9. The Company will also adequately remunerate any person who will communicate timely information to their officers of any leakages or wastes of water, and whether the same be accidentally, negligently, or wilfully occasioned or suffered.

10. The Company do not permit their officers, servants, workmen, or agents, to solicit or receive any fee or gratuity whatsoever, and desire to be informed with respect to any infraction of this regulation, and also in respect to any act of incivility or neglect of attention on the part of such officers, servants, workmen, and agents, or any of them.

By order of the Directors,
JOHN SULTZER, Chairman.

N.B.—Applications for a supply of water, and all other information, must be made, and may be obtained at the Company's offices, in Surrey Street, Norwich.

In case of fire, it is requested that immediate information may be given to the Company's officers and turncocks.

For the enforcement of the regulations made by the Waterworks authorities, power is in all cases obtained by the special legislation. It is true that, by the 'General Waterworks Clauses Act, 1847,'* the provisions of which are usually embodied in the special Acts, the communication pipes have 'to be of a strength and material to be approved of by the undertakers, or, in case of dispute, to be settled in England or Ireland by two Justices, and in Scotland by the Sheriff, or in either case by the inspector to be appointed as aforesaid,'—that is, one appointed under any local or general Act for the purpose of inspecting or superintending works connected with the paving, drainage, or supply of water. Moreover, this Act confers a power to inspect premises supplied with water, and inflicts a penalty for wilful waste. Sections 54, 55, and 56 give control over the house fittings, but, curiously enough, only under the intermittent system. By the Waterworks Clauses Act of 1863 the penalty for waste is extended to cases where the fittings are not in proper repair, or so used or contrived as to occasion waste, misuse, or undue consumption. The powers thus conferred, however, were found totally inadequate to control the distribution of water under the constant system with economical results. A prescriptive power was found necessary, and in most cases authority was obtained, by special enactments, to make regulations absolutely and without appeal; and in the Sheffield Act it was provided that the regulations were to be approved by two Justices. The propositions of the Waterworks Company were opposed by the Municipal Authorities, the enquiry before the Justices was extended over three months, and costs to nearly ten thousand pounds, were incurred. The following are the sections of the Norwich Act which have reference to the means adopted for the prevention of waste.

XLV. For the purpose of preventing the waste, misuse, or undue consumption or contamination of the Company's water, the Company may from time to time prescribe the size, nature, strength, materials, mode of arrangement, and repair of the pipes, valves, cocks, cisterns, water-closets, and other apparatus to be used, and may interdict any arrangement, and the use of any pipes, valves, cocks, cisterns, water-closets, and other apparatus which in their judgment may tend to any such waste, misuses, undue consumption, or contamination.

XLVI. The Company shall not be bound to supply any water, unless the pipes, cocks, cisterns, water-closets, or other apparatus to be used be made of such size, nature, strength, and materials, and be so arranged and repaired as the Company from time to time prescribe or approve; and in the event of any dispute as to whether such pipes, cocks, cisterns, water-closets, and other apparatus are of such size, nature, strength, and materials as aforesaid, or have been so arranged and repaired as prescribed and approved by the Company, such dispute shall be settled by two justices, either of the City of Norwich or the County of Norfolk, in the manner provided by 'The Railways Clauses Consolidation Act, 1845,' with respect to the recovery of damages not specially provided for, and of penalties, and for the determination of any other matter referred to Justices.

XLVII. The Company may, after twenty-four hours' notice, repair or alter any pipe, valve, cock, cistern, water-closet, or other apparatus of any person supplied by them with water, so as to prevent any waste of water; and the expenses of the repair or alteration shall be repaid to them by the person on whose credit the water is supplied thereto, and may be recovered by them as damages.

XLVIII. Every person supplied with water by the Company who wilfully or negligently suffers any pipe, valve, cock, cistern, water-closet, or other apparatus to be out of repair, or so used as that water supplied to him by the Company is wasted or misused, so as to allow an undue consumption of the Company's water, or to allow the return of foul air or other noisome or other impure matter to return into the pipes belonging to the Company, or connected with the mains or pipes of the Company, shall for every such offence forfeit to the Company a sum not exceeding five pounds.

The compilation of the rules is without appeal, but the decision of two Justices may be taken on the question of the regulations having been duly complied with. Under the 'Metropolis Water Act, 1871,' the regulations are to be made by the Companies for their respective districts, and are to be subject to the approval of the Board of Trade.

An efficient code of regulations having been framed, the enforcement of their strict observance is an essential to success. There have been cases where regulations excellent in themselves have been allowed to

* See Page 224.

remain almost a dead letter, and of course with the worst results in respect of waste. The first thing that is necessary is to ensure that all the pipes and fittings are put right ; and the next is that their state of efficiency shall be maintained. On the first introduction of the constant supply into Manchester, the Corporation followed the plan adopted in many small towns; they became their own plumbers, in order to ensure that their work should be satisfactorily executed. This measure, however, excited great opposition, and ultimately the system of 'authorised plumbers' was adopted, and with the best results. The Corporation have no power to prevent the execution of work by unauthorised plumbers; but the advantage of the consumer in employing a tradesman of whose work the approval is guaranteed, are so well known that unauthorised plumbers are but very rarely engaged. Where the pipes and fittings have once been properly adjusted, their maintenance in a state of efficiency is not a very difficult matter, and at the same time the facilities for wilful or negligent waste are considerably reduced. There have been at times loud expressions of opinion against the supposed inconvenience to which consumers would have to submit in the shape of inspection of the domestic apparatus by the Waterworks authorities. But there are no complaints on this score from the towns where the constant system, with its necessary house-to-house inspection, has been in operation for years. Indeed, an annual visit appears to be sufficient in most cases, although the General Waterworks Clauses Act of 1847, as we have seen, gives to the officers of the Waterworks full power of entry between the hours of 9 a.m. and 4 p.m., and power to cut off the supply in case of admittance being refused. In the Metropolis, and in some provincial towns, any person refusing to the officers of the Waterworks Company admittance for the purpose of inspection, or, if need be, repair of fittings, is liable to a penalty of five pounds. For neglecting to attend to the regulations made by the Waterworks authorities, and for permitting the fittings to be in such a state as to cause waste, the consumer is, in most towns, under special Acts for the constant supply, liable to a penalty of five pounds, and to the discontinuance of his supply.

In introducing the service of water to a house for the first time, the pipes and fittings taken collectively are found to cost less for the constant than the intermittent system. With the constant system, it is true, there are the superior fittings and the stronger pipes, but with the intermittent there are the larger storage cisterns (supposing waste-preventing cisterns to be used for the constant service) and the larger pipes. There is great contrariety of opinion, however, as to what arrangements are best when changing an established intermittent system into a constant one, and as to the cost attending the change.

In considering this question it should be remembered that although powers are generally secured to control the existing fittings, and make them conform to the regulations, such powers have seldom, if ever, been exercised without a prudent discretion. In the lower class of property, the waste from imperfect fittings is always greatest, and here it is necessary that the regulations should be enforced ; but in houses of the better class the fittings are generally in a fair condition, and the existing arrangements are not interfered with unless they are found defective and occasion waste ; and where such is the case, and there only, is the opportunity taken of making the whole conform to the rules. These are important considerations, and affect not only the expense, but the inconvenience of the change.

First, with regard to the communication pipes, and their capability to resist the increased pressure, which, as we have seen, would necessarily accompany the constant system. 'When the change was made,' says Mr. Bateman, 'in Manchester, no alteration was made in the pipes, and yet the pressure was increased. When the water was introduced into Glasgow, which was partially an intermittent and partially a constant supply, the pressure was increased at least 100 feet over the whole city, and although here and there a few pipes might have burst, there was nothing like a general alteration whatever. Here and there defective pipes told their own defects, and had to be supplied, but there was nothing like a complaint of the alteration, or of the cost, nor was it necessary to make any extensive alteration.'

Some light will be thrown on this point by a comparison of the weights prescribed in some of the principal constant-service towns with those generally found in the Metropolis. Take, for instance, $\frac{3}{4}$-inch pipes. In Manchester it is 9 lbs. per yard ; in Sheffield and Norwich, 11 lbs. In London the majority of $\frac{3}{4}$-inch pipes are in all probability $6\frac{3}{4}$ lbs. per yard ; and in some districts a pipe of this diameter, and weighing not more than $4\frac{1}{2}$ lbs. per yard, is allowed. What alterations would be found imperative under such conditions as these it is, of course, impossible to say ; but it is worth while here to record that in one of the districts of the New River Company, where the standard for $\frac{3}{4}$-inch pipes is $6\frac{3}{4}$ lbs. per yard, the constant system, with not a very high pressure, was put to 121 houses for several days consecutively, and 19 of the communication pipes burst in consequence.

The relative cost of the mains and distributing pipes, or service under the two systems, is generally introduced into the discussion upon their respective merits. First, with regard to size, *i.e.* discharging capacity of the mains. With constant service the draught on the mains will of course vary directly with the consumption, and this is known, at certain times of the day, to reach from $2\frac{1}{2}$ to 3 times the average rate, some say more. But it is frequently forgotten that, generally speaking, in the intermittent system the service is spread uniformly over about 12 to 14 or 15 hours of the day—the rate of delivery being thus about twice the average consumption. With the same pressure and consumption, then, and supposing the rates of draught to be twice and three times the average consumption in the intermittent and constant systems respectively, the mains in the former case should be able to discharge half as much again as in the latter. But an important feature here suggests itself. As we have seen in a former chapter, the consumption in intermittent-service towns may be taken in round numbers at 30 gallons per head per day; and in constant-service towns—both those originally laid out as such, and those which have been changed into the intermittent—at 20 gallons. If, then, to get the proportionate discharging capacities of the mains, we multiply the 20 gallons by 3 (for the ratio of the maximum to the average draught), and the 30 gallons by 2, there will be in both cases the same result, namely, a maximum draught at the rate of 60 gallons per head per day. As a general principle, then, it cannot be said that the mains will require to be larger for the constant than for the intermittent system. In respect of strength, too, the mains of the two systems are on an equal footing, in so far as that in both cases they will be subject to the same weight, *i.e.* the maximum or hydrostatic pressure.

The distributing pipes or services are, on the other hand, differently circumstanced in the two systems. In the intermittent they are very frequently arranged to deliver the whole day's supply in from one to three hours; so that they must be capable of discharging at from eight to twenty-four times the average rate, as the case may be. In the constant system they, like the mains, will have to deliver at only about three times the average rate, thus being a considerable advantage over the pipes of the intermittent system. In respect of the strength, however, the constant-service distributing pipes will be at a disadvantage, for they will have to withstand the full hydrostatic pressure, whereas this pressure is shut off from the services of the intermittent system, and the latter are exposed only to the hydraulic pressure. The considerations affecting the primary relative cost of the mains and distributing pipes will, of course, to a greater or less extent, determine the cost of the change.

In connection with the subject of mains may be mentioned an objectionable feature of the intermittent system which in its rival is avoided. When the water is shut off from any service or district main of pipes, that which is in the pipes is drained off at the lower levels, thus causing a partial vacuum in the higher parts. Into this vacuum will be drawn any noisome gas or liquid filth, which by means of open stool-cocks, or leaky service or communication pipes, may have access from choked closet-pans, sewage-saturated ground, dust-bins, or the like. Here is a new source of contamination, and instances of its frequency are unfortunately not wanting. With a constant high-pressure service it is scarcely possible for this evil to exist. Its only chance is when an excessive draught from the lower districts causes a vacuum in the higher—an occurrence which should never take place in a system properly regulated. While on the subject of pipes, it will be necessary to mention that it has been objected to the constant system, that there would be great danger of the house pipes bursting in frosty weather. To this objection, Mr. Tomlinson answers:—'In large houses, where the supply pipes go up-stairs to the water-closet cisterns, at the entrance of the communication pipe into the house we place a stop-cock; generally this enters into the underground or basement kitchen, and the tap which they use for ordinary purposes in the kitchen is lower than the whole of the communication pipes up-stairs; in the winter time, I have recommended that the stop-tap, as it enters the house, should be closed; and at night, when the ordinary requirements for water have ceased, the draw-off tap should be opened, so allowing all the water in the communication pipes to be drained; that prevents their freezing. In some cases, where they had no stop-taps, I recommended that the supply should be kept on at a very small stream, and I have found that, during this last winter, that has had the effect of greatly decreasing the number of burst pipes; it has increased the consumption to some extent during the time, but nothing in comparison with the advantage given in respect to the saving of the pipes.' This increase amounted to about 10 per cent. during the time the frost continued.

Some peculiarities of the intermittent system in connection with the extinction of fires have already been noticed; and amongst them is the inconvenience to which consumers must be subjected, if they have no store cisterns, and if it be necessary to shut off their supply for a time in order to concentrate the pressure in the neighbourhood of the fire. The relative advantages of the two systems for fire service may, perhaps, be best illustrated as follows, taking as a fair representative of the intermittent system one in which the water is shut off from the services for about twelve hours, the mains, however, being charged night and day.

If the fire occur where a supply can be conveniently drawn from one of the mains, and if it take place during the day—say, between six or seven in the morning, and in the same hours in the evening—during which time the 'service' in the intermittent system generally lasts, then in the intermittent system either the pressure may be concentrated to the locality of the fire without inconvenience to the consumers, or, if this be not done, the pressure will be reduced by the draught on the mains being at about twice the average consumption; but in the constant system either the pressure is concentrated, and the consumers are thereby inconvenienced, or, if this be not done, the pressure will be reduced by an amount depending upon the time of day,—if in the morning the draught on the mains will be, as we have seen, from 3 to 3½ times the average; and the pressure will vary inversely as the rate of draught. If the fire occur during the night—meaning by this the time during which the service in the intermittent town is discontinued—the intermittent system will have some advantage on the score of pressure.

If, however, the fire takes place where the supply of water cannot be conveniently drawn from a main, but must be taken from a service, then, be it night or day, the constant system will have that most important advantage, namely, that the water will be immediately available, and this consideration alone far outweighs all that can be urged in favour of the intermittent system. True it is that with the intermittent system, after the turncock has arrived, and the cisterns have been filled, the pressure may be concentrated, as it could not in the constant system; but, by this time, the principal damage may have been effected, or the delays may have allowed the flames to gain a mastery, which cannot be overcome till it is too late. Although we have taken care to give the intermittent system credit for all the advantages it offers in case of fire, the balance is evidently largely in favour of the constant system; and in corroboration of this may be mentioned that in Manchester, before the constant supply was introduced, the loss by fire was 21 per cent. of the value of the property attacked; it is now less than 7 per cent.*

Such, then, are some of the principal features of the two systems of service and their chief relative advantages. On the question of purity the intermittent system seems to fail; as far as general convenience to the consumer is concerned, there is not much, perhaps, to choose between the two, and the same may be said with regard to the cost; for the extinction of fires, the advantages are notably on the side of the constant system. It is not intended, however, here to pronounce a decisive opinion, more especially as an experiment is on the eve of being carried out and on a scale of magnitude not yet even approached.

* Evidence of Mr. Bateman on the 'Metropolis Water (No. 2) Bill, 1871.'

CHAPTER XVII.

DESCRIPTION OF PLATES.

Wells: Reservoir Dams and Filter Beds: Bradford and Sheffield Waterworks: Dams, &c.; Bombay Waterworks: Dam and Tower; New River Company's Filter Beds; Leicester Waterworks: Filter Beds and Spencer's Carbide Filter: Covered Reservoirs: Diagrams of Pumping Engines; Eastbourne Waterworks: Engine and Pumps; Lambeth Waterworks: Engine and Pumps: Stand Pipes and Air Valves: Mains; Dublin Waterworks: Valves; Liverpool Waterworks: Valves, &c.: Street Appendages: Hydrants, Meters, &c.; Bideford Waterworks: General Plan and Sections; Reservoir Dam; Filter Beds and Service Reservoir; Dundee Waterworks: Plan of Storage Reservoir; Embankment, &c.; Rotherham Waterworks: Plan of Storage Reservoir; Sections of Embankment, Byewash, &c.: Valve Well, Foot Bridge, Filter Beds, &c.; Port Glasgow Waterworks: Embankment, Filters, &c.; Manchester Waterworks: Reservoirs, Embankments, Sluices, Valves, Compensation Gauges, &c.; Loch Katrine Waterworks: Gauge Weir, Aqueduct, Bridge, &c.; Inlet Sluice, Salmon Stairs, Sections of Aqueduct, &c.; Sluice Valves, Straining Well, &c.; Halifax Corporation Waterworks: Plan of Reservoirs, Waste Weir, Section of Embankment, &c.; Foot Bridge, Valve Well, &c.; Aberdeen Waterworks: Service Reservoir, Inlake, Reservoir Embankment, Inlet Details, Filters, &c.: Cast-Iron Aqueduct, &c.; High Service Reservoir, Sections, Details, &c.; Sections of Aqueduct, Culverts, and Overflow Tanks; Cockermouth Waterworks: Reservoir and Filter Beds; Sunderland Waterworks: Plans, Sections, Details of Service Reservoir, &c.; Engine and Boiler House, Chimney Shaft, &c.; Engine and Boiler House, Details of Engine Frame, &c.; Sections of Well and Staple, showing Pumps, &c.; Details of Pumps, &c.; Canterbury Waterworks: Depositing and Lime Water Reservoirs, General Plan, &c.; Depositing and Lime Water Reservoirs, Engine and Boiler House, &c.; Engine, Boiler, and Well Houses, Service Reservoirs and Filling Pipes, Pumps, Emptying Pipes for Depositing Reservoirs, &c.; Dr. Clarke's Softening Process: Plans and Sections of Depositing, Lime-Water and Service Reservoirs, &c.; Water Towers: Wallasey, Croydon, Birkenhead.

PLATE 1.—WELLS.

ALL these wells, with the exception of Fig. 9, were sunk by Messrs. Thos. Docwra and Son. Fig. 1 is a section of a well belonging to Messrs. Vickers and Co., of Westminster, which was sunk and bored in 1865. Cast-iron cylinders are sunk through the sand and gravel into the clay, and serve to keep surface and land waters out. The top of the 15-inch bore-pipes is above water level, so that by closing the 6-inch cock at the bottom of the well, the latter can be laid dry for examination of pumps. The yield is more than required for all purposes, and the water never flows over the bore-pipe. All the water is from the chalk.

Fig. 2 is a section of a well at the Northampton Waterworks. The water in this well in 1848 rose to within 55 feet of the surface; but by continually pumping to supply the town, the water level was reduced to 106 feet from the surface; as ascertained in 1862.

Fig. 3 is the well at Aspinall's Brewery, Birkenhead, sunk in 1857 and 1858. It was commenced by a local well-sinker, who was unable to continue the sinking on account of the water from the Mersey finding its way through the sand, which he was unable to shut out. At this stage Messrs. Thos. Docwra and Son were consulted, and they inserted a cast-iron bore-pipe, which was carried down into the hard clay. This had the desired effect of shutting out the brackish and unwholesome water. The boring was then carried into the red sandstone for about 34 feet, when a large vein was struck, and the water rose to the surface and flooded the premises; the water flowing out through a pipe which had to be inserted to prevent damage. The supply of water is abundant, and with the available pumping power can only be lowered a few feet. Wells have also been sunk at Cook's Brewery and the Canada Works, in which cases the water runs over, as at Aspinall's.

Fig. 4 is a well at Kensington Gardens, sunk for supplying the Serpentine. The extra thickness of brick-work above the water level in this well is for the support of the girders which carry the pump. The cylinders were misered, and driven through the running sand and pebbles overlying the chalk, shutting out the water entirely. The boring was executed by hand to the depth of 321 feet from the surface, being about 58 feet in the chalk.

Fig. 5 is a well sunk in 1846 at Southampton, through shingle and running sand, the tide having formerly flowed over the site. The two tires of cylinders were sunk and misered 80 feet; a bore-pipe 12 inches diameter was then inserted, and driven into the clay 120 feet from the surface, until the pipe was firmly embedded in the same; the water in the cylinders rose and fell with the tide. A diver was employed to put concrete into the bottom of the well or cylinder to render it watertight, thereby excluding all tidal or drainage water. The boring was carried down 100 feet in the blue clay, and an 8-inch cast-iron pipe inserted into a layer of running sand, making in all a depth of 220 feet from the surface. The water rose in the well and flowed over the top.

Fig. 6 represents a well sunk for Messrs. Berger and Co., at Bow, in 1864. The top two cylinders were firmly driven into the blue clay to keep out surface water. The well was sunk 7 feet in diameter to the upper surface of the live white sand, and steined with 9-inch brickwork. Cylinders 6 feet in diameter were carried down through the various veins of running sand and pebbles. Internal cylinders 4 feet 6 inches in diameter were then inserted and carried through about 50 feet of live sand full of water, and driven through a vein of flints into the chalk at 174 feet from the surface; the chalk was then bored into for a depth of 150 feet, making a total depth of 324 feet.

Charrington, Head and Co.'s well (fig. 7) was sunk in 1866. The top cylinders, 10 feet diameter, are for keeping out surface water. The brickwork below was hung by wrought-iron rods and cast-iron curbs. Cylinders 9 feet diameter were misered and driven into the green sand overlying the chalk. Internal cylinders 7 feet 6 inches diameter were then driven through the flints into the chalk to a depth of 204 feet 6 inches from the surface. An abundant supply of water rises to within about 80 feet of the surface.

Fig. 8 shows a well sunk at Messrs. Savill's Brewery at Stratford, in 1864. Cylinders of 7 feet diameter were carried down through the various strata into a grey sand 95 feet from the surface; and internal cylinders 5 feet diameter passing through a large pebble vein 3 feet thick, overlying the chalk, were driven firmly into the latter, shutting out all surface water. A dome of brickwork 8 feet 9 inches deep was then built under the cylinders to carry them, and the well increased to 7 feet diameter at a depth of 138 feet 6 inches from the surface, where it terminates.

Fig. 9 is a well sunk under the direction of Mr. James Pilbrow, C.E., for supplying the town of Gosport. In this neighbourhood all the surface water obtained from wells overlying the hard blue clay is brackish and appears to have some connection with the sea, so that it is totally unfit for domestic use. Probably this may be from the several strata cropping out or being denuded by the channel between the mainland and the Isle of Wight. From the sand underneath the clay, at a depth of about 300 feet, a good supply of pure water is obtained. In sinking the well great difficulty was experienced in getting through so much running sand, in shutting out surface water, and in providing sufficient pumping power to keep the water down during the progress of the work, as it naturally stood at about 4 feet from the surface, and this level was not altered by the sinking. It is easy, therefore, to imagine the enormous lateral and hydrostatic pressure acting at the back of the work when at a considerable depth; in fact, the heavy iron cylinders were crushed in, and brickwork in cement was inserted to strengthen them and prevent a sudden collapse. At a lower level it was necessary to have an internal cylinder, the annular space between the two being filled up with concrete. On the large cylinders obtaining a depth of 83 feet it was found quite impracticable and unsafe to attempt to move them again, and the same was the case even with the smaller ones, so strong was the pressure of water, and so great its volume, and at about 90 feet the attempt was abandoned, and a bore-hole commenced. To secure the bottom of the well against the upward pressure of the water, a large portion of the space between the cylinders was filled with solid concrete and brickwork. The bore-hole was started with a diameter of 2 feet, but soon altered to one of 12 inches, which was continued to the bottom with a 15-inch guide-pipe for a distance of 138 feet. The lower 25 feet was lined with a perforated copper pipe, all above it being a close and well-jointed cast-iron pipe; so that when the well was finished the water entered at the bottom of the pipe and rose up into the well above, standing, when the pumps were not at work, at about four feet from the surface. The water on being submitted to the analyst was pronounced of the finest and purest quality, thus showing the total exclusion of the brackish water from the upper strata. Such an enormous quantity of sand was 'blown' and pumped up during the progress of the work, that for some few years considerable settlement of the ground around the well took place. The time occupied in the construction of the works was about three years.

Fig. 10 is a well sunk in the Hampstead Road for the New River Company. The upper part of this well, to a depth of 128 feet, was sunk by Messrs. Hunter and English, and the remainder by Messrs. Docwra and Son, who had great difficulty in getting the cylinders through the running sand overlying the chalk. In 1841, the supply not being sufficient, Messrs. Docwra and Son deepened the well about 70 feet (making a total depth of 372 feet from the surface), and increased the diameter to 13 feet. The supply a second time proving too small, four headings were driven (fig. 11) at points where the larger fissures existed, and carried on, until a supply of 300 gallons per minute was obtained, that being the greatest quantity that could be delivered by the pumps.

PLATE 2.—SUGGESTIONS BY ROBERT RAWLINSON, C.E., C.B.

The several diagrams illustrated on this plate are suggestions by Robert Rawlinson, C.E., C.B., Chief Inspector of the Local Government Board, and were intended for the guidance of Surveyors to Municipal Authorities and Local Boards, in preparing plans, &c., for a water supply. It contains illustrations of a Reservoir, Embankment, or Dam, Filter Beds, and Service Reservoirs. Figs. 1, 2, and 3 are views of an ideal embankment, suggested by the Bradfield Reservoir failure. Fig. 1 is a longitudinal elevation, and fig. 2 a cross-section through the outlet culvert. The culvert is constructed in the solid ground so that the greatest amount of security against disruption may be obtained. The bottom of the culvert is about twenty-five feet above the junction of the inner slope of the embankment with the bottom of the reservoir at its deepest part, and a syphon pipe is employed to take off the water lying below the level of the culvert. The horizontal culvert is connected with an upright shaft or valve-well, in which the valves for drawing off the water from the reservoir are placed; the whole of the outlet works are thus under the engineer's command and control, and the pipes and valves may at any time be removed for renewal or repairs. Fig. 4 is an enlarged cross-section of the top of embankment. Figs. 5, 6, and 7 represent the arrangements for a pair of filter beds. Fig. 5 is a plan of the two beds, side by side, with the filtering medium removed, showing the brick channels through which the filtered water is conducted to the well, and thence to the clear water basin, or service reservoir. Fig. 6 is a section through the side of the filter-bed and two of the small drains; and fig. 7 a section through the main drain. The sides of the filters are excavated to a slope of one to one, and both they and the bottom covered with puddle one foot thick; and upon this is a layer of concrete, one foot thick on the bottom and nine inches at the sides. Stone sets are then laid all round the sides from top to bottom. The composition of the filtering medium and the thicknesses of the several strata are clearly indicated in the figures. Figs. 8 and 9 are plan and section of a covered service reservoir. Thorough ventilation should be provided, and provision made by means of manholes for obtaining access to and cleaning out the interior. Fig. 10 is an iron tank for a daily supply. It may be made of cast or wrought iron, and should be well supported and stayed by wrought-iron ties and gusset-pieces. These tanks should always be arranged with a separate supply cistern, so that the supply may go on independently of the tank, thus affording an opportunity for cleansing and repairing, which should be done with regularity. A covering should be fixed over the tank for the purpose of excluding atmospheric impurities and protecting the water against the direct action of the sun's rays. Inlet, outlet, overflow, and wash-out pipes are required, and a valve connecting the cistern with the main tank. An example of this description of tank will be found in the section of the Wallasey Water Tower (fig. 1, plate 50), of which Mr. Rawlinson was the engineer.

PLATE 3.—BRADFORD AND SHEFFIELD WATERWORKS.

Illustrates some of the embankments of the reservoirs belonging to the Bradford Corporation and the Sheffield Waterworks Company, and also the Bradfield reservoir failure. Fig. 1 is a section of the embankment of the Grimwith reservoir, which is situate on the River Dibb, and is 877 feet above sea-level. The greatest height of the dam is 83 feet, and greatest depth of puddle-trench 66 feet. The mean depth of the puddle-trench is 35 feet. The water area of the reservoir is about 94 acres, and its capacity 634,000,000 gallons. The top of the bank is six feet above the level of the waste weir. Two culverts 4 feet by 4 feet take the water into the valve pit, from which it is conducted by a culvert 5 feet 6 inches by 5 feet 6 inches into the gauge basin. Figs. 2 and 3 are sections of the culverts. They are of solid masonry bedded on 3 feet of concrete. The top and sides are protected by 3 feet of puddle. Fig. 4 is a section of double row of 3-feet pipes, which form the upper outlets at this reservoir. The pipes are laid in puddle underneath the bank. Fig. 5 is a section of the Barden reservoir embankment. This reservoir is on Barden Beck, and is about 700 feet above sea-level. The embankment is 86 feet high; the greatest depth of puddle-trench is 60 feet, and the mean depth 45 feet. The water area is 66 acres, and the capacity of the reservoir 440,000,000 gallons. The top of bank is 6 feet above the waste-weir. Fig. 6 is a plan of the culverts and valve-well. The inner culvert is two feet square, and the outer culvert 3 feet 6 inches by 4 feet 6 inches. They are of masonry, and rest on planking, which, in its turn, is bedded on concrete. Fig. 7 is an elevation of the lower outlet, and figs. 8, 9, and 10 are sections of the culverts. There is also an upper outlet from the reservoir to the valve-well, which consists of a 15-inch cast-iron pipe. Fig. 11 is an elevation of this outlet. Fig. 12 is the embankment of the Silsden reservoir, situate on Silsden Beck, at about 580 feet above the level of the sea. The greatest height of dam is 94 feet, greatest depth of puddle-trench 41 feet, and mean depth of same 30 feet. This reservoir contains about 230,000,000 gallons, and has a water area of 25 acres. Fig. 13 shows a section of inner culverts, which convey the water from the reservoir to the valve-well; their dimensions are 3 feet 6 inches by 3 feet 6 inches. The outer culvert from the valve-well is 5 feet by 5 feet, of which fig. 14 is a section. Fig. 15, Stubden reservoir, has an elevation of about 1,030 feet above the sea, and is situated on Stubden Beck. It has an area of 11 acres, and a capacity of 85,000,000 gallons. The greatest height of the bank is 82 feet, greatest and mean depth of puddle-trench 61 and 30 feet respectively. The inner culvert, of which fig. 16 is a section, is 2 feet square; the outer culvert, fig. 17, is 4 feet 3 inches diameter. The Doe Park reservoir (fig. 18) is about 805 feet above the level of the sea; it has an area of about 20 acres, and a capacity of 110,000,000 gallons. The greatest height of the bank is 60 feet, greatest depth of puddle trench 72 feet, mean depth about 45 feet. The valve-well is also used as a waste-pit. The two inner culverts leading to the valve-well are 3 feet 6 inches by 3 feet 6 inches, and the outer culvert 8 feet by 8 feet. The whole of the reservoirs belonging to the Bradford Corporation were inspected by Mr. Rawlinson in 1864, and, with the exception of Doe Park and Barden, were found to be in a satisfactory and safe condition. Figs. 21 to 24 give plan and sections of the embankment of the Bradfield reservoir, the failure of which, on the 11th of March, 1864, caused such disastrous loss of life and property. The reservoir was a mile long, had an area of 78 acres, and a capacity of 114,000,000 cubic feet; at the time of its bursting it was nearly full. The height of the embankment was 95 feet, and the length 1,254 feet. The width of the base through the centre of the bank was 500 feet. Both outer and inner slopes were $2\frac{1}{2}$ to 1, and the bank at the top was 12 feet wide. For a great part of its length the puddle-wall was carried down to a depth of 60 feet before an impermeable stratum was reached. At the surface of the ground the puddle-wall was 16 feet wide, but diminished, with a batter of $1\frac{1}{2}$ inches per foot, to 4 feet at the top. The total cubic contents of the finished bank were 406,000 cubic yards; of this quantity nearly 100,000 were washed away in half an hour. The outlet pipes were 18 inches in diameter, and $1\frac{1}{4}$ inches thick, socket-jointed, and of cast-iron. Two lines of these pipes were laid naked through the embankment at its widest part. They were laid side by side in a puddle-trench 9 feet 6 inches wide, as shown in figs. 21 to 23. The pipes were 2 feet 6 inches apart, with 21 inches between them and the side of the trench. There was also 18 inches of puddle both above and below the pipes. To prevent the pipes being broken in crossing the puddle-wall, the pipe-trench was sunk to the depth of the wall (about 30 feet), and battered 100 feet each way along the line of the pipe-trench, as shown in fig. 22. Socket-jointed pipes were used in order to allow a margin for subsidence of the pipes, as they would admit of drawing a little at the lead-joints. The valves, of which there were a pair, were placed outside the embankment, so that in the event of the pipes breaking it would have been impossible to have saved the bank, as the water could not have been shut off. Figs. 25 to 28 are plan and sections of the waste-weir. Although the most eminent engineers were examined as to the cause of the failure of this bank, no two opinions were alike. Perhaps the general tendency was to believe that a slip of the earth had taken place under the embankment. Mr. Rawlinson, in his report to the Home Secretary, was of opinion that a sinking of the pipes by the weight of the embankment took place to such an extent as to cause either fracture or dislocation of the pipes when crossing the puddle-wall, or to leave a hollow in the puddle-wall above the pipes, as shown in fig. 22, and thus cause a passage for the water. Experienced engineers, however, were found who did not agree with this view, and, indeed, to the present day the question as to the cause of the disaster remains a moot-point.

PLATE 4.—BOMBAY WATERWORKS.

These works, of which Mr. Conybeare was engineer, were commenced towards the close of the year 1856. The Vehar basin, in the valley of the Goper, was chosen as the site for an impounding reservoir. The area draining into this basin is 3,948 acres, but this area might be enlarged, by the extension of catch-water drains, to 5,500 acres. The storage capacity of the Vehar reservoir is 10,800,000,000 gallons. The maximum depth is 80 feet, and it covers an area of 1,394 acres. The water was impounded by three dams, 835, 555, and 936 feet long. Fig. 1 is a longitudinal section through the axis of the first embankment. The extreme height of this dam is 84 feet. Fig. 2 is a contoured plan of the same, also showing the waste-weir. Fig. 3 is a section across the dam. The top width of this dam, which carries a road, is 24 feet. The inner slope is 3 to 1 and the outer $2\frac{1}{2}$ to 1. These embankments were formed in layers of 6 inches. The puddle walls are 10 feet wide at the top, and have a batter of 1 in 8 on each side. The trenches for the foundations were excavated into the solid basalt below the surface rock. The slopes and tops of all the embankments are covered with stone pitching 12 inches in depth, with another 12 inches of broken stone underneath. Fig. 4 is a section through the waste-weir. This weir is 358 feet long, with a top width of 20 feet. It is faced throughout with chisel-dressed Ashlar set in cement. On the inner margin is a plank screen to prevent the water being blown over the weir. Fig. 5 is a cross section of the dam at inlet tower. Figs. 6, 7, 8, 9, and 10 show elevation, sections, plans, &c. of inlet tower. This tower has four inlets, fixed at vertical intervals of 16 feet apart, through which the water is drawn from the reservoir. The inlets are 41 inches in diameter, and are provided with conical plug-seats, faced with gun-metal. The plugs are suspended exactly over their seats from the balcony above, and are raised or lowered at will, by crane-work at the top of the tower. The inlet in use is surmounted by a wrought-iron straining-cage covered with No. 30 gauze copper wire, and fixed to a conical ring, fitting into the inlet orifice, in the same manner as the plugs, and equally capable of being raised and lowered at pleasure. At the bottom of the inlet well, and exactly over the orifice of the supply main, another conical seat is fixed, into which a similar straining-cage (but with No. 40 gauze copper wire) is inserted. The tower is a very good example of Indian architecture.

PLATE 5.—NEW RIVER COMPANY.

Filter Beds.

Fig. 1 is the general plan of the filter beds at this station of the company, showing the way in which the water is taken from the New River. The bed No. 3 is illustrated with its filtering material removed, and shows the means by which the water is drained into the two wells, and thence into the emptying drain or filtered water culvert.

The beds numbered 6 and 7, though of smaller area, are constructed to filter the same amount of water. A description of the means by which this is accomplished, and the saving thereby effected, will be found in Chapter IX. Figs. 2 and 3 are longitudinal sections of these two beds, fig. 3 showing the transverse section of the inlet pipe by means of which the water is discharged on to the sand. Fig. 4 is a transverse section of bed No. 7, showing the two drains by which this filter is traversed, and the inlet pipe in section. Figs. 5, 6, and 7 are sections of Filter No. 3, but equally illustrate the filter-beds numbered 1, 2, 4, and 5, Fig. 8, is an enlarged plan, showing the brick flooring, a sectional plan of the emptying drain, and plan of the extraction-pipe. Fig. 9 is a part-transverse section of one of the beds 6 and 7, showing the battered walls, by means of which, together with the brick flooring, the above-named saving of cost is effected. Fig. 10 is a section through one of the two main drains of filters 6 and 7. Fig. 11 is an enlarged plan, which shows the arrangement by which the water is admitted and withdrawn from the remaining five filters. Fig. 12 is a transverse section of the New River at one of the intakes, with the discharge on to the filter. Fig. 13 is a similar section showing the well and valve to the emptying drain.

The material of the beds 7 and 8, as will be seen by fig. 10, consists simply of fine sand, 2 feet 6 inches in depth, and a 6-inch layer of gravel. A greater depth of gravel, with shingle (3 feet), is used in the other five beds, and the fine sand is only 2 feet in depth.

PLATE 6.—LEICESTER WATERWORKS.

Filter Beds.

Figs. 1 to 6 illustrate the filter beds at the New Leicester Waterworks, of which Mr. Thomas Hawksley is the engineer. The works are situated at Bradgate Park, about seven miles from Leicester. The reservoir has a water area of 130 acres, and a capacity of 500,000,000 gallons. From the reservoir the water passes into the filter beds, of which there are four. The upper stratum of the filtering material consists of a layer of siliceous sand 2 feet 6 inches in thickness, which is obtained from the River Trent, at a cost of 13*s.* 6*d.* per cubic yard. The total thickness of filtering medium is 6 feet. When the sand has to be cleaned a layer $\frac{3}{8}$-inch thick is taken from the top and placed in an iron tank in the centre of the filter bed. This tank is 9 feet deep, and the sand in it is washed by an upward current of water, the contents being agitated by stirrers. Any sand that may pass away with the water is deposited in a catch-pit, thus preventing any waste. The water passes through the filter beds at the rate of 6 inches per hour, or at the rate of 750 gallons through every square yard of surface in twenty-four hours. From the filters the water passes into the pure water tank. To prevent the pressure exceeding a certain limited amount, the filtered water is delivered into the pure water tank through a stand pipe, the top of which is two feet below the water level in the filters.

Figs. 7 to 10 illustrate Mr. Spencer's Patent Carbide Filter. The curved dotted lines illustrate Mr. Spencer's extraordinary notion of the paths very obligingly taken by the particles of water in passing through the filtering media.

PLATE 7.—COVERED RESERVOIRS.

Figs. 1 to 5 are plans and sections of a covered reservoir constructed at Selhurst for the Lambeth Waterworks Company, of a capacity equal to $2\frac{1}{4}$ million gallons, from the design of the late Mr. James Simpson, C.E. The covered reservoir at Putney, constructed about the same time for the Chelsea Waterworks Company, from the design of the same engineer, has a capacity of 10,000,000 gallons, and cost £22,000. Figs. 6 and 7 are sections of a covered reservoir belonging to the Brompton, Chatham, Gillingham, and Rochester Waterworks Company, from the design of Mr. James Pilbrow, C.E. Figs. 8 to 11 are plans and sections of a reservoir in Greenwich Park, belonging to the Kent Waterworks. The reservoir is circular in form, and was originally an open one. By covering it the impurities are kept out and an additional depth of water obtained. Fig. 12 shows the details of one of the girders which carry the brick arches. This reservoir was designed by the late Mr. Morris.

PLATE 8.

Illustrates the various types of pumping engines, which are fully described in Chapter XI., to which the reader is referred.

PLATE 9.—EASTBOURNE WATERWORKS.

Represents a pumping engine made by Messrs. Moreland and Son for the Eastbourne Waterworks Company. This engine is of a kind peculiarly well adapted to situations where economy is desirable in the construction of the engine-house and foundations. This was particularly the case on the site of the above-named works, where there is a bed of soft ooze from 25 to 30 feet thick, affording no foundation for even a light structure till it is penetrated and the greensand rock below it is reached. The well from which the water has to be pumped is over 100 feet deep, and is built in brickwork down to the greensand rock of the dimensions shown in figs. 6 and 7. The engine and pump work is so constructed that the whole is carried on the brickwork of the well, and at the same time so arranged that there is room for a duplicate engine on the same foundations, and duplicate pumps in the well whenever such may be required. The engine is condensing and expansive, with the cylinder steamjacketed both round the side and at the ends; and the high level at which the cylinder is placed enables the condensed water from the jacket to be returned to the boiler. The cylinder is fitted with variable expansive slides working on the back of the slide-valve, by which the steam can be shut off at any point from $\frac{1}{5}$ to $\frac{3}{4}$ of the stroke. The air pump and condenser are placed on two girders secured in the brickwork of the well, as shown in figs. 1, 2, and 8. These girders also carry the well pumps. The girders and the pump-work resting on them are made strong enough to carry the whole of the pump-work reaching to near the bottom of the well, where provision is made for inserting two girders (see fig. 4) just below the working barrel of the pump. Immediately above the girders and under the working barrel is the suction-valve box (see figs. 4 and 5), with two travelling wheels attached to it. When the pump is at work these wheels are $\frac{1}{2}$ inch clear of the girders, but when it is required to obtain access to the suction-valve the bolts are taken out of the flange-joint which connects the valve-box to the pump-barrel, thus lowering the valve-box and suction-pipe on to the girders. The wheels enable them to travel on the girders, so that they can be kept clear of the pump-work above. The suction-valve can thus be examined, and, if desired, lifted out by a chain lowered from the top of the well. The pump-bucket can also be lowered out of the working-barrel, so that it can be conveniently packed if necessary, and restored to its place with much less labour than if taken out at the top. The pipe and cock attached to one side of the working-barrel, as shown in figs. 4, 9, and 10, are for establishing a communication between the upper and lower ends of the working-barrel when the engine is being started, and thus making it more easily turned round by hand or got into motion by the steam. When the engine is going steadily the cock is closed. The opening or closing of this cock is effected by a lever and weight (fig. 10) and a copper wire rope extending to the top of the well. The principal dimensions of this engine are as under:—

Diameter of steam cylinder, 29 inches.
„ pump barrel, 17¼ „
Length of stroke, 2′ 6″.

The lift when pumping from the lowest water level in well to lowest service reservoir is 270 feet. The lift to the highest reservoir is about 400 feet. The average duty of this engine's working for twelve months was 50,000,000 lbs. raised one foot high for each cwt. of coals consumed.

PLATE 10.

This engine was constructed by Messrs. Simpson and Co. for the Lambeth Waterworks Company. A full description will be found in Chapter XI., pages 166 and 167.

PLATE 11.—AIR-VESSELS AND STAND-PIPES.

Figs. 1, 2, and 3 are sections and plan of wrought-iron air-vessel at the Bourne Waterworks. These works were designed and carried out under the superintendence of Mr. Pilbrow, in 1857. The works are very simple; in fact, these three figures show all the works except the mains and bore hole that were necessary for the supply of the town. A boring was made through clay, gravel, and limestone, till, at 90 feet, a fissure was entered, when the water rose rapidly. To prevent the water escaping through the gravel an iron tube was inserted, the bottom of which was driven firmly into the rock. This was connected with a large air-vessel at the top, and the whole enclosed in an arched brick vault. From the air-vessel the main is led into the town. The yield from this boring is considerably over half a million gallons a day, a quantity sufficient for five or six towns like Bourne.

Pumping-engines are liable to serious accidents from the bursting of the mains beyond the engine, whereby the engine suddenly loses its load; and, as these breakages almost always occur during the indoor stroke, with the full pressure of the steam on the piston, and when the velocity is greatest, a violent blow, and often a serious accident, is the result. This evil is sometimes sought to be avoided by the erection of a stand-pipe close to the engine-house, and equal in height to the full hydrostatic load on the engine. These are at all times very expensive erections, and only applicable to limited heights of lift.

Mr. Husband's patent Balance-valve (fig. 4) is designed to supersede the costly stand-pipe. It is applicable under all conditions of load, and by its use all possibility of accident arising from the bursting of mains is entirely avoided, for it suddenly closes a valve at the moment of fracture, and thus prevents the possibility of the engine ever losing its load.

Fig. 4 is a section of the complete apparatus. Fixed vertically as near to the engine as practicable is a strong casting provided with two short flanged branches, the lower one being connected with the discharge outlet from the pumps, and the upper one with the delivery main. Between these branches a gun-metal valve of the double beat description is placed, and is connected to an additional water-tight beat working on the top of the valve seating. The seating is firmly held down by bolts passing through it and fastened to the casing. A ram lined with gun-metal, and of the same diameter as the upper valve, is secured, water-tight, into it by a cotter, and works vertically up and down, passing through a stuffing-box packed with cup leather, bolted to the upper portion of the casing. The head of the ram works in a cross-guide bushed with gun-metal, and supported by four strong vertical pillars. The ram is loaded with weights nearly equal to the minimum load of the engine; the lowest weight is provided with lugs, working loosely over the vertical pillars, which are provided with adjusting nuts and leather washers, for the purpose of preventing the valve from falling heavily and injuring its seating.

The action of the apparatus is as follows: The water, on entering the casing from the pumps, acts upon the under side of the upper valve. The area of this valve is the same as that of the ram, which, being loaded somewhat under the working load of the engine, is immediately lifted, raising the valve with it, and thus giving the water free access to the delivery main. In the event of the main being fractured at any point beyond the valve the pressure within the mains is suddenly reduced on account of the great escape of water, and is consequently nable to support the loaded valve, which immediately closes; thus the working load of the engine is retained, and the possibility of accident by racing prevented.

Some of the largest London waterworks engines have been fitted with this apparatus, where they have been in operation for some years, with the most complete success.

Figs. 5, 6, 7, and 8 illustrate a cast-iron air-vessel, proposed to be erected at the Trowbridge Waterworks, and similarly arranged to one erected by the late Mr. W. R. Morris, of the Kent Waterworks. A full description of the mode of charging will be found in Chapter X., page 154.

Fig. 9 is the elevation, and Fig. 10 the sectional plan of the stand-pipe at Battersea, belonging to the Southwark and Vauxhall Waterworks Company. There are three pipes, which are strongly braced together. The largest one, which is open at the top, reaches a height of 178 feet.

Figs. 11, 12, and 13 are section, elevation, and plan of stand-pipe tower, which is connected with the Grand Junction Waterworks, at Kew Bridge. The chimney being carried up inside the tower allows of the temperature of the water in the stand-pipe being maintained above the freezing point in winter.

PLATE 12.—PIPES AND PIPE-JOINTS.

Figs. 1, 2, 3, and 4 represent branches or outlets of various diameters; figs. 1 and 2 having $\frac{1}{8}$ bend outlets of equal diameter. Fig. 3 is a 4-inch pipe, with 3-inch $\frac{1}{8}$ bend outlet; and fig. 4 a 6-inch pipe, with 3-inch quarter bend outlet. Fig. 5 is a quarter bend, 7 inches diameter; fig. 6 a junction piece, 2 feet diameter; fig. 7 a quarter and an eighth bend. Fig. 8, a front view and longitudinal section of a ball and socket or universal joint, and is specially convenient for curves, or in places where the main is liable to be deflected. The interior of the socket is bored, and the exterior of the ball turned, in order to make the joint close and watertight. Fig. 9 is a reducing piece, tapering in this instance from 5 inches at the large to 4 inches at the small end. Figs. 10 and 12 are hydrant pieces. Fig. 11 is a collar or barrel, 6 inches diameter; fig. 13 a breeches-piece; fig. 14 a reducing piece; fig. 15 a bell-mouthed inlet; fig. 16 a special casting, provided with a flange or shield for the purpose of preventing the water creeping along the entire length, when the line of pipes passes through a bank or puddle wall. Fig. 17 is an ordinary lead-joint for the 44-inch main of the Liverpool Waterworks; fig. 18, lead-joint for 48-inch main, Dublin County Waterworks; fig. 19, lead-joint for 7-inch main, Canterbury Waterworks; fig. 20, lead-joint for 12-inch main for same. This pipe is provided with bosses round the socket-end, for convenience in attaching the house services. Fig. 21, turned and bored joint for 42-inch main, Dublin County Waterworks; fig. 22, turned and bored joint for 36-inch main, Liverpool Waterworks; fig. 23, turned and bored joint for 12-inch main, Glasgow Waterworks; fig. 24, joint for 12-inch main, Trieste Waterworks; fig. 25, joint for 6-inch main, Launceston Waterworks; fig. 26, for 12-inch main, Buenos Ayres Gas-works; fig. 27, for 9-inch main, Dundee Waterworks; fig. 28, 18-inch main, Hamilton (Canada) Waterworks; fig. 29, 12-inch main, Fylde Waterworks; fig. 30, 10-inch main, Hobart Town Waterworks; fig. 32, Mr. Downie's suggestion for a turned and bored joint; fig. 33, turned and bored joint 30-inch main, Sydney Waterworks; figs. 34 and 35, bored joints 36-inch main, Liverpool Waterworks. The former is made slightly spherical, to admit of small deviations in the line of pipes, or in case of settlement of the ground.

Figs. 37 and 38 are designed to prevent the contraction of water-way in a main by the spigot of a joint not being set concentric or fair with the adjoining pipe. The bore is enlarged almost to the extent of the play between the spigot and socket. In fig. 39 the enlargement of the back of the socket will assist in working straight pipes round a curve in the road, and would also have a tendency to prevent the joint drawing, but the ioint is of a form rather unfavourable to the process of setting up. Fig. 40, lead-joint, 32-inch main, Bombay Waterworks.

PLATE 13.—DUBLIN WATERWORKS.

Figs. 1, 2, 3, 3*a*, 3*b*, 4, 5, and 6 illustrate a self-acting throttle-valve. Valves of this description are placed on the main for the purpose of automatically shutting off the water should a fracture occur on the line of main beyond them. Fig. 1 is a section through the pit containing the valve, showing an elevation of the same, and also of the 33-inch sluice-valve. Fig. 2 is a cross-section of vault, showing side elevation of 33-inch sluice-valve. Fig. 3, a half-sectional plan of vault, showing part plan of throttle-valve and manhole for entering the 33-inch main, and half-plan on top showing doors for covering the stop-valve, and for obtaining ingress to the vault. Figs. 3*a* and 3*b* are enlarged section and plan of these doors. Figs. 4, 5, and 6 are enlarged elevation, plan, and cross-section of the throttling gear. A more detailed description of this valve and its mode of action will be found in Chap. XII. Figs. 7 and 8 are cross and longitudinal sections of an ordinary 24-inch single-acting sluice-valve, and fig. 9 a cross-section of a 27-inch double-acting sluice-valve. Fig. 10 is a section of a percussion valve, used for absorbing the concussion in the mains occasioned by the closing of the large sluice-valves. Fig. 11 is section of a single-acting air-valve. These valves are placed on the summits of the undulations in a line of main, in order to allow of the escape of air from the mains when they are being charged, and at other times as it may accumulate. A fuller description of these valves (figs. 7 to 11 inclusive) is given in Chap. XIII.

PLATE 14.—LIVERPOOL WATERWORKS.

Figs. 1 to 4 illustrate a self-acting throttle-valve in use at the Liverpool Waterworks, of which Mr. Hawkesley was the engineer. The throttle-valve M is placed on a horizontal spindle in the main, and on the outer end of the spindle is a chain wheel, E, carrying a heavy weight, which tends to close the throttle-valve M, but is prevented from doing so by the trigger A catching the stop on the wheel E. A flat disc C, about 18 inches diameter, is held in the main at the end of a long horizontal lever, presenting its flat face against the current; and as long as the velocity of the current does not exceed the proper limit the disc is held stationary in its place by the weight D (see figs. 3 and 4), the vertical spindle on which the disc lever C is carried being geared by toothed sectors to the spindle of the weight lever D; and the throttle-valve M then stands full open, presenting its edge to the stream, as shown by the dotted line M M, fig. 3. When a fracture takes place on the down-stream side the velocity of the current along the main is increased, the disc C is pressed forwards, as shown in fig. 4, the trigger A is released, and the weight on the wheel E of the throttle-valve spindle descends, turning the throttle-valve M across the main, as shown by the dotted line in fig. 4, and thereby stopping the passage of the water. The spindle of the throttle-valve is placed $1\frac{1}{2}$ inch out of the centre of the valve, so that the pressure of the water may assist the weight in closing the valve. In order to prevent the throttle-valve from closing too suddenly, and thereby causing an injurious concussion upon the main by the sudden stoppage of the long column of water, its motion in closing is retarded by a piston working in a small water cylinder K, the piston-rod being connected to the wheel E on the throttle-valve spindle. A small pipe communicates from the top of the cylinder K to the small cistern B on the top of the main, and a second pipe from the bottom of the cylinder to the cistern; in the first of these a stopcock H is placed, worked by a lever F, and as the wheel E turns round, closing the throttle-valve M, a stud on the wheel raises the lever F, and gradually closes the stopcock H, as shown in fig. 4, so that the discharge outlet from the cylinder K is throttled, and the closing of the throttle-valve M retarded. When the valve M has to be opened again the small hand force pump L connected with the cistern B is used to force the piston down to the bottom of the cylinder K, thereby turning back the wheel E into its original position and opening the throttle-valve M. The delivery-pipe from the force-pump enters below the stopcock H, which is kept closed until the opening of the valve M is completed, when the whole apparatus is set again in its original working position. Owing to the use of the retarding cylinder K and stopcock H, about three minutes are occupied in shutting the throttle-valve M. These self-acting throttle-valves were furnished by Sir W. G. Armstrong and Co., of the Elswick Works.

Figs. 5 and 6 are sections and plan of self-acting shut-off valve. This valve is placed on the outlet-pipe from the various reservoirs for the purpose of ' shutting off the flow of water from the reservoir when a fracture takes place on the pipe line on the delivery side. The outlet-pipe N has an upturned end, fitted with a brass face, over which is suspended vertically the cylindrical valve P of the same diameter, with a brass face on the bottom, fitting the face of the pipe N. In the outlet-pipe is hung a flat disc C at the end of a long lever, presenting its flat face to the current of water flowing off from the reservoir, and weighted by the weight D, so as to stand still as long as the water flows through the pipe at the proper velocity. But whenever a fracture takes place on the delivery side of the pipe the current is accelerated, and the disc C is thereby thrown forwards, as shown dotted in fig. 5; the trigger A is thus released and thrown off, and the large suspended cylinder P descends on the orifice of the pipe N, shutting off all further passage of the water down the pipe. Alarum bells connected with the valves have recently been fitted to each of the cottages at the reservoirs, where these valves are placed, so that if the valves run down the bell is rung to warn the keeper.'

Figs. 7 and 8 are section and elevation of an escape-valve. These valves have been placed along the line of main and behind the self-acting throttle-valves. They are loaded slightly over the working pressure in the main, and communicate with some convenient watercourse; so that, when the current is stopped by the closing of the throttle-valve, the escape-valve is lifted as soon as the recoil reaches it, an escape of some water takes place, and so on at every pulsation, until the force of the recoil falls within the limit to which the valve has been loaded over the working pressure, whereby all danger to the main is prevented.

Figs. 9, 10, and 11 are elevation, section, and plan of a reflux valve. One of these is ' placed on the end of the inlet-pipe supplying the water to the reservoir.' It ' consists of a series of hinged doors or flaps with brass faces hung on the orifice of the inlet-pipe, which has also brass faces slightly inclined to the vertical. The current of water entering the reservoir keeps the flaps sufficiently open to allow the water to pass in; but whenever a fracture occurs at a point on the down stream side lower than the water in the reservoir, the weight of the valves and pressure of the water closes them, and so prevents a reflux of the water from the reservoir.'

Figs. 12 and 13 are section and plan of a float-valve. ' The pipe is fitted with a sloping end-piece N, on which is hinged a flap-valve M. When any stoppage takes place on the down stream side the water rises in the tank, and the floats C rise, and by means of the levers A close the flap-valve M and shut back the water in the supply pipe N ; until the water again falls on the lower side, when the floats fall and open the valve again, as shown dotted in fig. 12, allowing the water to run free as before.'

Figs. 14, 15, and 16 show a regulator to prevent waste. The water is admited into an iron tank through the pipe N, which is turned up at the end. A beam is supported above the tank, to one end of which a float C is attached, and to the other end a cylinder, P, which is immediately over the orifice of the pipe N. As the water rises to the required level the float C rises with it, causing the cylinder to descend till it reaches the orifice of the pipe N, and stops further entrance of the water. B is the outlet orifice, an enlarged section of which is shown in fig. 14.

PLATE 15.—STREET APPENDAGES.

Fig. 1.—Two-inch Hydrant and Stand-pipe. This firecock was designed and patented by Messrs. Bateman & Moore in 1849, and supreseded the wooden plugs then in use. Among its advantages are, 1st, that the opening

and shutting are accomplished so gradually that all concussion is avoided; 2ndly, that their construction prevents their being injured by frost; and 3rdly, which is not the least important advantage from an economical point of view, they serve as self-acting dischargers of air. Fig. 1 is a vertical section of the fire-cock or hydrant, with standpipe attached, showing also the connection of the former with the main at G. The hydrant is contained in a cast-iron casing, and when in exposed situations is protected by a cast-iron box with an ordinary loose lid. The stand-pipe is a copper or iron tube, through which the water rises to two discharging tubes, one of which, H, is provided with a screw cap for use when one outlet only is required. Both outlets have screws for connection with the hose, and by means of the revolving-joint at C can be turned in any direction. At the lower end is a screw, cut down to a collar L, which is faced at its lower end with a leather washer. This works in a female screw, which is provided with projecting pins F F for passing under the lugs P P (figs. 2 and 4). The stand-pipe is attached by slipping the pins F F between the lugs P P, and turning it half round, so that the pins are caught under the lugs; when this is accomplished the stand-pipe is screwed down to the seating N, the washer ensuring a perfectly water-tight junction. The valve A is a solid ball made of some elastic substance of less specific gravity than water. It is kept closed against a seating, O, of leather or similar substance, by the pressure in the main. The spindle B, which opens the valve, has a handle at the top, and passes through a stuffing-box down the centre of the pipe to the bottom, where it works in a screw. The spindle has a cup-shaped termination, which, when the handle is turned, presses down the valve A, and allows free passage to the water. When released the ball is forced up by the water. If, however, the main be empty or air get in, the ball falls and allows the air to pass up. Figs. 3 and 4 show valves patented by Chrimes. The valve E is a metal disc, and to prevent this dropping, when the main is empty, a spring R is introduced. Fig. 3 shows the valve when open; fig. 4 closed. Figs. 6, 7, and 8 illustrate Siemen's Water Meter. It measures, inferentially, within 2 per cent. of the actual quantity of water passing through it. Fig. 6, which is a section of this meter, shows the inlet union at A, for connection with the supply-pipe, the measuring-drum, and outlet union at B. The water passes through a strainer, C, into the inlet chamber, D, of the meter, thence through another strainer, E, which prevents the passage of any injurious matter that may have got through the first strainer from passing through the measuring-drum, to which latter the water is conducted by the funnel F. The water in passing out of the drum through the curvilinear pipes, H (fig. 8), causes the drum to revolve. From the chamber I, which is always full, the water is discharged through the pipe K. Attached to the drum are regulating vanes L, (fig. 8), to ensure the same number of revolutions of the drum under varying velocities. The wheels of the dial-work are protected from the action of the water by oil, with which the chamber M is filled. This dial-work is set in motion by the screw N on the spindle O; above this are the dial-plate and differential wheels, which are protected by the glass plate P. The drum may be taken out by unscrewing the bottom plate R. Figs. 9 to 13 represent an ordinary 4-inch sluice-valve. The valve is double-faced, and both faces and their seatings, together with the spindle and nut for working the valve, are of brass or gunmetal. Eyebolts, A A, are used to facilitate the removal of the gland.

PLATES 16, 17, & 18.—BIDEFORD WATERWORKS.

Plate 16.

Fig. 1 is a general plan showing the gathering ground, storage reservoir, and line of pipes to Bideford. Fig. 2 is a section along the line of mains. Figs. 3 and 4, an enlarged plan and section of storage reservoir and filter beds. The reservoir is of irregular shape, about 700 feet long. The dam is over 450 feet in length, and about 50 feet high on the stream-line. The filters are two in number, placed one on each side of the service reservoir or tank. Fig. 5 consists of a number of transverse sections through the reservoir, &c.

Plate 17.

Fig. 1 is a section through the dam and outlet culvert. The inner slope of the dam is pitched with rubble, resting upon a layer of fine selected material 1 foot thick, which again is underlaid by a layer of puddle 2 feet in thickness. The width of the bank at top is 12 feet, and its height above top water 3 feet.

The width of the puddle-wall is 4 feet at the top, and 17 feet at the bottom. The puddle-wall is carried down 7 feet below the natural surface of the ground, and bedded on concrete. The outlet well is composed of cast-iron cylinders; a wooden foot-bridge connects it with the dam. The culvert, through which two lines of cast-iron mains are laid, is of brickwork 4 feet in diameter, and is strengthened at intervals of about 8 feet by additional rings. Fig. 2 is a longitudinal section through dam. Figs. 3 and 4 are plan and sections of cylinder, which is 4 feet in diameter, widening to 5 feet 9 inches at the bottom. Figs. 5 to 8 are sections of overflow weir. Figs. 9 and 10 are plan and section of pipe-culvert. Figs. 11 and 12 are plan and elevation of bridge at dam. It will be noticed that the section of the dam shown in Fig. 1 is not that at the vertical plane, which passes through the axis of the outer culvert: the culvert is formed in the solid ground.

Plate 18.

Figs. 1 to 5 are sections and plan of filter beds and service reservoir. The service reservoir is covered with brick arches. It is 60 feet in length by 40 feet in breadth. The height from floor to springing is 11 feet, and to crown of arch 15 feet 6 inches. The depth of water is 10 feet. The floor of this reservoir is pitched with stones 9 inches deep grouted with cement, on which are laid two courses of terra-cotta tiles bedded in cement. The piers supporting the arches are carried down below the solid ground, and rest upon foundations of concrete. The reservoir is well protected by puddle below the floor, and at the sides up to the springing of the roof. Ventilators are provided in the roof. The filters are 72 feet long by 42 feet broad at the top, and have each a sand area of nearly 200 square yards. The sides are formed to slopes of $1\frac{1}{2}$ to 1, and are pitched with stones 9 inches in thickness, backed with 2 feet of puddle. The bottom is pitched with stones 6 inches in depth, on which is laid the filtering material, consisting of:—

12 inches	gravel,	which will pass through a	2″	mesh,	but not through a	$1\frac{1}{4}$″
4	”	”	$1\frac{1}{4}$″	”	”	$\frac{3}{4}$″
4	”	”	$\frac{3}{4}$″	”	”	$\frac{3}{8}$″
4	”	”	$\frac{1}{4}$″,			

making a thickness of 2 feet of gravel, on which is laid 3 feet of washed sand. The depth of water on the filter is 3 feet. The water is admitted by a pipe, the mouth of which is turned up to prevent the sand being scoured. A drain is laid along the whole length of the filter, with which are connected smaller perforated pipes running laterally; each of these has a ventilating pipe attached to it.

The population of Bideford is about 6,000. The area of the gathering ground to be taken at first is about 350 acres. Of this 200 acres lie north of the road, and drain into the Gammerton or port streams. The drainage of the 150 acres on the south of the road can be conducted by a short adit or tunnel by Woodville, and a collecting water-drain or pipes on the south-west. The available rainfall is about 95,287,500 gallons per annum. Should a larger supply be required, a further watershed of 120 acres, with an available rainfall of 12 inches, may be added, by continuing the pipes along the south-west, giving 32,670,000 gallons per annum, and a further watershed of 530 acres, giving 144,292,500 gallons per annum, may also, if necessary, be obtained, thus making a total watershed of 1,000 acres, and giving at 12 inches per annum a total available supply of 272,250,000 gallons, or a supply for more than double the present population at the rate of 30 gallons per head per day. The last two named areas of 150 and 530 acres may be obtained at a cost of £700.

By increasing the height of the dam 3 feet the reservoir capacity has been increased from 18,000,000 gallons to 24,000,000 gallons.

The following is the cost of the works:—

	£	s.	d.
Reservoir and outlet	3,213	7	2
Raising bank of ditto 3 feet	426	10	7
Pipes	2,178	4	3
Sluices, hydrants, &c.	354	5	4
Filter beds and covered reservoir	643	7	9
Lithographing	5	7	6
	£6,821	2	7

PLATE 19.—DUNDEE WATERWORKS.

Fig. 1 represents a general plan of the original works; Fig. 2, the Crombie Den reservoir, with commencement of aqueduct to Craigton; Fig. 3, longitudinal section through embankment; Figs. 5, 6, and 7, sections through embankment by side of road (see fig. 2) at Crombie Den reservoir; Fig. 8, transverse section through embankment, outlet-tower, and culvert, showing gangway to outlet tower; Fig. 9, part plan of embankment of Crombie Den reservoir, with bye-wash, outlet-tower, and channel; Fig. 10, front elevation of iron screen, 20 feet high, with hinged grated cover, 6 feet wide. The grating consists of vertical wrought-iron bars, $1\frac{1}{4}$ inch diameter, with $1\frac{1}{2}$-inch spaces, and eight curved horizontal bars, $3\frac{1}{4} \times \frac{5}{8}$ inch, built into the stone. The cover, framed and riveted, consists of crossbars, $3\frac{1}{4}$ by $\frac{5}{8}$ inch, and $1\frac{1}{4}$ inch round bars. Fig. 11, sectional plan of outlet-tower and sluice, with plans of coping and grated cover. Figs. 12 and 13 represent the outlet shaft or well, showing the method of fixing the platforms and ladders for descent; the four 13-inch square baulks of timber being bolted securely through the wall, having 15 1-inch screw-bolts to each, with cross beams supporting the platforms. The hinged and vertical gratings are also here shown. Fig. 14 is a front view of sluice to outlet-tower. Figs. 15 to 19 are details of the sluice and guides. The catchment basin of these works has an area of 49 square miles. The rainfall averages 33 inches, and the loss by evaporation is found to be about 14 inches.

PLATES 20, 21, 22, & 23.—ROTHERHAM WATERWORKS.

Plate 20.

Fig. 1 is a general plan of the Ulley storage reservoir. The reservoir is situate at the junction of two valleys, and covers an area of nearly 20 acres. It is formed by a dam over 170 yards in length, which is placed across the valley below the junction of the streams. The road from Rotherham to Ulley crosses the reservoir, and is shown on the plan to do so by means of a bank, thus cutting off part of the reservoir from the rest. In consequence of this the water has to be carried under the road by means of a culvert. A bridge has, however, been carried across, in lieu of the bank, since this drawing was made. There are inlets at the head of each valley, which are divided by cutwaters, so that the flood-waters are carried over weirs into channels which carry the water to the stream below the dam. The filters, two in number, are situate immediately below the reservoir. Figs. 2, 3, and 4 are sections of embankment, proposed to carry the roadway, and the culvert underneath, for which, as before stated, a bridge has been substituted. Figs. 5 to 11 are sections, plans, and details of the inlet. Three sluice-gates admit the water into the reservoir, but when the reservoir is full the water flows over the weir into the flood-water channel.

Plate 21.

Figs. 1 and 2 are plan and section of part of main embankment, showing the gangway, valve-well, and outlet culvert. Fig. 3 is a cross-section, taken through the middle of the embankment. It is 15 feet wide at the top, and has an outer slope of 2 to 1, and an inner slope of 3 to 1. The lower part of the inner slope of the embankment is protected with broken stone. The upper portion is pitched with coursed stone, 12 inches deep, laid on a layer of broken stone 6 inches in thickness. The top of the embankment is finished on the inside with a rubble wall about 3 feet high. The puddle wall is 6 feet in width at the top, and batters, 1 in 12, down to the natural surface of the ground. The top of the embankment is 6 feet above top-water level. Figs. 5 to 9 are plans and sections of byewash, showing the outlet culvert, which, for a distance, runs under the byewash. The byewashes, which are stepped, are 6 feet wide inside, with side walls of coursed stone. The bottoms are of Ashlar pitching set on concrete. The outlet culvert, which has an internal diameter of 3 feet, is of 14-inch brickwork, set in cement. For the first 9 feet length from the valve-well the culvert encases a cast-iron pipe. The culvert discharges into the waste-water channel from the north side of the reservoir; the supply pipe to the screening chamber is as shown in fig. 9.

Plate 22.

Figs. 1 and 2 are enlarged sections of valve-well. It is divided in the centre by a wall, forming one-half into a wet well and the other half into a dry one. The brickwork is 2 feet 3 inches in thickness, and is surrounded up to the surface of ground by 15 inches of concrete. Nine inches above the bottom of the wet well a culvert 2 feet in diameter is run out into the reservoir; about 12 feet from the bottom is a second, and, higher up, again is a third (see also Fig. 2, Plate 21). In the wet well cast-iron frames support screen-plates. At the respective positions shown on the drawing, three iron pipes are carried through the division wall, terminating in the wet well with a cup bored out to receive a ball or plug, a boss being cast in the bend to support a small iron pipe, carried up to the top of the well, on which the balls slide. These plugs are for the purpose of closing the pipes in case the valves require removal when there is water in the reservoir. In the dry-well the valves are fixed, being supported on the girders that carry the pedestal for the valve spindles. Step-irons are fixed in each well, and hand-irons in the coping opposite. Figs. 3, 4, 5, and 6 are details of pedestals and girders. Figs. 7 and 8 are sections of the screen-plates. Fig. 9, sectional plan, and fig. 10, plan on top of valve-well. Figs. 13 to 17 are elevation, plan, sections, and details of the foot-bridge leading from the bank to the valve-well. The top flanges of the girders are T irons, 4 inches by 3 inches by $\frac{1}{2}$ inch; and the bottom flanges are also T irons, 4 inches by 3 inches by $\frac{3}{8}$ths of an inch. The vertical stiffeners are L irons, 2 inches by 2 inches by $\frac{1}{4}$-inch, which are riveted in the middle of their length with a packing-piece between. The diagonals are also of L iron. The ends of the girders are stiffened by means of a $\frac{1}{2}$-inch plate, 1 foot 3 inches wide, riveted between L irons, and the girders are tied together at each end by a 1 foot 3 inch plate, $\frac{1}{2}$ inch thick, which acts as a bearing plate on the walls. The guides are strutted from the outside by L iron struts, bearing on horizontal L irons, $2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches by $\frac{3}{8}$ of an inch, riveted to the bottom flange of each girder, and produced outward about 2 feet; wooden bearers, 3 inches by 3 inches, are bolted to transverse L irons riveted under each girder, and the flooring is of 2-inch battens spiked to these beams. The bridge is bolted down by two $1\frac{1}{8}$-inch bolts, 3 feet long, to the abutment on the embankment, and rests, without fixing, in a recess in the masonry of the valve-well. Figs. 11 and 12 are elevation and details of handrailing round the valve-well.

These works were executed from the designs of Messrs. Lawson & Mansergh, at a cost of £35,000.

Plate 23.

Illustrates filter beds and screening chamber. Fig. 1 represents general plans of filter beds and screening chamber, showing the arrangements of the inlets and outlets, with a by-pass and a plan of the drains, which are of brick, set dry, the smaller ones being covered with quarles or flags; Fig. 2 is a longitudinal section through the screening chamber by-pass and wet wells; Fig. 3 plan of screen; Fig. 4 cross section of screening chamber and elevation of screen; Fig. 5 section of outlet from screening chamber to wet well and by-pass; Fig. 6 inlet pipe to screening chamber; Fig. 7 part of longitudinal section of outlet end of filter bed, showing the drains and air pipes, with the filtering medium, which is composed of 1 foot 9 inches of coarse gravel, 6 inches of fine gravel, and 1 foot 9 inches of sand, making a total of 4 feet; Fig. 8 is a part longitudinal section of inlet end, showing a cross section of the cast iron distributing tank for regulating the flow on to the sand; Fig. 9 is a cross section of the outlet end of the screening chamber, showing the overflow and screen pipes; Fig. 10 is a section at the outlet end of filter bed, showing outlet and overflow; Fig. 11 is a section through the wet wells at the outlet, showing outlets and by-pass, as also overflows and scour pipes. These works were executed from the designs of Messrs. Lawson and Mansergh, at a cost of £35,000.

PLATE 24.—PORT GLASGOW WATERWORKS.

These works were designed in 1864 by Mr. J. M. Gale. The gathering ground is about 225 acres in area, and is situated $2\frac{3}{4}$ miles south-east of the town. The reservoir has an area of nearly 22 acres, and a capacity of 56,500,000 gallons. There are two embankments, one 230 feet long and 16 feet high, the other 825 feet long and 35 feet high. These dams have an outside slope of 2 to 1, and an inner slope of 3 to 1.

They are 12 feet wide at top, and are 4 feet above top water level. Fig. 1 is a cross section of the northern embankment, showing the stand-pipe and gauge-well. The stand-pipe is of cast-iron, 42 inches internal diameter, with three valves, each 5 feet apart, for drawing the water off at different levels. These are worked by means of rods which are attached to them and carried to the top of the stand-pipe. The topmost valve is 5 feet below top water level. The stand-pipe is connected with the bank by means of a wrought-iron foot-bridge. The outlet-pipe is carried from the bottom of the valve-stand through the bank, and is supported at every length by masonry, so that it may not be deflected by the weight of the bank. It is supported on ashlar where it passes through the puddle wall, and is protected by a collar from any creep of water along the outside. From the gauge-well the water is conveyed in a 9-inch clay pipe for 495 yards, and then for 2,005 yards in a clay pipe conduit until it reaches the Park Hill filters. The point where the 15-inch pipe commences is the site proposed for a reservoir, should Port Glasgow require a greater quantity than the present works could supply.

Fig. 2 is a section through the clear water tank and filter bed. The tank is circular, with a diameter of 55 feet, and an available water depth of 13 feet. It has a capacity of 193,000 gallons. The tank is open, with ashlar walls carefully puddled, to prevent the slightest escape of water. The basin is cleansed by means of a 6-inch wash-out pipe. The filter is 36 feet wide and 82 feet long. It has 4 feet of filtering material disposed as under:—

	Feet.	Inches.
Broken whinstone, 3 inches	1	0
,, ,, 2 inches	0	7
Gravel	0	3½
Perforated glazed fireclay tiles, 10 inches square, and 64 holes to each	0	1½
Sand	2	0
	4	0

Fig. 3 is a general plan of the filter, tank, &c. Fig. 4 is an enlarged section of filter. Figs. 5 and 6 are plan and section of the sand-washing box, which is similar to that in use at the Gorbals Waterworks, where it has been successfully worked, with very little expense for repairs. The wooden box is made to contain 1½ cubic yards of the sand, and has a false bottom, which is perforated with holes. The sand rests on this perforated cast-iron plate, and water is caused to flow through it under a slight pressure. Very little water is wanted, and the manual labour required is not great. This operation costs 6*d.* per cubic yard.

At the tank on the inside end of the service-pipe is fixed a framework of strainers, to exclude all small particles that may have found their way into the clear water tank.

The town is supplied through a 9-inch main, 2¼ miles long. The distribution is effected in the usual manner, and the full pressure of the tank, 250 feet above the lowest part of the town, is constantly on, in case of fire. The cost of these works for a population of 12,000 was £13,805.

PLATES 25 & 26.—MANCHESTER WATERWORKS.

PLATE 25.

The Manchester Waterworks were designed by Mr. Bateman, in 1846, and commenced in the autumn of 1848. The supply is brought from the river Etherow, which divides the counties of Derby and Chester. The drainage ground lies about midway between Manchester and Sheffield, and is about 19,000 acres. The district consists of the shales and sandstones which form the lower portion of the coal series. The upper millstone grit, which forms the cap of the steep escarpments on each side of the lower millstone grit (which may be said to separate the coal measure shales from the limestone shales), is found in the bottom of the valley. The main impounding reservoirs are five in number, the highest of them being 790 feet above the sea. The point at which the water leaves the lowest reservoir to be conducted to Manchester is about thirteen miles from the city. The total capacity of the five reservoirs is about 550,000,000 cubic feet, and their area when full 400 acres. The average rainfall of this district is about 50 inches per annum, and the main available storage for three consecutive dry years may be taken at 33 inches in each year; this, if it were all stored, would yield about 39,000,000 gallons per day. From this, on an average, 13,000,000 gallons a day are guaranteed to the mill-owners, leaving 26,000,000 gallons for the city and suburbs, whilst the quantity already supplied is little over half this amount. Fig. 1 is a plan of the Vale House and Bottom's reservoirs, including the waste weir and watercourse, of which Fig. 2 is a longitudinal, and Figs. 3, 4, and 5 are transverse sections. Fig. 6 represents a longitudinal section of embankment looking north; Fig. 7 is a transverse section of embankment between the two reservoirs; Fig. 8 is a longitudinal section of discharge tunnel, showing the valve-house and shaft; Fig. 9, enlarged plan of portion of pipes in central discharge tunnel; Fig. 10, transverse section of inner and outer tunnel; Fig. 11, transverse section of central tunnel.

Plate 26.

Figs. 1, 2, and 3 are vertical sections, front elevation, and sectional plan, showing the construction of the 48-inch sluice valves, which are used for draining off the water from the large reservoirs. The valve is divided into three portions, A, B, and C, each of which can be opened by the power of one man, unless the valve be under more than 80 feet of pressure.

Figs. 4 to 8 are elevation section and details of the gauge sluices, which are placed in the various conduits and act not only as stop-gates but also as gauges for determining the quantity of water passing along each conduit. Gauge rods are placed before and behind the sluice B, and by an index, A, the extent to which the sluice is opened is known. By taking the difference in the level of the water behind and in the front of the sluice, and the area of the opening through which the water is discharged, the quantity of water passing through may be at any time ascertained. Figs. 9, 10, and 11 illustrate the turbine, or, rather, reacting wheel, which is supplied with power from watercourses above the level of the reservoir, and is used for the purpose of closing and opening the two deepest reservoirs, viz. Woodhead and Torside. The turbine, A (of which fig. 11 is an enlarged plan), is geared by the spur-wheel and pinion D to the worm-wheel gearing B, working the valve spindles C C C. The water for driving the turbine is controlled by a hand stop-valve at F in the supply-pipe E. A self-acting supply-pipe is placed at H, connected to levers worked by tappets upon the valve spindles C, whereby the water is shut off from the supply-pipe of the turbine and turned into the waste-pipe K, as soon as the main sluice-valve is either fully opened or fully closed. This arrangement prevents the possibility of accident, should the attendant neglect to stop the turbine in time by the stop-valve.

Fig. 12 illustrates the means by which the turbid waters are separated from the clear streams after recent rains. A D is a weir erected across the stream, having the passage B, made within the masonry, for the reception of the clear water. When the stream is small, the narrow opening C traps it. The stream in this condition (not swollen by floods) is indicated by the letters E E. But when the stream is swollen, as shown by the upper water-line F, the velocity with which it passes the weir carries it over the slot into the ordinary river course or to the settling reservoirs. Figs. 13 and 14 show this principle as applied to small streams, the same object being effected by a transverse slot C, in a trough D, which crosses the pure water conduit B, the storm water being carried over the slot and the clear water in the normal state of the stream falling through the opening C into the clear water channel B. Fig. 15 is a plan of the arrangement for gauging the water given in compensation to the mill-owners.

Fig. 16 is a longitudinal section through the gauge and test-basins A and H. Figs. 17, 18, and 19 show the working of the principle drawn to a larger scale. The water is first admitted into the gauge basin A, through the openings E E E, and the level is carefully regulated by means of sluices. It then passes through two apertures in vertical gauge plates, C, by which the quantity of water passing through may be accurately computed. In order to ensure a uniform discharge of water under a varying head, the gauge plates C are each fitted with a slide actuated by the float D, whereby the size of the gauging orifice is rendered self-adjusting, and varies inversely as the height of the water in the gauge-basin A, thus giving a constant discharge. In order, however, to prevent the possibility of dispute, the water discharged from each gauge aperture C into the river below it is carried by a trough F across a square test-basin H, 30 feet square and 10 deep. In the bottom of each trough (F) is placed a tumbler (K) in a horizontal position, turning on an axis in the centre, and this tumbler ordinarily forms the floor of the trough, the water passing over it as shown in fig. 18. But on drawing back the hand lever L into the position shown by the dotted line, so that the extremity of the tumbler just clears the edge of the trough, the tumbler is instantaneously reversed by the stream of water and turned vertically across the trough, where it is caught by the stop P, as shown in fig. 19. In this position the water is discharged through the opening in the bottom of the trough into the test-basin below, and at the same time the tumbler opposes an effectual barrier to its passage along the trough beyond the opening. The previous level of the water being noted, together with the time at which the stream is turned into it, the tumbler is again replaced at the end of a given interval in its original position, shown in fig. 18, by raising the stop P by the handle L, so as to release the tumbler; the discharge of the water into the test-basin is thus immediately arrested, and the water allowed to pass along the trough F as before, into the river below. The height to which the basin has been filled, is then ascertained, and the time noted and the quantity discharged is thereby accurately determined. The gauge is open to the inspection of all who are interested in the supply of the compensation water, and the quantity discharged may at any time be tested by these means. Fig. 23 is a gauge at Godley reservoir, where the quantity of water passing is duly measured in the basin A. Figs. 20, 21, and 22, are sections through gauges, which have been found to give as co-efficients of discharge 5·6, 7·0, and 7·6 respectively.

PLATES 27, 28, 29, & 30.—LOCH KATRINE WATERWORKS.

These works were designed, and for the most part constructed, by Mr. J. F. Bateman, C.E.; and when opened by Her Majesty Queen Victoria, in the autumn of 1859, were the largest and best-constructed waterworks in the British Isles.

The system of lochs within the limits of the Loch Katrine Waterworks includes Loch Katrine, Loch Achray, Loch Drunkie, and Loch Vennachar. Of these Loch Achray is not interfered with. These works were designed to be made capable of supplying to the City of Glasgow, if requisite, 50,000,000 gallons per day, in addition to the amount of compensation water (which was fixed to be 40,500,000 gallons) to be discharged to the River Teith. The drainage area of the Loch Katrine works to the Loch Vennachar outlet, where the works of the Corporation terminate, is 45,800 acres, or about 72 square miles. The water area (at summer level) is: of Loch Katrine, 3,000 acres; Loch Vennachar, 865; and Loch Drunkie, 83; making a total of nearly 4,000 acres, with a total capacity of 1,455,000,000 cubic feet, of which Loch Katrine has 910,000,000, Loch Vennachar 425,000,000, and Loch Drunkie 120,000,000 cubic feet. The works at the outlet of Loch Vennachar consist of a dam of masonry, across the mouth of the loch, and a new channel for the river, to enable the water to be drawn down below the old summer level. At the lower end of the channel is the compensation gauge-weir, which is 100 feet wide. At the upper end is a range of cast-iron sluices, built in masonry, 110 feet long and 15 feet thick, with 11 arched openings for discharging the water. Salmon-stairs are also provided. The level of Loch Drunkie has been raised 25 feet by two earthen embankments, and the area of the loch increased about 60 acres. The northern embankment is 150 yards long, and 21 feet high; the other, which is at the original outlet of the loch, is 40 yards long and 32 feet high; through this latter is a cast-iron pipe 24 inches diameter, with a valve at the outer end to regulate the discharge. The works at the outlet of Loch Katrine are similar to those at Loch Vennachar, but on a much smaller scale, as the quantity of water to be discharged is less. The point at which the aqueduct leaves the loch is above 5 miles up from the outlet. The total length of the aqueduct from the inlet at Loch Katrine to the service reservoir at Mugdock is 25¾ miles, of which 13 were tunnelled; 3¾ miles are iron piping across valleys, and the remaining 9 miles are open cuttings and bridges. Two of the tunnels are 2,325 and 2,640 yards long respectively; besides these there are others, 700, 800, 1,100 and 1,400 yards in length. Along the line of aqueduct there are 80 distinct tunnels, and 25 important iron and masonry aqueducts over rivers and ravines, besides smaller constructions.

Plate 27.

Figs. 1, 2, and 3 are the plan, elevation, and longitudinal section respectively of the basin at the inlet to the aqueduct. This basin is 55 feet long by 40 feet wide inside, with three iron sluices, each 4 feet by 4 feet, for regulating the flow in the aqueduct, and a line of strainers across the middle to keep fish, &c., from passing down. Over the entrance to the aqueduct (fig. 2) is a granite tablet, bearing the following inscription:—

Glasgow Corporation Waterworks.

Designed in 1853 and 1854 . . . . . Robert Stewart, Lord Provost.
Act of Parliament, 1855 }
Works commenced, 1856 } . . . . . Andrew Orr, Lord Provost.
Works completed, 1859 . . . . . . Andrew Galbraith, Lord Provost.

Opened by Her Majesty Queen Victoria, 14th October, 1859.

John Frederick Bateman, Engineer.

Fig. 4 shows the strainers, before mentioned, in elevation. Fig. 5 is the elevation of the iron sluices. Fig. 6 is one of the loftiest bridges on the line of aqueduct, being more than 70 feet in height. It is constructed of masonry. The bottom of the waterway is of concrete, and the top is covered in with 3-inch planking. Figs. 7 and 8 are the plan and transverse section respectively. Figs. 9 and 10 are cross-sections of the aqueduct near its junction with the bridge. Fig. 11 is a section showing the method adopted for carrying streams under the aqueduct by means of a culvert. Fig. 12 is a plan of the gauge-weir at the end of the Mugdock tunnel. The water from the aqueduct is delivered at Mugdock reservoir, first into a circular basin, which it leaves by falling over thin-edged cast-iron gauges having a total length of 40 feet; it then passes to the inner reservoir over the apron or weir. The depth of water flowing over is carefully recorded, and the cubic feet per day flowing into the city computed. Fig. 13 is the elevation of the gauge-weir, and figs. 14 and 15 are sections of the same. Fig. 16 is a section of the Mugdock tunnel.

Plate 28.

Fig. 1 is the elevation of the sluices at the Loch Vennachar outlet. They are of cast iron, and are eleven in number, built into a wall of masonry 110 feet long and 15 feet thick. Three of the sluices have a clear width of 4 feet and a height of 4 feet, four are 6 feet wide and 2 feet high, and the remaining four are the upper end of salmon-stairs. Fig. 2 shows a longitudinal section of these salmon-stairs, which are formed to allow the fish to get into the loch at its different levels. These stairs are each 6 feet wide between the walls, and have a general inclination of 1 in 12. They are sloping channels formed into a succession of deep pools by planks upon edge placed across the channel and over which the water falls. The height of the planks is varied as the level of the water in the loch changes, so as to keep a depth of from 15 to 20 inches always flowing over. The top of the dam is roofed in, and forms a sluice-house for protecting the working gearing.

Fig. 3 is a longitudinal section of the waste-weir, which is 150 feet wide, and is a continuation of the masonry of the dam across the top of the new river channel. Figs. 4, 5, and 6 show details of the salmon-sluices. Figs. 7, 8, and 9 show to a large scale the inlet sluice from Loch Katrine to aqueduct. Figs. 10, 11, and 12 are sections of the aqueduct where it passes through rock. Figs. 13 and 14 are transverse sections of Culegarton tunnel, the former being through wrought-iron tube, and the latter through cast-iron trough. Figs. 15, 16, 17, and 18 are elevation, plan, and sections of the Blairgair aqueduct.

Plate 29.

Fig. 1 is the longitudinal section of the Drymen bridge, which consists of two separate lengths of cast-iron piping, carried on masonry piers. Provision is made for carrying a third length of piping. The pipes are surrounded with wood lagging, and the space between the wood and the iron is filled with creosoted sawdust. Fig. 2 is the plan, and fig. 3 the cross-section of the same. Fig. 4 is a transverse section of the cast-iron troughs, showing recent addition to height of sides, and the rubble embankments which have been rebuilt in mortar. Fig. 5 is part of the Culegarton aqueduct, showing the junction of the wrought-iron tube with the cast-iron trough. Fig. 6 is a plan of the same; and figs. 7 and 8 show details of this junction. Fig. 9 is a section of the 48-inch syphon-pipe crossing Aberfoyle Road.

Plate 30.

Figs. 1 and 2 are elevation and section of sluice and hydraulic cylinder. Fig. 3 is a sectional plan of the same. Fig. 4 is a plan of the aqueduct outlet. Figs. 5, 6, and 7 are plan and sections of 36-inch stop-valve. The clear water way is 4½ square feet, against 7 square feet, the area of the pipe, the smaller slide having an area of 1 square foot, and the larger 3½ square feet; Sir William Armstrong's plan being adopted of dividing the valve into compartments, one of them being reduced in area so as to be equivalent to a small valve, and easily opened by one man. The smaller division is the one first opened, and the passage of the water through this opening so much reduces the pressure upon the slide of the larger compartment that it also can be opened with ease. In shutting the valve the small slide is the last closed. Figs. 8, 9, and 10 are plan and sections of the Mugdock straining well. This well is situated about 50 yards from the reservoir, and is cut out of the rock. It is 40 feet in diameter and 63 feet deep; the water is strained by being passed through copper wire-gauze, forty meshes to the inch, arranged in oak frames, and forming an inner well of octagonal shape, 25 feet diameter; from this latter the water finally passes into the two lines of pipes leading to the city. Water can also be drawn direct from the gauge-basin and from the upper compartment of the reservoir into the straining well by a line of 4 feet pipes through the bottom of the reservoir.

PLATES 31 & 32.—HALIFAX CORPORATION WATERWORKS.

These works were designed by Mr. Bateman as early as 1852.

The several supplies have been obtained from the waters of the Hebble, Luddenden, Greave, Widdop, and Walshaw streams.

The supply was first obtained from the Hebble, where a reservoir, called 'Ogden Reservoir,' was made, capable of holding 36,000,000 cubic feet. This is also the compensation reservoir, from which the millowner's water is discharged for twelve hours per day.

The conduit for the supply of Halifax follows the hill-sides into another reservoir at Mixenden, capable of containing 18,000,000 cubic feet. This has only a small drainage area, and is simply an auxiliary to Ogden for storage.

Next comes Ramden Wood reservoir, and here is the junction with the Luddenden works, drawings of which are shown on Plates Nos. 31 and 32.

The conduit from hence to the service reservoirs in and about the town is large enough to discharge 12,000,000 gallons in twenty-four hours.

The Luddenden works were started in 1864 and finished in 1870. They consist of a large reservoir, 1,350 feet above the sea, called 'Fly Flats,' or 'Warley Moor Reservoir,' situate at the top of Luddenden Brook, and having a capacity of 26,000,000 cubic feet. It is formed by an embankment more than half a mile long, and 44 feet high, the area of top water being 70 acres. Being at such a great height the drainage is small, and is augmented by a catch-water drain running round the hill. Compensation water is discharged from here.

Plate 31.

Some 300 feet lower down, and on the Luddenden stream, two reservoirs are made, called Dean Head, Upper and Lower, of which a general plan is shown on plate 31, fig. No. 1. The mode of discharge, which is the same at both reservoirs, is shown in fig. 2, with cross-sections of the various parts at figs. 13, 14, and 15; and enlarged plans of tailbay at figs. 16, 17, and 18. The forebay is shown at fig. 9, and drawings of the grating for same at figs. 8, 10, 11, and 12. The plan of the waste weir is shown at fig. 3; it is placed in the line of the flood watercourse, which runs round all the reservoirs. As these reservoirs are for pure water, storm or dirty water is not admitted, but passed round. Fig. 4 shows a section along the flood watercourse, with the mode of crossing the puddle trench. Fig. 5 is a section from the reservoir to the flood watercourse, showing the arm puddle trench and the steps to the flood watercourse. Figs. 6 and 7 show sections of the weir walls, and fig. 19 a section of the flood watercourse itself.

Plate 32.

Fig. 1 is a section of the outlet tower, and a sectional elevation of the bridge leading thereto from the top of the embankment. To draw off the water at various levels five cylindrical valves are provided. The tower is shown in elevation in fig. 7, and details of the bridge are given in figs. 6, 8, and 9.

Fig. 10 is a plan of the weir at the head of the upper reservoir, which is made so as to allow of the stream being turned either into the reservoir or down the flood watercourse. This is effected by means of stop-planks. Full details are given on the plate.

The works are now being extended so as to include the Widdop and Greave streams.

PLATES 33, 34, 35, 36, & 37.—ABERDEEN WATERWORKS.

The Aberdeen Waterworks which were constructed in 1831 having been found inadequate for the supply of the city, a preliminary survey for new works was made in 1855. In 1862 an Act was obtained, and on April 21, 1864, the work was commenced. The whole of the works were designed and carried out under the superintendence of the late Mr. James Simpson, F.G.S.

The water is taken from the river Dee, about twenty miles above Aberdeen, and three miles west of the village of Banchory. At the intake the channel of the river was deepened for a short distance along the north side, as the water exhibited a tendency to sheer off to the south. A cutting was made in the bank, sloping to the depth of 3 feet below the bed of the river, nearly at right angles to the stream, which, while admitting the water freely into the channel, will not allow it to run in with too great velocity. A strong wall of granite was constructed on the foreshore of the river, with an opening 7 feet wide and 10 feet high, protected on the outside by a strong iron grating, to keep out the salmon, and on the inside by a finer grating, to prevent leaves and other small substances getting through. A little farther on is a measuring tank, from which the water is conveyed in a brick aqueduct, for about 100 yards, to the tunnel, which is 760 yards long. After leaving the tunnel it is again conducted by a brick aqueduct, for about half a mile, to the reservoir at Invercannie. From the reservoir it passes into the filters, thence it is conveyed to the low service reservoir at Brae of Pitfodels. This reservoir is capable of holding fully a day's supply, 6,000,000 gallons ; its level is about 160 feet above high water, and it is capable of supplying about nine-tenths of the city. The remaining population is provided for by a smaller tank, called the High Service Reservoir, situated at Hillhead of Pitfodels. Its elevation is 396 feet above high water, and it has a capacity of 600,000 gallons. The water is pumped into it by a hydraulic engine worked by spare water from the aqueduct.

Plate 33.

Fig. 1 is a plan of the low service reservoir at Brae of Pitfodels. It is circular on plan, with a diameter of 270 feet, and a depth of 17 feet. Figs. 2 and 3 are sections of the same. Its bottom is laid with puddle to the depth of 1 foot; on the top of this is 6 inches of concrete. The sides are built of masonry, with a batter 1½ inch to the foot, and backed with puddle. Outside is a strong bank of earth and gravel, with a slope of 2 to 1. For a short distance west of the reservoir 30-inch pipes are laid to carry the water to the top of the reservoir wall, and so discharge it into the basin. Immediately below the waterfall the floor is laid with flags, to prevent its being worn away. A 27-inch iron pipe is laid from the end of the aqueduct, past the north side of the reservoir, which communicates with the latter by two sluice cocks, and the water may be sent into the city without passing through the reservoir at all. Figs. 4, 5, and 6 are enlarged sections of the reservoir, showing the inlet and outlet pipes. Figs. 7 to 13 are plan, elevation, and sections of the intake at Cairnton, showing the measuring tank. This tank contains a large floating gauge, which is placed at the end of the aqueduct and acts as a mouthpiece. It is kept constantly on a level with the surface of the river, rising and falling with it, by two large copper balls, 2 feet 6 inches in diameter, filled with air. The mouth of the pipe is 7 feet wide by 18 inches deep, and admits exactly the required quantity, 6,000,000 gallons daily, when the water flows over the gauge 7½ inches deep.

Plate 34.

Fig. 1 is a general plan of the reservoir and filters at Invercannie. Before the water enters the reservoir it passes through a second measuring tank at the south side. The sluice at the end of the aqueduct is 2 feet in diameter; when opened it allows the water to flow through a gauge weir 12 feet in circumference, and fall over the edge about 4 inches deep, giving the necessary quantity in the tank. Two smaller sluices communicate with the reservoir. The reservoir is 450 feet in diameter at the top, 16′ 6″ deep, and the sides have a slope of 2 to 1. The outer slope of the bank is also 2 to 1. The bank is 8 feet broad at the top. The bottom of the reservoir is of puddle 18 inches thick, and the whole of the inner surface is overlaid with 6 inches of lime concrete. At the east side of the reservoir is the outlet pipe, 36 inches in diameter, which is fed by two moveable pipes of 27 inches diameter. These are hinged to a breeches piece at the bottom (fig. 11), and are supported at the top each by two floating copper balls (fig. 10) which maintain the upper ends of the pipe at a constant level of about two feet below the surface of the water. A large pipe passes through below the embankment, and goes between the filters, two branch pipes discharging the water into the filter beds. A spill-water has been provided at the north side of the reservoir, by which any surplus will be discharged through a pipe into the Burn of Cannie. There is also another overflow—the measuring tank in the aqueduct—which will let off the water, should the quantity coming from the tunnel exceed that required at the reservoir. Fig. 2 is a section through the reservoir; fig. 3, a section through one of the filter beds. The filters are 136 feet in diameter, with slopes of 1½ to 1. The bottoms and sides are covered with a layer of concrete 6 inches thick, resting upon 12 inches of clay puddle. The banks have a puddle-wall 18 inches thick. The inner slopes are pitched with rubble for 10 feet from the top. In each filter bed is an open jointed brick conduit, with side and end walls and arches. The lower portions of the side walls are built in cement, and the arches are turned with 6-inch radiated bricks laid in cement. A layer of cement is rendered over this arch, on which 3-inch stone landings are bedded and built into the side-walls. This prevents any water making its way into the conduit that has not passed through the filtering material. Glazed perforated stoneware pipes, 12, 9, and 6 inches diameter, are laid in the lower filtering stratum to convey water to the centre drain. Three-inch cast-iron air escape pipes are connected with the ends of the 6-inch drains and centre drain, carried up the slopes, and terminated with grating heads. The filtering material consists of a bed of gravel laid on the concrete, over which is laid 2 feet of sand. The thickness of the material varies from 5 feet in the centre to $4\frac{1}{2}$ feet at the sides of the filters. Each filter has an overflow tank and pipe to carry any surplus water to the Burn of Cannie. The filtered water flows into a tank, 10 feet in diameter, on the east side, where the aqueduct commences. Fig. 4 shows the filtered-water tank and the arrangement of the different pipes. Figs. 5 and 6 are sections through the filter and filtered water tank. Fig. 7 is an enlarged section of the bank of reservoir, showing the supply pipe to filters. Fig. 8 is a cross-section of the steps leading to the top of bank. Fig. 9 is a section through the bank and the supply-pipe. Figs. 10 and 11 are plan and elevation of the floating pipes. Figs. 12, 13, and 14 are sections and plan of inlet and gauge tank. Figs. 15, 16, and 17 are plan, elevation, and section of overflow tank.

Plate 35.

Fig. 1 is a longitudinal section of the syphon-pipe which crosses the Culter Burn. The pipe extends to a length of 400 yards, and its diameter is 36 inches ; where it crosses the burn it is supported by two granite piers 25 feet high. Fig. 2 is a plan of the same. Figs. 3, 4, and 5 are plan, section, and elevation of the junction with the brick aqueduct. Figs. 6 and 7 are details of the pipes and piers. The pipes are each 12 feet long, and rest upon cast-iron saddles bolted into the stone. Figs. 8, 9, and 10 show the junction tank at the other end of the ravine. Figs. 11 and 12 are plan and longitudinal section of the Crathes Burn aqueduct, which consists of cast-iron pipes 40 inches in diameter in 12-feet lengths, supported at intervals by brick piers. Figs. 13 and 14 are plan and section of the overflow and drain tank at the commencement of the pipe aqueduct. Figs. 15 and 16 show junction tank at the other end. Figs. 17 and 18 are enlarged sections of the pipes and piers. Figs. 19, 20, and 21 are elevation and sections of the drain leading from the overflow tank into the burn. Figs. 22, 23, 24, and 25 are plan and sections of the Burn of Cannie aqueduct. It consists of 5 cast-iron pipes 11 feet long by 3 feet internal diameter, bolted together, and passing beneath a girder-bridge which carries the roadway. Fig. 26 is an enlarged view of girders, and Fig. 27 details of pipe.

Plate 36.

Fig. 1 is a general plan of the site of hydraulic engine house, from which the water is pumped into the high service reservoir at the hill of Pitfodels by means of an hydraulic engine situated at Cutts, near the River Dee, and driven by water from the aqueduct, a quarter of a mile distant, at a pressure of 155 feet. The diameter of the pipe from the aqueduct is 18 inches, and the engine lifts one gallon of water by an expenditure of $2\frac{3}{10}$ gallons, which run off into the Dee. The engine is of 40-horse power, one-third of which is used at present, and it forces 400,000 gallons per day through the rising-main, a mile long. Fig. 2 is a section from the Dee through the engine-house. Figs. 3, 4, and 5 are sections through the roadway leading to the engine-house. Figs. 7 and 8 are section and plan of the tank from which a supply-pipe is taken to the engine-house. Fig. 6 is a section along the line of mains from the engine-house to the high service reservoir. Figs. 9 to 13 are plans and sections of the reservoir. This tank is 80 feet in diameter, and has a mean depth of 16 feet 6 inches. It is similar in construction to the low-service reservoir.

Plate 37.

This plate gives several general details which require no further description than is already contained on the plate. The quantities of materials used in these works were as follows: Upwards of 7,000,000 of bricks, about 42,000 tons weight, equal to nearly 12,000,000 of common bricks, those used being considerably larger than ordinary bricks; 70,000 tons of clay-puddle were used in the reservoirs and aqueducts; 2,500 tons of iron were used for the pipes and other ironwork. The quantity o earthwork excavated for the aqueduct was about 300,000 cubic yards, and of filling-in about 170,000 cubic yards, and there were nearly 60,000 cubic yards of rock excavation in the tunnel. From 1,000 to 1,500 men were employed on the works. The cost of the works was about £150,000, including £10,000 for land and £15,000 Parliamentary expenses.

PLATE 38.—COCKERMOUTH WATERWORKS.

The Cockermouth water supply is drawn from the River Cocker, a mountain stream, which acts as the overflow to the lakes of Buttermere and Crummock Water. The works consist of a pumping station, a heading from the river Cocker to the pumping well, rising main to storage reservoir, two filter beds, covered service reservoir, and the distributing mains, with the necessary valves and hydrants in the town. The pumping station consists of a boiler-house, coal-store, and engineman's cottage. The heading is driven through the rock, and partially filled with clean gravel, which acts as a rough filter. The pumping machinery consists of a beam condensing engine, having a cylinder 24 inches in diameter and 6 feet stroke of piston, working a bucket and plunger pump. The bucket is $17\frac{1}{4}$ inches, and the plunger 12 inches in diameter, with a stroke of 3 feet. There are two double-flued Cornish boilers, 27 feet in length and 6 feet 6 inches diameter, each of which is quite capable of driving the engine. The chimney, which is nearly 100 feet in height, has a 3-feet cylindrical flue. The firing-floor is about 8 feet below the engine-house floor. The coal store is immediately in front of the boilers and on a level with the firing-floor; it is arched over, and has gratings for supply at the level of the ground. Adjoining the engine-house is a workshop and store. The bottom of the pumping well is about 143 feet above ordnance datum. The water is forced from the well through a 10-inch cast-iron rising main to the storage reservoir, the top water level of which is 273.

Figs. 1 and 2 are section and plan of the storage and service reservoirs and filters. The storage reservoir is an open one, with a capacity of about 400,000 gallons. It is about 116 feet in length, with a breadth of about 81 feet at one end and 48 feet at the other. The depth of water is about 10 feet. The sides are formed to a slope of 1 to 1. From the reservoir the water flows into a well, from which it is conducted into the filters. Each filter has a sand area of about 200 square yards. They are about 52 feet long by 41 feet 6 inches broad. The service reservoir is covered, and has a capacity of nearly 300,000 gallons. Fig. 3 is a section through the bank which covers the service reservoir, showing two valve wells. Fig. 4 is a plan of the same. Fig. 5 is a plan and fig. 6 a section of parts of storage reservoir and filter beds to an enlarged scale, showing the inlet to and outlet from the storage reservoir, the valve wells and the position of drains in the filters. There is about 4 feet of filtering material, with about 2 feet of water on it.

Figs. 7 to 10 are sections and plan of service reservoir. The depth of water is 15 feet. Masonry steps lead down to a landing, whence the bottom is reached by an iron ladder. The supply main to the town commences with a 10-inch pipe, which gradually diminishes, according to the branches taken off, to 3 inches.

These works, which supply a population of between 8,000 and 9,000, were constructed at a cost of £10,496 7*s.* 11*d.*, made up of the following items:—

Engine, boiler, and pumps	£1,610	14	10
Cast-iron pipe mains	1,852	7	2
Hydrants and casings	107	15	9
Sluice-valves, &c.	212	11	0
Laying and jointing cast-iron mains	726	15	6
Engine and boiler-house, chimney-heading and fence	2,789	7	4
Reservoirs, filter beds, fence walls, &c.	2,860	7	6
Cottage for engineman	300	0	0
Sundry works	36	8	10
	£10,496	7	11

PLATES 39, 40, 41, 42, & 43.—SUNDERLAND WATERWORKS.

Plates 39 to 43 illustrate the Ryhope pumping station, which forms part of the extensive works at Sunderland, of which Mr. Hawksley is the engineer.

PLATE 39.

Fig. 1 is a general plan of the service reservoir, cooling ponds, and engine and boiler house. The reservoir and cooling ponds are ornamental in character.

Figs. 2, 3, 4, and 5 are sections through the reservoir and cooling ponds. The greatest length of the reservoir is 360 feet, and the greatest breadth 175 feet. An open drain runs across the reservoir. The depth of water at each end is 15 feet 6 inches, but in the middle, where the channel crosses, it is 14 feet 6 inches. The cooling ponds have 5 feet 6 inches of water one end and 4 feet 6 inches the other. Figs. 6, 7, and 8 are plan and elevation of the outlet overflow and cleansing pipes. There is a small platform supported on cantilevers, from which the valves are worked. The pipes are 24 and 15 inches in diameter respectively. Figs. 9, 10, and 11 are elevations and plan of overflow and cleansing-pipe. Figs. 12, 13, and 14 are plan and sections of the channel in reservoir. The channel is 2 feet in width, and has sides of masonry 6 inches wide, with openings 3 feet wide at intervals of about 17 feet. Fig. 15 is a view of the suction pipe through which water is taken from the cooling pond. Fig. 16 is the inlet to reservoir; Fig. 17, overflow and cleansing pipe to cooling pond; and fig. 18 the inlet to cooling pond.

Plate 40.

Figs. 1 and 2 are longitudinal section and sectional plan of engine and boiler house. Figs. 3 and 4 are section and elevation of chimney shaft. The engine-house contains a pair of double cylinder rotative beam-engines; the small, or high-pressure, cylinders being 27 inches in diameter, and of 5 feet 4 inch stroke, while the large, or low-pressure cylinders, are 54 inches in diameter, and of 8 feet stroke. By comparing Fig. 1 with Fig. 1 Plate 42, it will be seen that from the fly wheel ends of the beams are worked the pumps which raise the water from the well into the staple, while attached to the cylinder ends of the beams are the spears of the staple pumps which deliver the water into the service reservoir. To supply steam to the engines there are six Cornish boilers 30 feet long, with shell of 6 feet diameter, and flues 3 feet; they are set with a 'wheel draught.'

Plate 41.

Figs. 1 and 2 are cross-sections of the engine-house through the staple and well. Fig. 3 is a cross-section of boiler-house; figs. 4 and 5, sectional plan and elevation of engine frame; figs. 6, 7, and 8, details of entablature and columns; figs. 9, 10, and 11, details of frame.

Plate 42.

Plans and sections of well and staple, showing pumps, &c. Fig. 1 is a section through the well and staple, showing the general arrangement of the pumps, girders, guides, &c. Figs. 2 and 3 are plan and enlarged section of the staple, showing the position of the pumps there; fig. 4 is a section of the heading between well and staple; figs. 5 and 6 plan and part section of the well, showing position of the well pumps and overflow pipe.

Plate 43.

Figs. 1, 2, 3, and 4 show details of pump-barrels and valve-box; figs. 5 and 6 spears and buckets; figs. 7, 8, 9, and 10, plans and sections of roses for staple and well-pumps; figs. 11 and 12, plan, elevation, and section of friction rollers for spear of well-pumps; figs. 13 and 14, plan and section of bucket of well-pumps; figs. 15 and 16, elevation of apparatus for drawing the suction valves of the pumps.

PLATES 44, 45, 46, 47, & 48.—CANTERBURY NEW WATERWORKS.

These works were designed by Mr. S. C. Homersham, and are now, and have been since the year 1870, in full operation for supplying water, softened by Dr. Clarke's process. They are the seventh set of works carried out by Mr. Homersham for the supply of softened water, the first being made in 1852, to supply Plumstead, Woolwich, and Charlton.

The City of Canterbury was originally supplied for the most part with water from the River Stour. Nearly all the houses had wells of their own, as water in the lower portion of the city is easily obtained by sinking to no great depth; such water, however, is always hard, and for the most part polluted by the drainage from adjacent cesspools and other offensive sources. In order to meet the want which was therefore felt for water of a softer and purer character, the Company, by the advice of Mr. Homersham, abandoned the River Stour as the source, and constructed the present works for supplying water from the chalk. The result has been most satisfactory.

The softening works are situate in Wincheap, alongside the high road from Canterbury to Ashford, and the service reservoir is about $2\frac{1}{4}$ miles distance, namely, at St. Thomas's Hill, at an elevation of about 180 feet. The present works are capable of softening 350,000 gallons per day (an ordinary working day), or 500,000 gallons per day, working overtime. But they have been laid out so that they can at any time be duplicated, many important arrangements having been made for this special object. The supply is obtained from two bore-holes, 2 feet in diameter, sunk into the chalk strata for about 500 feet in depth. At present only one of these is in use, as that furnishes an ample supply for the present requirements of Canterbury, the quantity of water furnished by it being 1,000 gallons per minute, or $1\frac{1}{2}$ million gallons in twenty-four hours, and the amount is limited not by the yield of the bore-hole, but by the capacity of the pump, as with a larger pump the yield would probably be doubled in quantity. Whilst yielding a supply of 1,000 gallons per minute, the level of water in the bore-hole is only temporarily lowered about 22 feet, the water at once rising again to the normal level directly the pumping is stopped. The borings were made by steam machinery, and the total time taken to sink both bore-holes was about twenty weeks. The first fissure tapped during the boring was a ta depth of 328 feet below the surface of the ground, or 290 feet below the level of the sea, when the water in the bore-hole suddenly rose about 8 feet. The tops of each of these bore-holes is lined to a depth of 36 feet with cast-iron cylinders, 26 inches internal diameter, of which a section is shown in fig. 1, plate 48. The total cost of both bore-holes, including the cast-iron cylinders, coal, wages, hire of steam-boring machine, temporary brickwork above tops of bore-pipes, testing yield of both bore-holes by a temporary pumping engine, and every other expense connected with them, was about £1,400.

The softening works at Wincheap are represented in the general plan, plate 44, fig. 1, and comprise engine, boiler, and well-houses, depositing or softening reservoirs, lime-water reservoirs, lime-house, chimney shaft, cooling pond, coal-store, workshop, gauge weirs, whiting well, cottage, store, offices, pumping engine, small blowing engine, &c., &c. Fig. 4, plate 44, represents sectional elevation through cooling pond, depositing and lime-water reservoirs, and whiting well. The dotted lines under the bottoms of each reservoir, as far as the whiting well, represent a 12-inch cast-iron pipe, with branches, to which valves are attached in the bottom of each reservoir; through this pipe the deposit of chalk precipitated from the well water is conducted to the whiting well, from which it is pumped (by a small water engine driven by the pressure from the main) into whiting pits. The whiting is then dried, and can be used again for making quicklime by burning in a kiln, and thus throwing off the carbonic acid. The whiting itself is a marketable commodity. Fig. 5, plate 44, represents sectional elevation through cooling pond, engine and well houses, soft water suction well, and one of the bore holes. The height to which the level of the water in each bore-hole stands above the level of the water in the River Stour is here distinctly shown.

Depositing or Softening Reservoirs.—Figs. 2 and 3, plate 44, are respectively sectional elevation and plan of depositing and lime-water reservoirs, lime-house, &c. Figs. 1, 2, and 3, plate 45, are also sectional elevations of the same. The ground in which the reservoirs are built is chiefly gravel, with a slight admixture of clay, but the bottom is, to a great extent, on the chalk. The outer walls of the reservoirs below level of top water are built for the most part of Portland cement concrete, with a brick toothing, as shown in section, and the bottoms of the reservoirs with Portland cement concrete, with concrete ribs stretching across the bottom. The walls of the reservoirs above the level of the water are built with Gault bricks, with the exception of a skirting inside, which is of red bricks, with stone stringcourses and stone coping, the whole being laid in Portland cement, and the joints raked out, and afterwards pointed with light-coloured mortar. It will be noticed that all the windows are very narrow, being only 12 inches in width. This is for the purpose of preventing the sun's rays getting on the water, and thus affecting its temperature. Each alternate window round the reservoir is provided with a ventilator of thin copper, perforated with holes sufficient for ventilation, but too small to admit anything larger than $\frac{1}{8}$-inch in diameter. The important object of maintaining uniformity of temperature inside the reservoirs is particularly considered in the construction of the roofs. They are made of wrought-iron rolled joists and Portland cement concrete. The average thickness of the concrete being 18 inches, the upper surface of the concrete is made with falls to conduct the rain-water or melted snow into the down pipes. The top of the concrete is covered with Seyssel asphalte $\frac{5}{8}''$ thick over the whole surface, and on the top asphalte there is a layer of well-washed small beach-stones or fine gravel for an average depth of 6 inches. The total thickness of the roof averages about 2 feet. The sides and bottoms of all the reservoirs are rendered in neat Portland cement about

$\frac{5}{8}$ inch thick. It will be noticed that advantage has been taken of the weight of the roof by partially distributing on it the intermediate walls separating the reservoirs, and thereby considerably augmenting their resistance to the great pressure which is daily brought on each of them, when one adjacent reservoir is full and another empty. There is a pathway all round the reservoirs constructed of York paving set in cement on cast-iron cantilevers ; and wrought-iron chains, hung in festoons from cast-iron standards, and fenderboards are placed round the edges of each reservoir, as shown in fig. 2, plate 44, and figs. 1 and 2, plate 45, the latter to prevent any dirt which might be brought in by visitors' boots from getting into the water. It will be seen that every possible care has been taken that the water shall be delivered in the greatest attainable state of purity to the consumers: the service reservoir at St. Thomas's Hill also is carefully roofed with concrete, and the manholes always locked, so that the water is never exposed to the action of the sun, nor can it be interfered with in any way until it is drawn from the taps in the consumers' houses. The spring water delivery pipes are introduced at the south-west end of each depositing reservoir; each pipe has an 8-inch valve, so that admission can be cut off or not as required, and it then terminates in eight cast-iron nozzles, as shown in plan fig. 3, plate 44. The delivery pipes for the lime-water are 8 inches diameter, and are introduced at the north-east end of each depositing reservoir, or the opposite end to that in which the spring water is admitted. On the end of each lime-water delivery pipe in each depositing reservoir is jointed one of the filling pipes—shown in figs. 7, 8, 9, 10, 11, and 12, plate 47—and outside each filling pipe an 8-inch valve, with handles in each case conveniently arranged for use. The sliding pipes for the depositing reservoir are placed near the centre of each reservoir, as shown in elevation in fig. 1, plate 45, and also in plan fig. 3, plate 44; they are used only for the purpose of conducting the water after it is softened to the soft water suction well, from which suction pipes to the soft water pump are carried, as shown in fig. 5, plate 45, and fig. 2, plate 46. The construction of these sliding-pipes will be better seen by referring to the larger scale section, shown in figs. 7, 8, 9, 10, and 11, plate 48; the outer cast-iron casings are fixed in wells sunk below the bottoms of each reservoir, as shown in fig. 2, plate 44, and again in fig. 1, plate 45. The sliding-pipes have copper floats fixed to the top, and are thus self-acting in their descent. The pipes are raised by means of wire ropes attached to the top of the copper floats, which pass over cast-iron pulleys 2 feet in diameter, fixed to the roofs, and thence to crabs placed on the centres of the intermediate walls. The sliding-pipes are retained in their position at the top when drawn up, during the filling of the reservoirs, by pawls attached to the barrels of the crabs. When the water is softened and ready to be pumped, the pawls are thrown out of gear, and the pipes are lowered in the water as far as the floats will allow, that is to say, until the top edge of the basin of the pipe is about a foot below top water; communication is thus made with the soft water pump. In the centre of each platform, across the centre of each depositing reservoir, is fixed a revolving hydrant, with a copper jet-pipe attached for the purpose of jetting the surface of the water immediately after the reservoir is filled; should any carbonate of lime remain on the surface of the water in any part, it is either precipitated or blown off through the overflow constructed to each reservoir. These hydrants, which are supplied from a 3-inch pipe with softened water from the main, with the full pressure always on, are also used for the purpose of jetting the interior of the building when required.

Lime-water Reservoirs.—There are two of these, each 17 feet 3 inches in depth. The clear lime-water is drawn off from each reservoir by means of a sliding-pipe, as shown in fig. 2, plate 45, in elevation, and in fig. 3, plate 44, in plan, these sliding-pipes being raised and lowered by means of a crab placed on the centre of the intermediate wall. The lime is introduced into each lime-water reservoir from the lime-house (where it is slacked) through the 4-inch cast-iron pipes, shown in figs. 2 and 3, plate 45, in elevation, and in fig. 3, plate 44, in plan. (See description of mode of making lime water, page 30.) Softened water is conveyed into each lime-water reservoir from either of the three depositing reservoirs by means of the filling pipes at the north-east end of the depositing reservoirs; by lowering one of these into the reservoir the water is drawn off in the required quantity, through the 8-inch main connecting the depositing and lime-water reservoirs, and is introduced at the bottom of either lime-water reservoir by means of a series of wrought-iron pipes, 1 inch in diameter, having a number of holes drilled in the sides. These holes are covered with valves of vulcanized indiarubber, to prevent the lime getting into the pipes. This series of pipes is also used for the introduction of air, being connected by means of a 3-inch pipe with a small blowing engine placed in the workshop. There is also a 5-inch main with valve in each lime-water reservoir for supplying softened water direct from the main, these 5-inch pipes being connected with another series of wrought-iron pipes, $1\frac{1}{4}$ inches diameter, placed immediately below, and in a direction at right angles to the former series of wrought-iron pipes just alluded to; these have holes drilled in the sides in a similar manner to the other set. It will be seen, therefore, that by means of these two series of wrought-iron pipes a number of jets of softened water can be introduced at the bottoms of the lime-water reservoir, either from the depositing reservoirs or from the softened water main, and also a series of air-jets by means of the blowing engine, either or both, as may be required. There are two small gun-metal hydrants, with india-rubber hose attached, conveniently placed for jetting the surface of each lime-water reservoir, or for any other part which may be required.

Lime-house.—The lime-house has three octagonal cast-iron cisterns, as shown in plan in fig. 3, plate 44, for the purpose of slacking the lime. The largest cistern is connected by means of two wrought-iron pipes, with a valve to each, to the two tunnel pipes shown on either side, and which conduct to each lime-water reservoir. By opening one of the valves the cream-of-lime will flow by its own gravity into either of the lime-water reservoirs as required. There are service pipes from the soft-water main, with stopcocks over each octagonal cistern, one to each of the smaller ones, and two over the larger one, for the purpose of slacking and preparing the cream-of-lime. The ordinary utensils required in the lime-house and lime store are bushel baskets, stirrers, ladles, buckets, and fine wire sieves.

Engine and Well Houses.—Figs. 4 and 5, plate 45, are two sectional plans, and plate 46 represents five sectional elevations of this block of buildings. The roofs are made of wrought-iron joists and concrete, similar to the reservoirs. The engine and well houses have been prepared to receive two beam-engines and two sets of main pumps, but at present only one beam-engine and one set of main pumps (consisting of one spring-water pump and one soft-water pump), have been erected and are now at work. These are fixed on that side of the engine and well-houses nearest to the boiler-house. Fig. 2, plate 46, represents a longitudinal section of engine and well-house, showing the position of the beam-engine and pumps with reference to one another. The lower pump, placed in the bore-pipes, is the spring-water pump, and is driven direct from the lower end of the piston-rod of the beam-engine, and has therefore the same stroke as the piston. The pump at the higher level is the soft-water pump, the suction pipe to which is shown coming from the soft-water suction well; this pump is driven from the other side of the beam of the engine, midway between the centre and flywheel end, and is therefore only half the stroke of the other pump. Both pumps are worked at the same time. The foundation for the engine is composed of brick in cement, with a bed of stone, 18 inches thick, stretching right across the well-house, as shown in section in fig. 3, plate 46. Two of these stones weigh 6 tons each. It will be seen that the holding-down bolts pass through the brickwork and stone, and the nuts and washer plates are placed on the under side of the 18-inch stone bed. The engine itself is partly carried on cast-iron girders, with a bed of oak 6 inches thick placed between the bedplate and the girders. The entablature is also tied at the sides, and at one end to the main wall, with cast-iron stays. Wrought-iron bars, supported by eyebolts passing through the roof, are fixed to the ceiling of the engine-room, immediately over the centres of cylinder and flywheel; these were required in erecting, in the first place, and are exceedingly convenient for lifting purposes at any time. The floor of the engine-room is paved with stone, and the walls have been coated with silicate zopissa composition, finished with a very light green tint. The spiral staircase, which it will be seen affords communication with the roof, is constructed with stone steps.

Boiler-house.—The flues of the boiler seatings are lined with Stourbridge fire-bricks set in fire-clay; these are carried up, as shown in section, fig. 5, plate 46, as far as the top of boiler-house. The inside of the chimney is rendered from this point to the top in Portland cement. The result of this is that the vacuum in the chimney whilst working, as tested by a gauge fixed for the purpose, is excellent. There are air passages left in the boiler seatings, and the top of the boilers is enclosed by a 9-inch wall, which makes a hot-room for drying purposes. There is a slate sliding door fitted in this 9-inch wall, opposite the door of workshop. There are three dampers at the ends of the boiler flues, just before they enter the main chimney, as shown in plan in fig. 5, plate 45; the handles for working these are placed in front of the boilers, being connected by means of wrought-iron chains. In addition to these there is another damper, placed at the top of the main chimney, which is worked by a screw in the boiler-house, the screw being connected by means of a chain passing up inside the chimney to the damper at the top. The main chimney is also fitted with a good lightning-conductor, which is made of four copper points, tipped with platinum, placed at the extreme summit; these are connected with a large iron rod passing down the inside of the chimney and thence to the pipes leading to the bore-holes, so that there is a good communication with wet earth. There are steps, constructed of wrought-iron bars, built in the inside of the chimney, by which access can be had to the top. The windows of the boiler-house are constructed in a similar manner to those in the reservoirs, some of them having copper ventilators. There is also a large ventilator in the roof, placed immediately over the ashpits and front of the boilers, as shown in fig. 5, plate 46. This ventilator has glass louvres on three sides, and the fourth is fitted with a plain sheet of glass, to enable the stoker to see the top of the main chimney from the stokehole, so that he may know in a moment if the smoke is not being thoroughly consumed in the furnace.

Coal Store.—The coal store is fitted with a weighing machine, the platform of which is level with the York paving of the boiler-house, so that a wheelbarrow filled with coal or coke can be run easily from one to the other. All the fuel used in the furnaces of the steamboilers is accurately weighed and noted down every day on a slate fixed in the boiler-house for that purpose.

Workshop.—The workshop, which is the room immediately adjoining the coal store, a section of which is shown in fig. 4, plate 46, is fitted with a vice-bench passing along the whole length of the wall, in which the windows are fitted. There are eyebolts fixed in the ceiling for the use of the men in handling any ironwork that may require to be lifted. On the side next the coal store is a small blowing-engine before referred to, the fly-wheel of which is turned to drive any shafting that may be required.

Small Store.—Between the coal store and the depositing reservoirs, is a small store for general purposes.

Cooling Pond.—This is shown in fig. 1, plate 44. It is 165 feet in length inside, by 44 feet in width, by 4 feet 6 inches depth of water. It is used only for condensing purposes for the beam-engine, but at the same time contributes very much to the ornamental appearance of the works. The hot water from the head-box or hot-well of the air-pump is discharged at the engine-house end of the cooling pond through a fountain pleasingly arranged with a variety of jets. There is a filter bed at the opposite or north-east end, from the centre of which is an 8-inch pipe to the injection sump placed at the south-west side of the engine-house, and from which the suction-pipe of the condenser of the beam-engine is supplied with cold water. The upper part of the filter bed, which is above the level of the water, is filled with Pampas grass; there are also twelve cylinders arranged round the cooling pond, filled with different kinds of water-lilies; these, together with a quantity of gold-fish, which propagate very fast, and some additional jets of water playing in different parts of the pond, present a very pleasing and ornamental appearance. There is an overflow, also an emptying valve and two hydrants supplied through a 5-inch pipe from the soft-water main; by means of these the pond can be emptied at any time if required, and re-filled from the soft-water main.

Gauge Weirs.—There are two gauge weirs, one for the spring water and one for the soft water pump, so that the discharge of either of these pumps can be tested at any time, and also, by the use of them, both the pumps can be worked at any time, independently of the reservoirs or the soft water main. The water from the gauge-weirs is discharged into the 15-inch barrel drain.

15-*inch Barrel Drain.*—There is a 15-inch barrel drain passing right round the land at Wincheap, commencing at the whiting well, near the letter F on fig. 1, plate 44, and thence on the S.W. side of engine-house and cooling pond across the turnpike road, through the fields to the River Stour. It will be seen that the whole contents of each of the depositing or lime water reservoirs can be discharged into it. It receives also the water from the down pipes, from the roofs, the gauge-weirs, from the steam-boilers through a 9-inch barrel drain constructed in front of the main buildings, from the cooling pond, &c., &c. It is, in fact, the general outlet, and is a very necessary and convenient part of the works.

Grounds.—The grounds have been laid out with grass, flowers, evergreens, &c., round the cooling pond and N.E. side of the reservoirs, as indicated by the shrubs shown on general plan, fig. 1, plate 44. The plot on the S.W. side is made into a kitchen garden for the use of the men. There are hydrants placed all round the grounds, so that every side and part of the main buildings can be jetted down, the pressure in the main being quite sufficient to command any part, as one of the hydrants on the 12″ main throws a jet over the main chimney, which is 90 feet above the surface of the ground. The yard is finished with fine gravel, arranged with suitable falls to a surface drain. The pathways between the main buildings, and also to the cottage, are laid with tooled York paving, to facilitate keeping the buildings in a state of perfect order and cleanliness in all weathers. Having described the buildings at Wincheap, it will be necessary before passing to the machinery, to describe those at St. Thomas's Hill.

Service Reservoir, St. Thomas's Hill.—The service reservoir, which is built at St. Thomas's Hill, is circular in construction, as shown in plan, fig. 1, plate 47. It is 60 feet inside diameter, and about 20 feet 6 inches total depth inside, and 19 feet 6 inches depth to overflow; the contents are, therefore, about 350,000 gallons. The roof is made of wrought-iron joists and concrete, in a similar manner to that of the depositing reservoir house. The wrought-iron joists are supported by two rows of cast-iron girders carried on cast-iron columns, as shown in figs. 1 and 2, plate 47. The pitch of wrought-iron joists or girders is 2 feet, and the depth 7 inches. The top of the concrete, which is made with falls, is covered with a composition consisting of Portland cement and tar boiled together, and laid on to the thickness of at least ¾ inch. The inside of the reservoir is rendered with neat Portland cement about ⅝-inch thick. The walls are constructed of a brick toothing and concrete in Portland cement. There is a dwarf wall at the bottom of the reservoir stretching across the centre 4 feet in height, which is for the purpose of enabling the supply to the city to be kept going whilst half the reservoir is being cleaned out, should it ever be required. It will be seen that the 12-inch main is divided into two branches, as shown in plan, fig. 1, plate 47, one being introduced on each side of the 4-feet wall. The method of cleaning out is by shutting the 12-inch valve in the cockpit, which is in the line of 12-inch pipes, communicating with the half of the reservoir which it is desired to clean out, and then opening the 3-inch valve immediately adjoining the 12-inch on the same line of main; the water is then discharged through the 3-inch valve into the sump at the bottom of the cock-pit, shown in fig. 6, plate 47, whence it flows away through a 12-inch barrel-drain, shown in plan, fig. 1. Wrought-iron ladders communicate with the bottom of the service reservoir. The ground in which the service reservoir was constructed was for the most part clay, and the field contained so much water that it was of great importance to be well drained. It will be seen there are two rows of drain-pipes carried right round the reservoir, and also a number of vertical drains shown in plan, constructed of fine gravel-stones. These drainpipes are also continued alongside, and at rather a lower level than the 12-inch water main, for about 250 yards down the turnpike road to a convenient outfall. In addition to these the company's ground has a series of drains arranged over its whole extent.

Valve House.—The Valve House is built over the cockpit of the service reservoir, but it is not illustrated. The valve house is built of brick in cement, with stone coping and facings, and a Kentish rag base. It corresponds in design to the depositing reservoirs at Wincheap. It contains a long index connected to a copper float for registering the level of the water in the service reservoir. The index has gilt lines and figures on a black ground. The pipe in which the copper float works is carried up inside the cockpit. For supplying a public establishment* the tanks of which are about 30 feet above the level of top water of the service reservoir, an apparatus is provided consisting principally of a weighted valve fitted to the top of a pipe which is carried up from the end of the shorter length of 12-inch main entering the service reservoir. There is an outlet valve fitted to this length of the 12-inch main, which, when closed, cuts off the ingress to the reservoir, except through the weighted valve, and the other or longer length of the 12-inch main shown in plan, fig. 1, plate 47. The weighted valve is loaded to a sufficient pressure to enable the water to flow into the tanks of the building, the connection through the longer length of 12-inch main into the service reservoir being cut off by the closing of the 12-inch valve during the supply of the building. False spindles, with handles conveniently arranged, are brought up inside the valve house for the use of the attendant. There is a second manhole, fitted with cast-iron cover, which is kept locked, placed immediately over the weighted valve and pipe in the service reservoir. A Bourdon gauge (registering in feet) is fixed inside the valve house and connected with the branch of 12-inch main which has the weighted valve, so that the pressure can be easily regulated. An overflow-pipe is brought from the tanks of the building and empties itself into a funnel-pipe, conspicuously placed in the valve house, so that the attendant can see immediately the tanks are full. The water from the funnel-pipe is discharged into the 12-inch barrel-drain leading from the sump at the bottom of the cockpit. The attendant then immediately opens the 12-inch valve, and the water follows its ordinary course into the service reservoir. The building is supplied every day. A man attends the valve house daily for this purpose, and at the same time notes the exact level of water in the service reservoir at a given time for the information of the engineman at Wincheap.

Having described the buildings, it will now be necessary to give a description of the engines, pumps, and machinery at the softening works at Wincheap.

Beam Engine.—The engine is an expansive, double-acting, rotative, condensing beam engine. The cylinder is 18 inches diameter, with a stroke of 3 feet, and is provided with a steam jacket and steam spaces at top and bottom, all connected together, and having an independent communication for steam from the boilers, with suitable valves and pipes to discharge the water into the headbox of the air pump. The air pump is 12 inches diameter, and 18 inches stroke. The air pump bucket-valve, also the delivery and foot-valves, are vulcanized india-rubber. There is a small air pump worked from the beam, for supplying air to either of the air vessels of the main pump if required. There is also a governor, with an improved throttle-valve, specially designed by the engineer of the works, by which the pressure on the top and under side of the valve is equalised and the valve made very sensitive. This is a very important feature connected with the engine, as during the summer season, when the streets are being watered, the sudden opening and closing of the hydrants cause a considerable variation in the pressure, which is of course felt by the soft-water pump and beam engine; but the governor and improved throttle-valve are so well arranged that a sudden rise or fall in the pressure of 50 feet is under the perfect control of the governor without the intervention of the engine man. The engine is designed to work at 40 revolutions per minute, and the slide-jacket of steam cylinder is fitted with expansion and slide valves, which are set to cut off at one-third of the stroke. The ordinary duty of the beam engine is to work the spring water and soft water pumps at the same

* The Clergy Orphan School.