen that if the lifting-ropes part, or the working-ram attachments, or the cage attachments, give way, the wedges would be pulled up tight by the double action of the falling cage and the travelling wedge.

The dimensions of the lift illustrated are as follow:—Height, 115 feet; load, 20 cwt.; size of ram, upper end $2\frac{1}{2}$ inches, lower end 6 inches; consumption of power-water per full journey, 29 gallons; speed limited to a maximum of 250 feet per minute.

Hydraulic lifts are now usually employed for luggage and goods in hotels and city warehouses. They are of two classes, viz., the cage-suspended lifts driven by the short-stroke hydraulic jigger for considerable elevations, and the direct ram-lifts without balance for lesser heights. As an indication of the important part which lifts occupy in a modern hotel, it may be mentioned that at the Hotel Métropole there are, including the two passenger lifts and that for passengers' luggage, Plate 4, Fig. 4, no less than seventeen hydraulic lifts in use day and night, while the total consumption of power-water at 700 lbs. per square inch often exceeds 20,000 gallons in the twenty-four hours. The work done represents about 2,000 tons lifted 40 feet in this time.

2. CRANES AND HOISTS.

The next largest use of the power is for working hydraulic cranes and hoists of various kinds along the river side and in the City warehouses.

Plate 4, Fig. 5, is an illustration of the cranes fitted in the first building served from the power mains in September 1883. This is a grain warehouse known as St. Mary Overy's Wharf, near London Bridge. The cranes are fitted with Priestman dredging buckets, but they can be used as ordinary cranes. The height of the lift is 80 feet, and the load 25 cwt.; the consumption of power-water per full lift is $25\frac{3}{4}$ gallons. The speed of working is such that three complete lifts are made in two and a half minutes. This includes filling, lifting, swinging, discharging, re-swinging and lowering the bucket, and is at the rate of seventy lifts per hour, lifting 35 tons of grain per hour. The cranes are of double power. The granary is also fitted inside with grain elevators and travelling bands, land side cranes, a lift from the basement to the ground floor, and a pump to deliver water from a well to a tank at the top of the building. The whole machinery is worked from the Hydraulic Power-mains without reserve power of any kind. During the four years the plant has been at work, power has always been available when it was required.

3. HYDRAULIC INTENSIFIERS.

It often happens that the pressure in the power-mains is not sufficient for pressing purposes. The apparatus known as an intensifier (Plate 4, Fig. 6) is then used. The mode of action is as follows:—Assume the ram A to be at the bottom of its stroke, the valve B is opened, and the pressure from the main raises the ram A, forcing water out through the valve D, and filling the interior of ram A. The valve C is then opened, the back-pressure valve G closes, and the pressure inside the ram is at once intensified in the inverse ratio of the areas of ram A and the hollow fixed ram E, which pressure is conveyed to the press by the pipe F. In the machine illustrated, this pressure is 4,500 lbs. per square inch, and is used for making lead pipes in a pipe press. The apparatus takes the place of about 15 HP., and the cost of the public supply is stated by the proprietor to compare favourably with the old system, notwithstanding that a large steam-power is still used for lead-rolling, &c.

The sizes of the apparatus are as follow :—

Diameter of ram A $15\frac{1}{2}$ inches.

 " " E 6 "
Stroke " E 13 feet.

The water used at 700 lbs. per stroke is 106·5 gallons

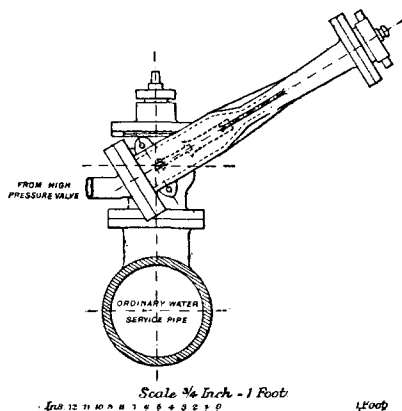
 " supply at 4,500 lbs. " 16 "

4. FIRE HYDRANTS.

Mr. Greathead's injector hydrant,¹ made at the Elswick Works, has been in use to a limited extent in London in connection with the power-mains. A small jet of high-pressure water, injected into a larger jet from the waterworks mains, intensifies the pressure of the latter in the delivery hose, and also increases the quantity. By this means a jet of great power can be obtained at the top of the highest building without the intervention of fire-engines.

This apparatus (Fig. 8) enables the Hydraulic Power supply to

FIG. 8.



act as a continuous fire-engine wherever the mains are laid, and is capable of rendering the greatest assistance in the extinction of fire, but there is an apathy on the subject of its use difficult to understand. In Hull, the Corporation has put down a number of these hydrants in High Street, where the Hydraulic Power-mains are laid, and they have been used with great success at a fire in that street.

¹ Institution of Mechanical Engineers. Proceedings, 1879, p. 364.

5. HYDRAULIC PUMPS.

Hydraulic power is adopted for deep-well-pumping. The pump illustrated (Plate 4, Fig. 7), is at work at Westminster Chambers raising water from the chalk, and supplying that and the adjoining block of buildings. The pump works at the rate of about 20 strokes per minute, and consumes about 330 gallons of power-water for each 1,000 gallons raised from the chalk to the tanks at the top of the buildings. The pump is set going in the evening and continues working till the tanks are full, or until it is stopped in the morning. For work of this kind done exclusively at night a discount is allowed from the usual rates. The cost for power per 1,000 gallons raised is in this case approximately 6*d*. Other pumps of a similar kind are in work, and their use will assuredly extend.

The simplicity of the system, its cleanliness, absence of noise, the small space occupied by the machinery, and its automatic action, are strong recommendations. At the same time, it would appear that if the Water Companies were willing to supply water for domestic purposes by meter at reasonable rates, deep wells to the chalk would not always pay the cost.

6. HYDRAULIC ENGINES.

The only other use of the power of importance in London is the driving of general machinery by rotary engines.

Thirteen of Brotherhood's three-cylinder engines are regularly working from the mains; they are too well known to require detailed description. The purposes to which they are applied are as follow:—

For factories, &c.	3
„ crushing oats, &c.	1
„ driving ventilating fans	3
„ coffee grinding	1
„ working electric dynamos.	1
„ carrying bands in grain warehouses.	2
„ for organ blowing	1
„ cutting machines	1

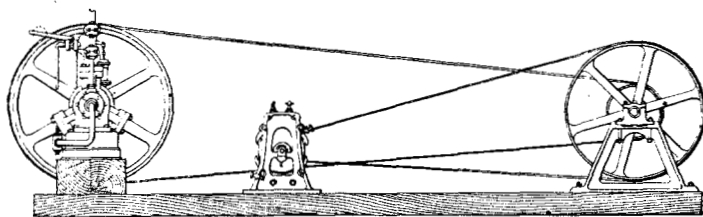
The present use of the power for rotary-work is therefore insignificant, but there will no doubt be a considerable increase as time goes on. At current rates, as already explained, the cost of working is too high for continuous driving, and the hydraulic engine is itself, at present, not a sufficiently 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.

In addition to those mentioned, two experimental engines are at work which, the Author understands, possess this desired peculiarity. One is a turbine driving a dynamo for charging electrical accumulators; the other is an engine designed and constructed by Mr. A. Rigg. This is also used for driving a dynamo for electric lighting. If the machines realize the expectations formed of them, they will prove of considerable value. The Author at present has had no opportunity of testing either of these machines. The useful efficiency of the hydraulic engines at present in use is from 60 to 70 per cent.

Mr. Higgins, of the Exchange Telegraph Company, has kindly furnished the particulars of his electric apparatus driven from the Hydraulic Power-mains for working over six hundred telegraphic instruments in the City and East end. The electricity produced is also used for lighting part of the company's offices. The general arrangement is shown by Fig. 9. There is a Brotherhood

FIG. 9.



Scale $\frac{1}{16}$ inch = 1 foot.

engine, with 4-inch cylinders by 3-inch length of stroke, running 48 revolutions per minute and driving through belts a Gramme dynamo running at 930 revolutions a minute. There are two hundred and ten E. P. S. electrical accumulators. The current produced by the dynamo at the above speed is 15 amperes at a tension of 194.15 volts. Taking 746 watts to the HP., the total electrical HP. was 4.684. In order to ascertain the efficiency of the system, observations were taken during a run of six and a half hours. The quantity of water passed was 7,700 gallons. The apparatus is fixed 80 feet above the street-level, which is 35 feet above Falcon Wharf. The pressure-gauge with the engine running registered 650 lbs. The total observed electrical HP. was 30.45, and the hydraulic HP. at 650 lbs. was 58.138. The efficiency, therefore, was 52.367 per cent. The total charge

during the six and a half hours at 15 amperes amounted to 97·5 ampere-hours, and the output from the accumulators as measured by a sulphate of copper voltmeter, was 88·128 ampere-hours. The loss in volume was 9·61 per cent., and, in pressure, the difference between 194·15 volts and 154·46, or 20·45 per cent.

The HP. of the electricity generated by the dynamo was estimated from the observed potential and volume of current, and was not measured as was the discharge from the accumulators. The hydraulic machine has been in daily use for ten months without interruption. It is to be observed that the efficiency given in these particulars is not that of the engine alone, but of the whole apparatus. The supply of power is conveyed from the street main through 120 feet of 2-inch and 1½-inch pipe, with several bends.

CONCLUSION.

The number of machines under contract to be supplied with power is sufficient, with a suitable reserve, to absorb the full capacity of the station at Falcon Wharf, and another station of about equal capacity is now in course of erection at Millbank Street, Westminster.

The total outlay on the London works to the end of the year 1887 was £150,000, excluding consumers' machinery. The Westminster Station is not included in this statement of cost. The pumping-engines, accumulators, valves, and a considerable portion of the consumers' machinery, except as otherwise mentioned, have been constructed by The Hydraulic Engineering Company, at Chester.

The works have been carried out jointly by Mr. Corbet Woodall, M. Inst. C.E., and the Author, who desire to express their appreciation of the untiring energy with which Mr. G. Cochrane has fulfilled the duties of Resident Engineer and Superintendent.

The Author believes it will be a matter of interest to the members to know that Sir James Allport, Assoc. Inst. C.E., who was the first to adopt hydraulic power for railway work, has been associated with the enterprise from the commencement of its operations in 1882. His wide influence and extended experience have greatly assisted the commercial development of the undertaking.

The Paper is accompanied by several illustrations, from which Plates 1, 2, 3 and 4, and the Figs. in the text have been prepared.

[APPENDIXES.

APPENDIXES.

APPENDIX I.—TRIAL OF A COMPOUND VERTICAL SURFACE-CONDENSING STEAM PUMPING ENGINE AND LANCASHIRE BOILER AT THE FALCON WHARF PUMP-ING STATION OF THE LONDON HYDRAULIC POWER COMPANY.

March 10th, 1887.

Time of trial 9.15 A.M. to 6.5 P.M. 8 hours 50 minutes.

Engines—

Diameter of high-pressure cylinder inches	19
„ „ two low-pressure cylinders . . . „	25
Stroke feet	2
Total revolutions	29,336
Average revolutions per minute	55.35
Barometer	30.225
Vacuum	27.89
Total indicated HP.	178.5

Boilers—

Total heating surface square feet	936
„ grate area „	19.25
Pressure of steam lbs. per square inch	82.5
Temperature of issuing gases ° Fahrenheit	602.6
„ „ „ after passing } economiser }	389.75
Amount of condensed steam from jackets . . lbs.	2,182

Coal—

Quality—Seaborne, rough small. Total weight } fed on to grates }	lbs.	3,460
Total weight of ashes „		33
„ „ clinkers „		110
Fuel burnt per hour „		391.7
„ „ square foot of grate „		20.348
„ consumed per HP. per hour „		2.19

Feed-water—

Feed temperature on entering economizer . . ° Fahr.	76.2
" " boiler "	250.66
Heating surface of economizer square feet	1,142
Total water evaporated lbs.	31,200
Evaporated per lb. of fuel "	9.01
" " from and at 212° (cal- 	

In a trial of the coal consumption for one week, from the 16th to the 23rd of December, 1887, with three sets of engines and two of the boilers working under the ordinary conditions, the results were as follow :—

Water pumped, calculated less 5 per cent. . .	gallons	2,053,176
Total coal fed on to grate	lbs.	67,648
Water pumped per cwt. of coal consumed . .	gallons	3,399

Being 25·42 per cent. less than the quantity pumped per cwt. of coal on March 10th, 1887.

APPENDIX II.—COMPARISON OF THE STRENGTH OF OLD AND NEW FORM OF FLANGES FOR 6-INCH PIPES FOR HIGH PRESSURE.

Breaking tests of 6-inch pipes.

Internal pressure. Blank flanges bolted on.

Date.	Old Form of Flange.	New Form of Flange.	Increase of Strength.	Remarks.
1884.	Lbs. per sq. in.	Lbs. per sq. in.	Per cent.	Short lengths specially made for tests at the Chester Works.
April 8 .	3,584	4,984	39·06	
May 14 .	3,584	4,928	37·50	
„ 16 .	3,584	4,704	31·25	
July 30 .	3,136	4,256	35·71	9-foot pipes taken from London stock.
„ 30 .	3,136	4,256	35·71	
	3,404·8	4,625·6	35·85	Average of above tests.

APPENDIX III.—REGULATIONS ISSUED FOR THE GUIDANCE OF MAKERS OF HYDRAULIC APPARATUS FOR CONNECTION TO THE COMPANY'S PRESSURE MAINS.

1. All cylinders, rams, pipes, valves, or other apparatus subjected to the pressure from the mains shall be tested to 2,500 lbs. per square inch.

2. All hydraulic machinery having rams working in cylinders shall be provided with permanent stops by which the rams will be prevented from being forced out of the cylinders, quite independent of any valve or tappet gear.

3. Back pressure non-return valves, or other approved similar apparatus, shall be fitted to all service pipes as near as possible to the inlet to the building.

4. An independent screw-down stop-cock shall be fitted immediately inside the building, in addition to the stop-cock fitted by the Company to its service-pipes.

5. A relief valve loaded to 800 lbs. on the square inch shall be fixed on all service-pipes exceeding 1 inch internal diameter. The relief valve to be fixed as near as possible to the main stop-cock inside the building. The escape-pipe from this relief-valve is to be connected to the general system of return water pipes.

6. Hydraulic cylinders, valves, and pipes are to be so arranged and fitted with air- and drain-cocks, that they can be efficiently drained and washed out.

7. Pipes and cylinders laid above ground, and in positions where they may be exposed to the action of frost, are to be encased with non-conducting material, or by some other means, such as the use of gas-flames, protected against damage by frost. Efficient means are to be provided for lubricating all working parts.

8. All machines in the same building are to pass the water after use into one system of return mains, so that one meter will suffice for measurement. The return main is to be led to the drain in such a manner as will allow of the Company's meters being fixed as directed by the Engineers. The water supplied by the Company must not be used for any other purpose than motive power—any breach of this regulation rendering the offender liable to penalties under the terms of the Company's Acts of Parliament.

9. The meters and tanks connected therewith will be fixed by the Company at its own expense, and will be connected to the Consumer's pipes, which are to be brought close up to the meters on both sides of them.

10. The service-pipe with stop-cock from the street main to the inside of the building, or within the premises of the Consumer, will be laid by the Company at the cost of the Consumer, and the pressure-water will be turned on after the receipt by the Company of the maker's certificate of test of the machinery and pipes, and after an inspection of the same in reference to the foregoing regulations. Should, after a trial, all be found in order, and no leakage apparent, the key of the street valve will be handed to the Consumer or his representative, and the supply will be continued from that time, according to the agreement entered into. The stop-cock should be screwed down after working hours every night, and on Sundays and holidays.

11. The Company's nominal pressure in the mains is 700 lbs. per square inch.

This is the average pressure in the service-pipe at its junction with the street main. The service-pipe will be laid of sufficient size to give whatever supply may be required and specified; and the makers of machinery must so proportion the pipes and valves on the Consumer's premises, as to convey the pressure to the machines without undue loss. The pressure will vary to some extent in different localities, and makers of machinery should ascertain from the Engineers of the Company what pressure will be given before constructing their machinery.

12. The Company reserves the right to discontinue the supply at any time should the machinery on the Consumer's premises fail, from any cause, to fulfil any of the foregoing regulations.

13. The Company will not be responsible for any damage that may arise either from interruptions of supply, or from any matter connected with the machinery, pipes, or other apparatus fixed upon Consumer's premises.

APPENDIX IV.—LONDON HYDRAULIC POWER COMPANY. SCALE OF CHARGES
for HYDRAULIC POWER, SUPPLIED per QUARTER, by METER.

Minimum charge, £1 5s. per machine.

Quantity of Water in Gallons.	Amount of Charge.	Quantity of Water in Gallons.	Amount of Charge.	Quantity of Water in Gallons.	Amount of Charge.
£. s. d.		£. s. d.		£. s. d.	
Or under 3,000	1 5 0	52,000	12 16 0	102,000	20 4 6
4,000	1 13 0	53,000	12 19 0	103,000	20 6 9
5,000	2 0 0	54,000	13 2 0	104,000	20 9 0
6,000	2 6 0	55,000	13 5 0	105,000	20 11 3
7,000	2 12 0	56,000	13 8 0	106,000	20 13 6
8,000	2 18 0	57,000	13 11 0	107,000	20 15 9
9,000	3 4 0	58,000	13 14 0	108,000	20 18 0
10,000	3 10 0	59,000	13 17 0	109,000	21 0 3
11,000	3 15 0	60,000	14 0 0	110,000	21 2 6
12,000	4 0 0	61,000	14 3 0	111,000	21 4 9
13,000	4 5 0	62,000	14 6 0	112,000	21 7 0
14,000	4 10 0	63,000	14 9 0	113,000	21 9 3
15,000	4 15 0	64,000	14 12 0	114,000	21 11 6
16,000	5 0 0	65,000	14 15 0	115,000	21 13 9
17,000	5 5 0	66,000	14 18 0	116,000	21 16 0
18,000	5 10 0	67,000	15 1 0	117,000	21 18 3
19,000	5 15 0	68,000	15 4 0	118,000	22 0 6
20,000	6 0 0	69,000	15 7 0	119,000	22 2 9
21,000	6 5 0	70,000	15 10 0	120,000	22 5 0
22,000	6 10 0	71,000	15 13 0	121,000	22 7 3
23,000	6 15 0	72,000	15 16 0	122,000	22 9 6
24,000	7 0 0	73,000	15 19 0	123,000	22 11 9
25,000	7 5 0	74,000	16 2 0	124,000	22 14 0
26,000	7 10 0	75,000	16 5 0	125,000	22 16 3
27,000	7 15 0	76,000	16 8 0	126,000	22 18 6
28,000	8 0 0	77,000	16 11 0	127,000	23 0 9
29,000	8 5 0	78,000	16 14 0	128,000	23 3 0
30,000	8 10 0	79,000	16 17 0	129,000	23 5 3
31,000	8 14 0	80,000	17 0 0	130,000	23 7 6
32,000	8 18 0	81,000	17 3 0	131,000	23 9 9
33,000	9 2 0	82,000	17 6 0	132,000	23 12 0
34,000	9 6 0	83,000	17 9 0	133,000	23 14 3
35,000	9 10 0	84,000	17 12 0	134,000	23 16 6
36,000	9 14 0	85,000	17 15 0	135,000	23 18 9
37,000	9 18 0	86,000	17 18 0	136,000	24 1 0
38,000	10 2 0	87,000	18 1 0	137,000	24 3 3
39,000	10 6 0	88,000	18 4 0	138,000	24 5 6
40,000	10 10 0	89,000	18 7 0	139,000	24 7 9
41,000	10 14 0	90,000	18 10 0	140,000	24 10 0
42,000	10 18 0	91,000	18 13 0	141,000	24 12 3
43,000	11 2 0	92,000	18 16 0	142,000	24 14 6
44,000	11 6 0	93,000	18 19 0	143,000	24 16 9
45,000	11 10 0	94,000	19 2 0	144,000	24 19 0
46,000	11 14 0	95,000	19 5 0	145,000	25 1 3
47,000	11 18 0	96,000	19 8 0	146,000	25 3 6
48,000	12 2 0	97,000	19 11 0	147,000	25 5 9
49,000	12 6 0	98,000	19 14 0	148,000	25 8 0
50,000	12 10 0	99,000	19 17 0	149,000	25 10 3
51,000	12 13 0	100,000	20 0 0	150,000	25 12 6
		101,000	20 2 3	151,000	25 14 9

LONDON HYDRAULIC POWER COMPANY. SCALE OF CHARGES—*continued*.

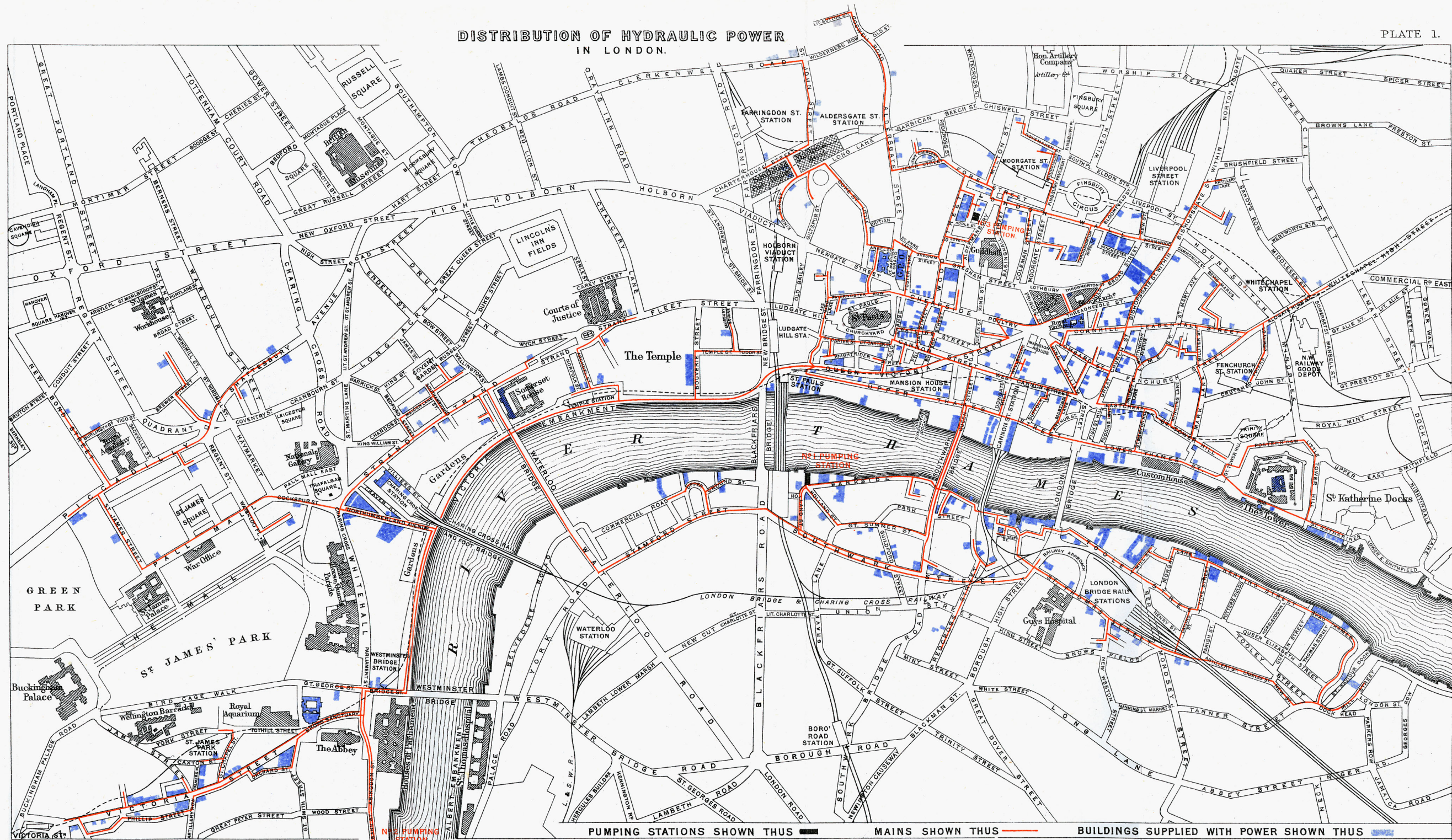
Quantity of Water in Gallons.	Amount of Charge.			Quantity of Water in Gallons.	Amount of Charge.			Quantity of Water in Gallons.	Amount of Charge.		
	£.	s.	d.		£.	s.	d.		£.	s.	d.
152,000	25	17	0	202,000	31	9	6	252,000	37	2	0
153,000	25	19	3	203,000	31	11	9	253,000	37	4	3
154,000	26	1	6	204,000	31	14	0	254,000	37	6	6
155,000	26	3	9	205,000	31	16	3	255,000	37	8	9
156,000	26	6	0	206,000	31	18	6	256,000	37	11	0
157,000	26	8	3	207,000	32	0	9	257,000	37	13	3
158,000	26	10	6	208,000	32	3	0	258,000	37	15	6
159,000	26	12	9	209,000	32	5	3	259,000	37	17	9
160,000	26	15	0	210,000	32	7	6	260,000	38	0	0
161,000	26	17	3	211,000	32	9	9	261,000	38	2	3
162,000	26	19	6	212,000	32	12	0	262,000	38	4	6
163,000	27	1	9	213,000	32	14	3	263,000	38	6	9
164,000	27	4	0	214,000	32	16	6	264,000	38	9	0
165,000	27	6	3	215,000	32	18	9	265,000	38	11	3
166,000	27	8	6	216,000	33	1	0	266,000	38	13	6
167,000	27	10	9	217,000	33	3	3	267,000	38	15	9
168,000	27	13	0	218,000	33	5	6	268,000	38	18	0
169,000	27	15	3	219,000	33	7	9	269,000	39	0	3
170,000	27	17	6	220,000	33	10	0	270,000	39	2	6
171,000	27	19	9	221,000	33	12	3	271,000	39	4	9
172,000	28	2	0	222,000	33	14	6	272,000	39	7	0
173,000	28	4	3	223,000	33	16	9	273,000	39	9	3
174,000	28	6	6	224,000	33	19	0	274,000	39	11	6
175,000	28	8	9	225,000	34	1	3	275,000	39	13	9
176,000	28	11	0	226,000	34	3	6	276,000	39	16	0
177,000	28	13	3	227,000	34	5	9	277,000	39	18	3
178,000	28	15	6	228,000	34	8	0	278,000	40	0	6
179,000	28	17	9	229,000	34	10	3	279,000	40	2	9
180,000	29	0	0	230,000	34	12	6	280,000	40	5	0
181,000	29	2	3	231,000	34	14	9	281,000	40	7	3
182,000	29	4	6	232,000	34	17	0	282,000	40	9	6
183,000	29	6	9	233,000	34	19	3	283,000	40	11	9
184,000	29	9	0	234,000	35	1	6	284,000	40	14	0
185,000	29	11	3	235,000	35	3	9	285,000	40	16	3
186,000	29	13	6	236,000	35	6	0	286,000	40	18	6
187,000	29	15	9	237,000	35	8	3	287,000	41	0	9
188,000	29	18	0	238,000	35	10	6	288,000	41	3	0
189,000	30	0	3	239,000	35	12	9	289,000	41	5	3
190,000	30	2	6	240,000	35	15	0	290,000	41	7	6
191,000	30	4	9	241,000	35	17	3	291,000	41	9	9
192,000	30	7	0	242,000	35	19	6	292,000	41	12	0
193,000	30	9	3	243,000	36	1	9	293,000	41	14	3
194,000	30	11	6	244,000	36	4	0	294,000	41	16	6
195,000	30	13	9	245,000	36	6	3	295,000	41	18	9
196,000	30	16	0	246,000	36	8	6	296,000	42	1	0
197,000	30	18	3	247,000	36	10	9	297,000	42	3	3
198,000	31	0	6	248,000	36	13	0	298,000	42	5	6
199,000	31	2	9	249,000	36	15	3	299,000	42	7	9
200,000	31	5	0	250,000	36	17	6	300,000	42	10	0
201,000	31	7	3	251,000	36	19	9				

Over 300,000 gallons, by special terms.

The special terms per 1,000 gallons beyond 300,000 gallons are usually 2s. per 1,000.

DISTRIBUTION OF HYDRAULIC POWER IN LONDON.

PLATE 1.



PUMPING STATIONS SHOWN THUS ■ MAINS SHOWN THUS — BUILDINGS SUPPLIED WITH POWER SHOWN THUS ■

DISTRIBUTION OF HYDRAULIC POWER. IN LONDON.

PLATE 2.

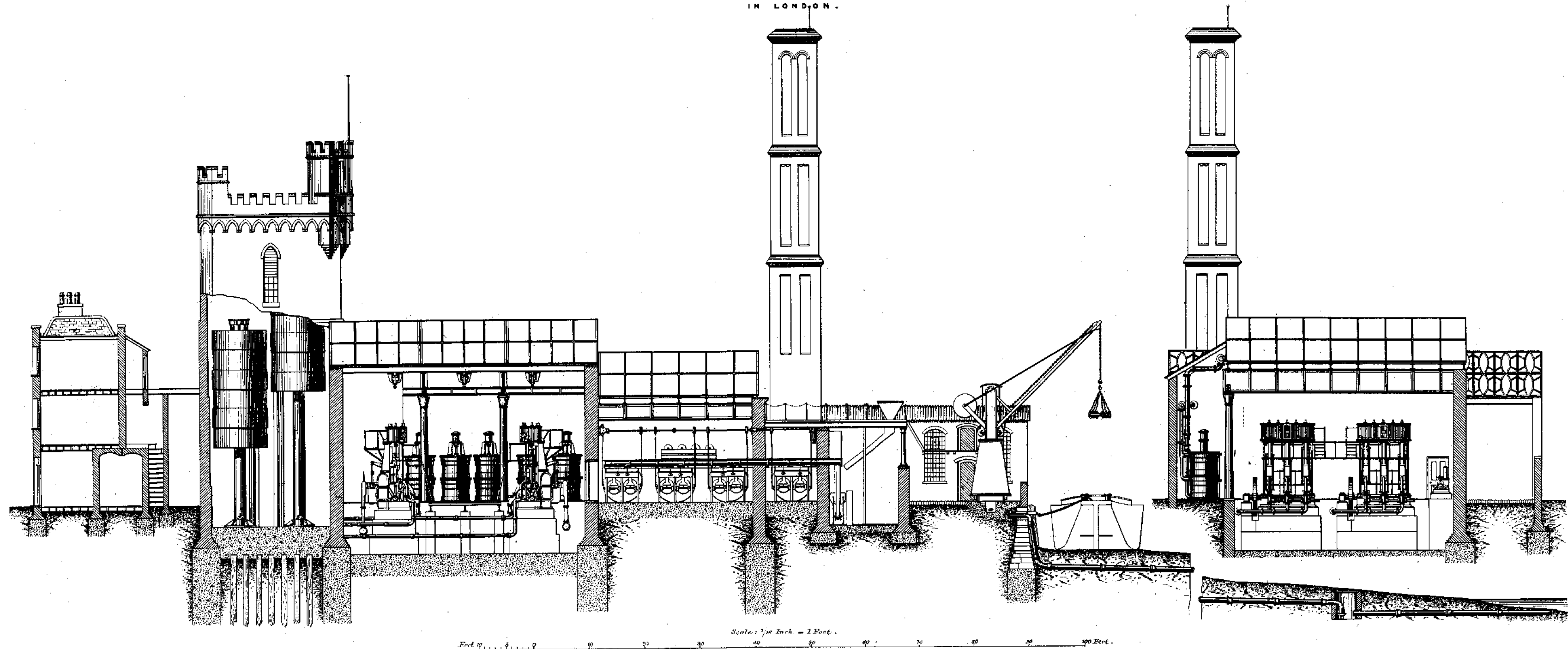


Fig: 1.

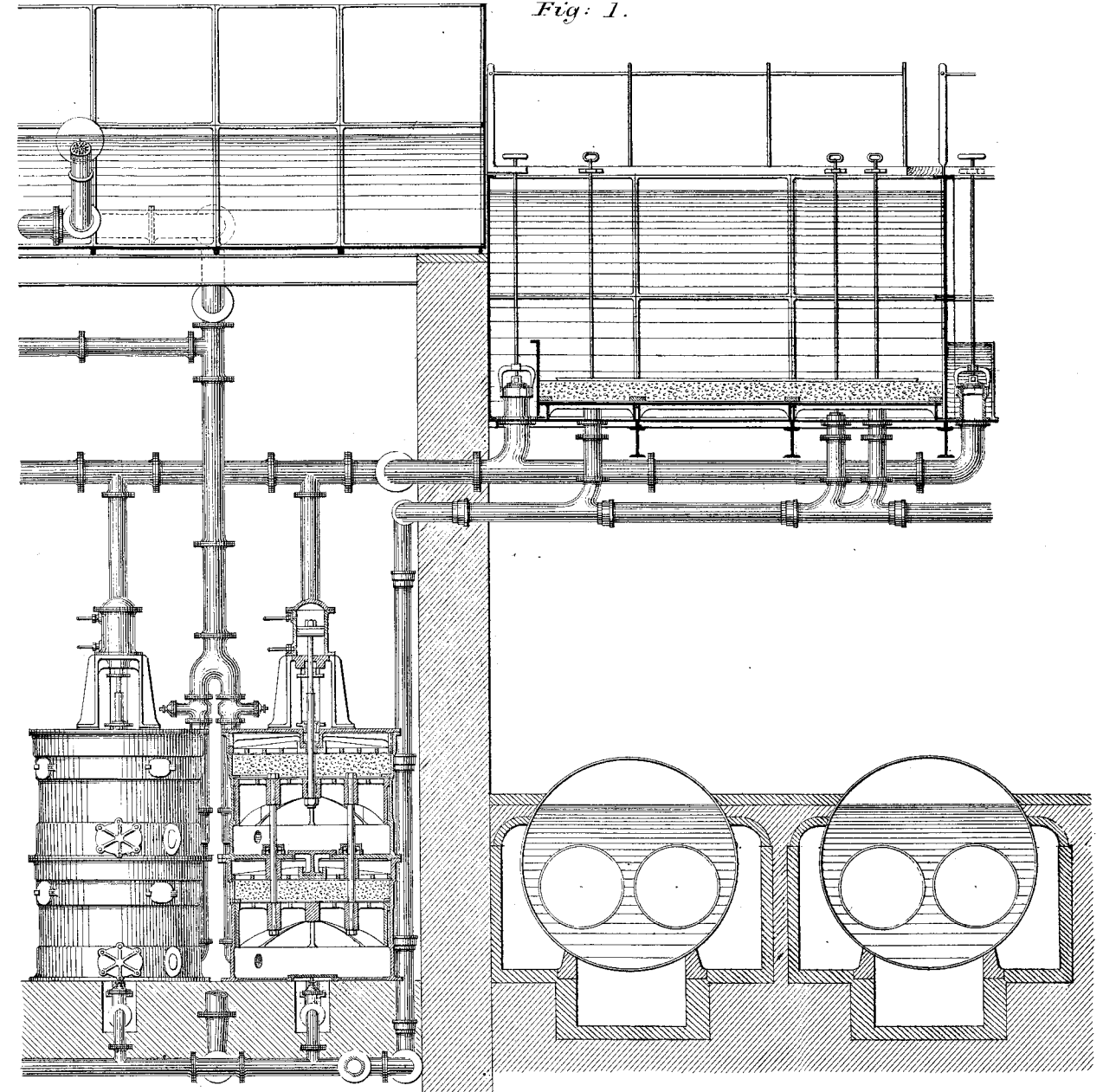


Fig: 2.

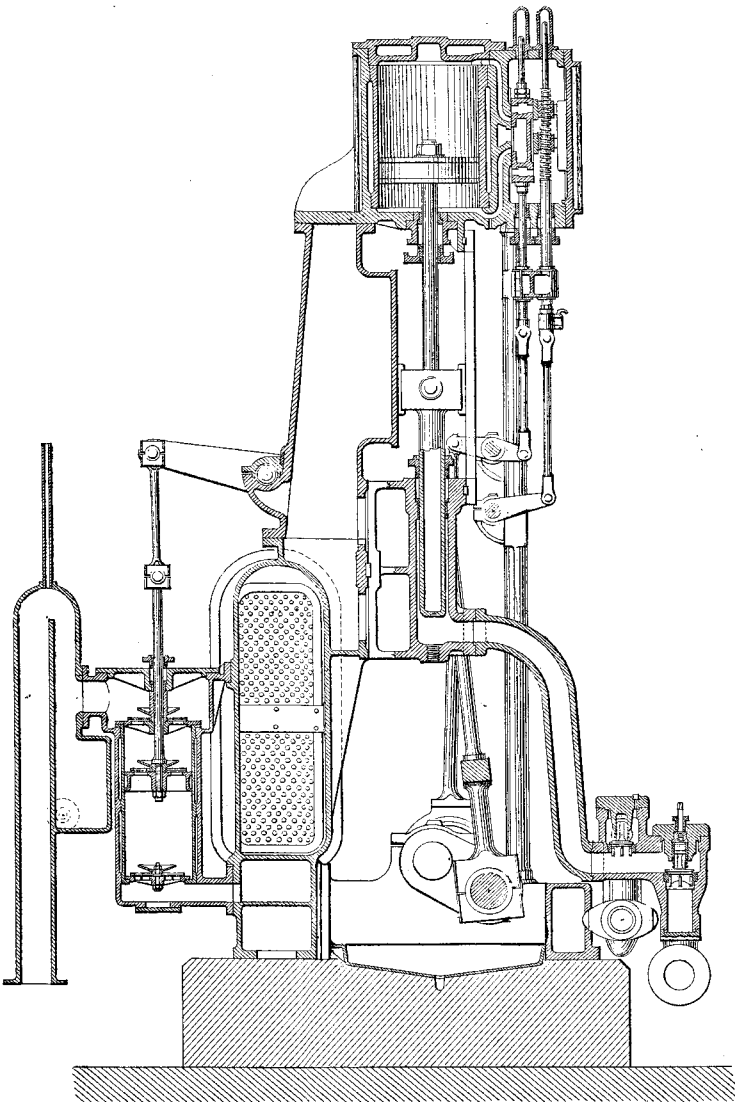
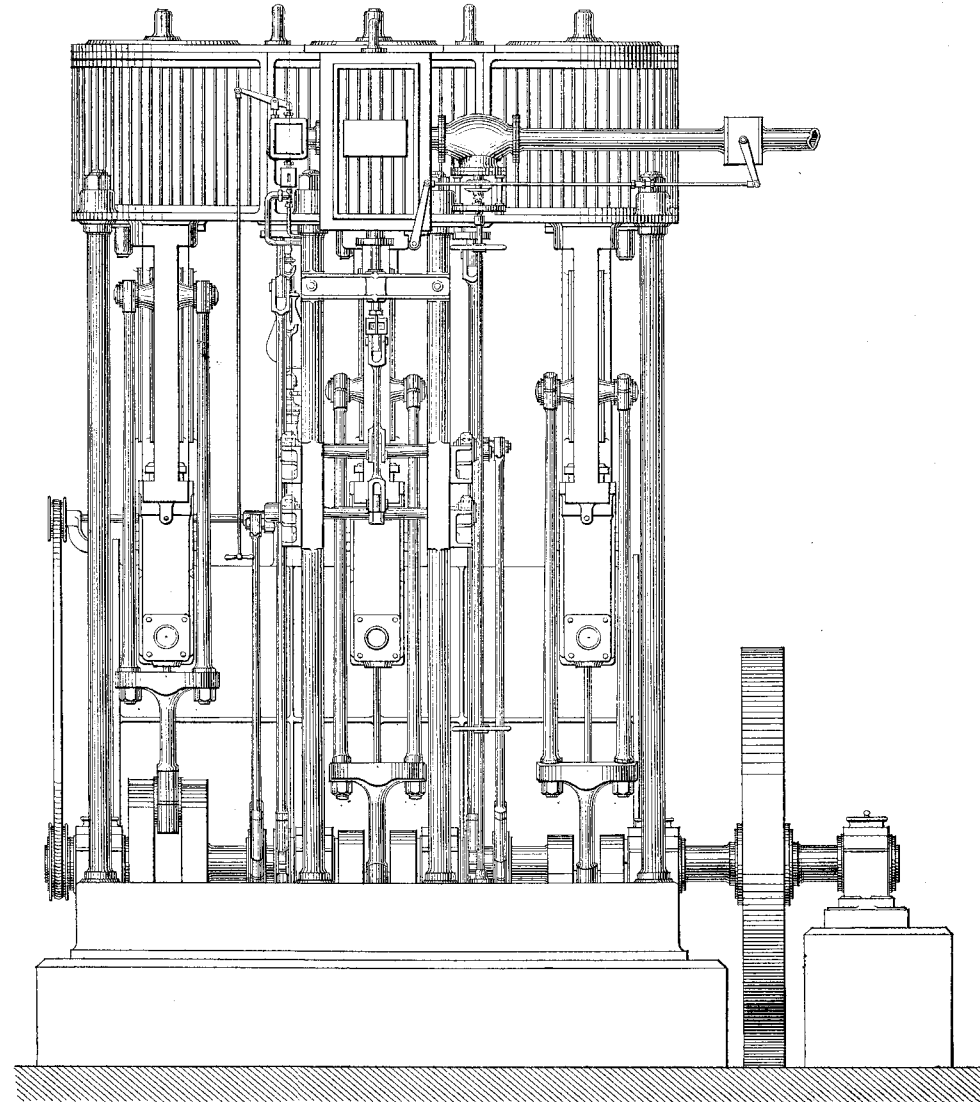
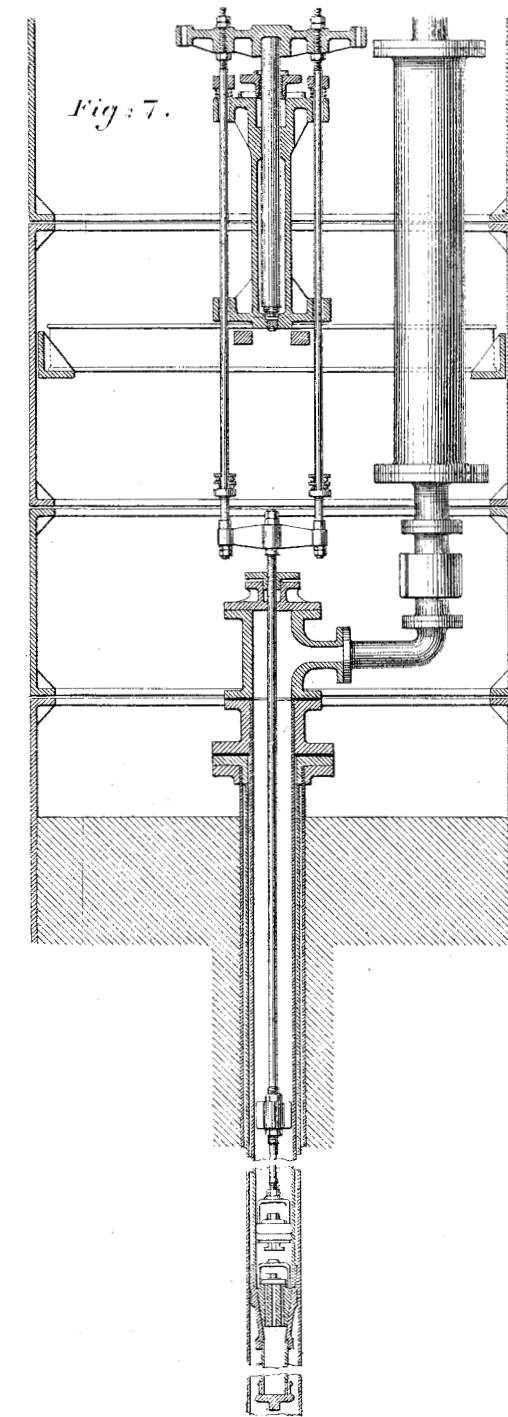
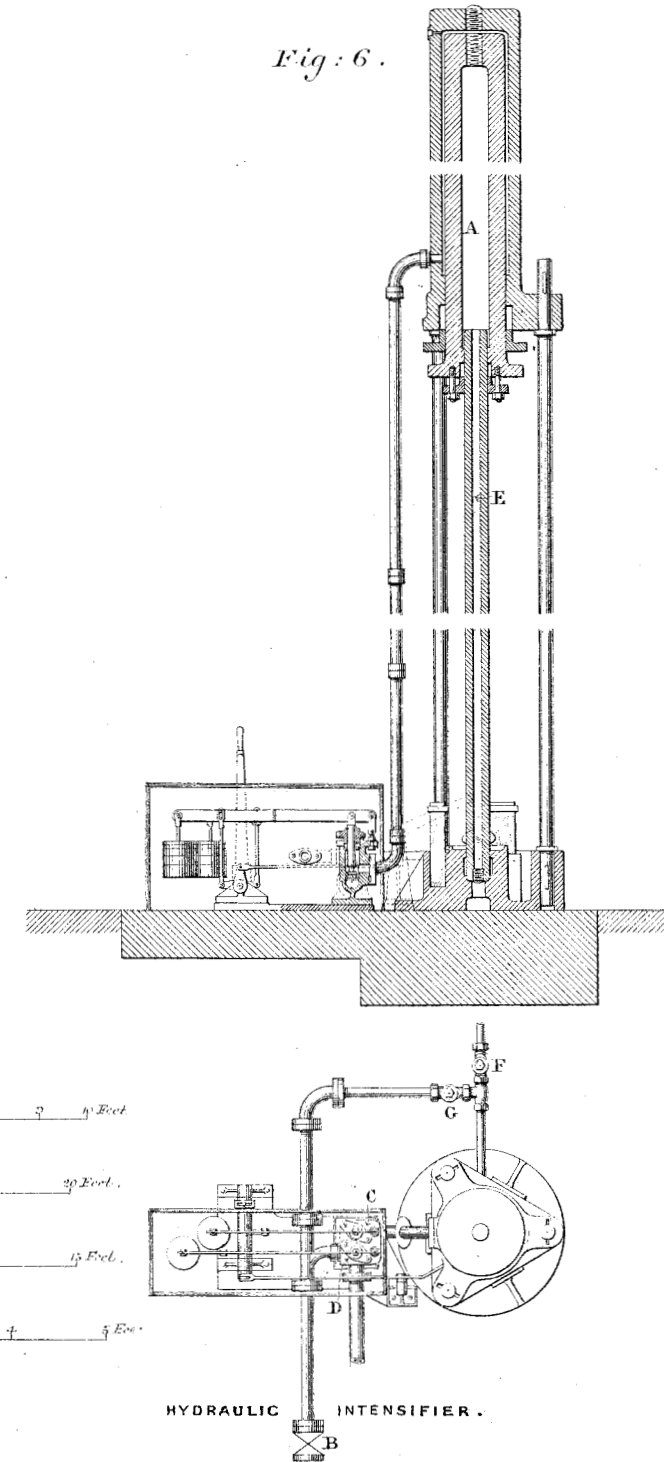
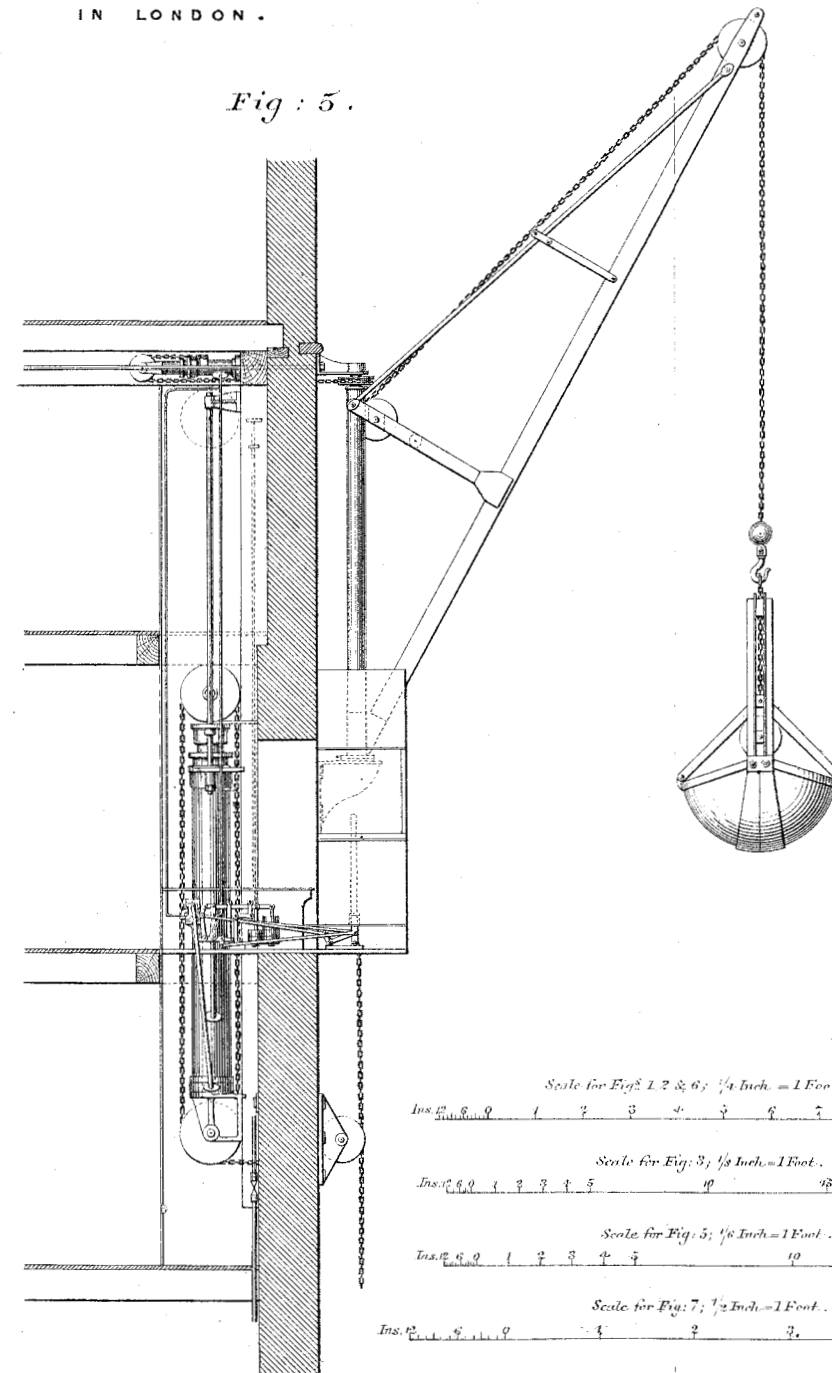
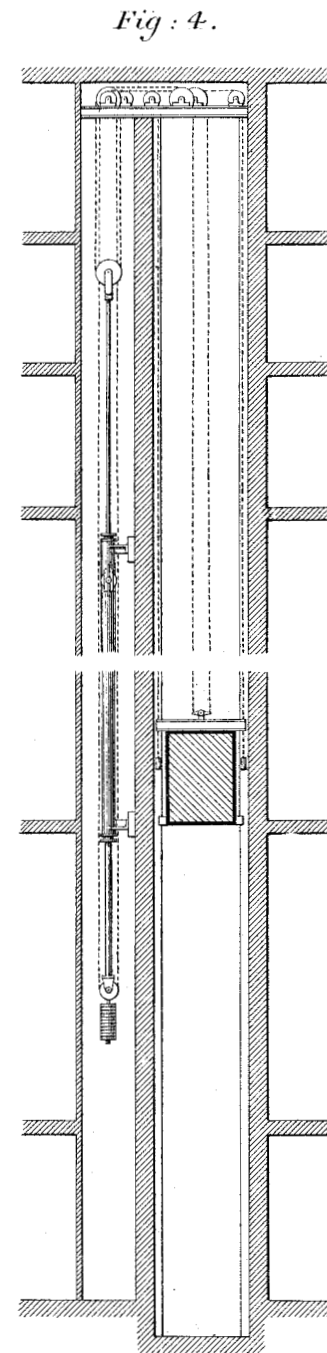
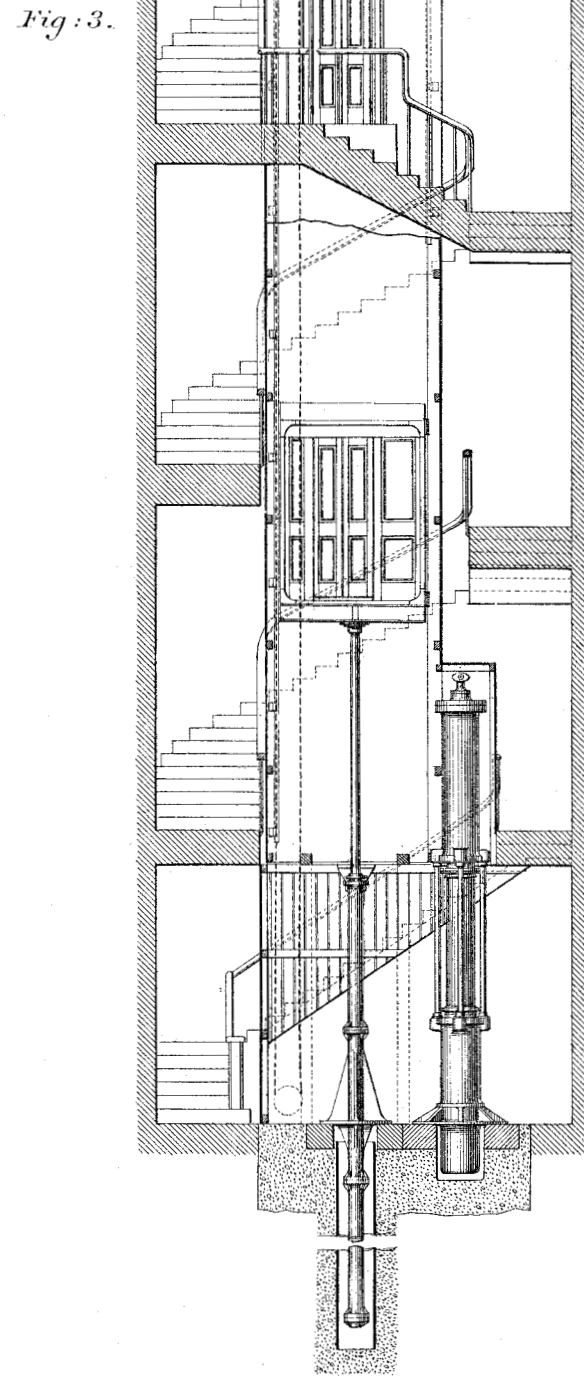
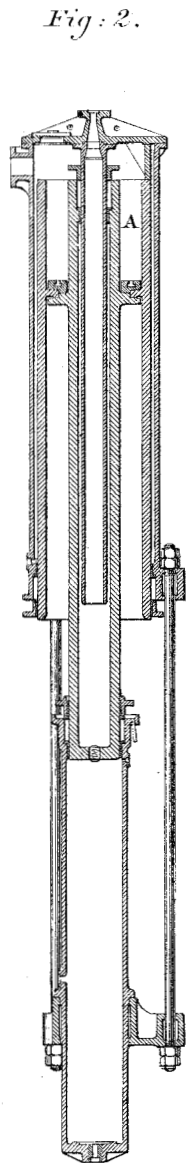
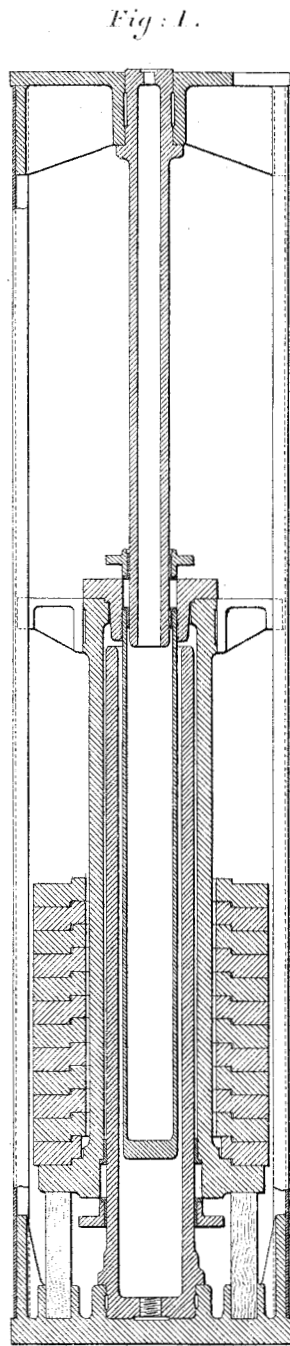


Fig: 3.





HYDRAULIC BALANCES.

HYDRAULIC BALANCE PASSENGER LIFT.

DIFFERENTIAL LIFT.

HYDRAULIC WALL CRANE.

HYDRAULIC INTENSIFIER.

DEEP WELL PUMPING APPARATUS.