tube being always completely filled with water, in order that its upper and lower parts may be kept at a more equal temperature, and that thus the racking strain which would arise from the top plates being exposed to the heat of the sun may be prevented. The arrangements for making a water-tight joint between the trough and the tube is shown on plate 29. The wrought-iron tube rests on a bolster of vulcanised india-rubber, placed in a groove in the bed-plate L, the india-rubber projecting sufficiently to bear the weight of the tube, without allowing the latter to come to a bearing on the bed-plate itself. The standards M M, running on either side of the tube, are also provided with a similar bolster, compressed against it by oak wedges, the bolster and wedges being kept in their place by a recess in the standard. The oak wedges rest one against the bolster, and the other against a piece of india-rubber at the back; the centre wedge is then driven down so that the india-rubber is closely compressed against the standards and the tube. The spaces round the oak wedges are filled in with oakum and white lead.

Some of the most extensive applications of syphon pipes in modern times are to be found on the Canal of Isabella II., designed by Don Lucio del Vallé, formerly Engineer-in-Chief to the Spanish Government, principally for the purpose of supplying Madrid with water from the River Lozoya, but partially for irrigating the market gardens in the environs of the capital. One of these syphons crosses a valley 1,400 mètres in length, and consists of four lines of cast-iron pipes 0·92 mètres in diameter.

The waters of the Culter Burn, which intersects the line of the Aberdeen conduit, are crossed by an aqueduct pipe, forming part of a syphon which follows the profile of the valley, and crossing the Burn itself on two granite piers, the caps of which are formed of a single stone to receive the saddles which support the pipes; the abutments are also of granite masonry. This syphon, as well as that at Crathes Burn, are illustrated in plate 35.

The Valley of the Charles River, which crosses nearly at right angles the line of the Boston Waterworks conduit, is passed by a syphon of iron pipes, two 30 inches and one 36 inches diameter, which, starting from a pipe-chamber on the western side of the valley, descends 52·11 feet below the level of the conduit, and after crossing a masonry bridge of three arches, follows the outline of the slope of the valley, and is connected again with the conduit by means of another pipe-chamber on the eastern side; the pipe-chambers are 17 feet 6 inches by 15 feet, and are built of granite, with iron doors and roofs.

Of the pipe-aqueducts occurring on the line of the Loch Katrine conduit, one crossing the Drymen Road is illustrated on plate 29. It is of considerable length, the pipes are supported on piers of masonry 18 feet apart, and where crossing the roadway are supported additionally by cast-iron cantilevers. The pipes are covered all round with 2½-inch creosoted Norway battens, dressed to the curve of the pipes, and laid on the outside of the projecting flange, leaving between them and the pipe a space of about 3 inches, rammed full with creosoted sawdust, the whole being bound round with iron hoops.

Conduits of small size have in some instances been constructed of earthenware pipes, but there is a great drawback to the popularity of this material in its liability to become fractured by the internal pressure of the water and the external pressure of the earth; moreover it is difficult to make a sound watertight joint that will stand. At Swansea, earthenware pipes were used having butt joints. At each joint a brick flat invert was turned and the two adjacent pipes bedded in the same with hydraulic mortar. The brick ring was then completed so as to encircle the pipes. At Sunderland pipes of red earthenware were originally used, with butt joints, the exterior surface of each end being tapered for a short distance. In forming a joint the ends of the two pipes were wrapped with spun yarn and red or white lead, and then driven into a cast-iron collar, the interior of which had a double taper, so that the joints were wedged up as the pipes were driven home.

Portland-cement joints will answer well if they are not disturbed when setting, or subsequently by settlement of the ground or otherwise. Joints formed with sulphur are better than Portland-cement joints in some respects. At the Paisley Waterworks a considerable length of the conduit (more than three miles) is laid with earthenware pipes of 21 inches and 16 inches diameter, with ordinary spigot and faucet joints made in the following manner: "Two strands of ropeyarn, steeped in thin cement, were wrapped round the spigot and caulked in after being inserted into the faucet; then the remainder of the faucet was carefully and closely filled up with cement, which was bevelled out from the end of the faucet, along the outside of the pipe, with a slope of 1 to 1, and when practicable, as in the case of the 21-inch and 16-inch pipes, a boy was sent to point the inside of the joint with cement." * In rocky bottoms the pipes were laid on a bed of earth 3 inches deep; and in porous soils they were surrounded with 12 inches of clay puddle. When the earthenware pipes were laid more than 9 feet below the surface of the ground, a relieving arch of rough rubble was turned over them to protect them from being crushed by the pressure of the superincumbent earth.

It has been proposed to bed the earthenware pipes in cement concrete to assist them in resisting the external and internal pressures, and, by improving the solidity of their foundation, to prevent leakages at the joints and

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* Minutes of the Proceedings of the Institute of Civil Engineers. Vol. xxxi. p. 41.

fractures at the angle of the faucets. But by this their economy in the first cost, the only inducement to adopt them, is lessened. It must be remembered, too, in comparing the relative advantages of earthenware with cast-iron pipes that the latter always represent a greater or less amount of convertible capital, whereas the former, if removed, would be comparatively worthless.

In every description of conduit it will be necessary to provide means for controlling the flow of water. In open conduits, overflows or waste-weirs should be formed where the waste water can be conveniently led into an adjoining natural watercourse. At such points, too, means should be provided for draining the conduits promptly and completely, and at certain intervals stop-gates, dam-boards, or other similar arrangements, should be provided; so that whenever it becomes necessary to lay dry the bottom of the channel for purposes of examination or repair, or in case of the rupture of the conduit at any point, the loss of water may be confined to the length of conduit between two such stop-gates.

In pipe conduits the above objects are fulfilled by the insertion of sluice-valves and washouts or scouring cocks. Where valley syphons are introduced on the line of an otherwise open conduit, washouts are very essential, with sluice-valves or stop-planks at each end of the syphon; and, if the pipes are large enough, a man-hole should be provided on one of them, near the bottom, to admit of examination and cleansing.

Fig. 158.

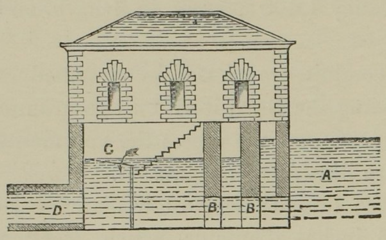
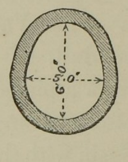


Fig. 158 shows the arrangement adopted at the Boston Waterworks, in which the water is screened previously to its admission to the conduit. A is the lake, or reservoir, BB the sluice, C the screen, and D the conduit. Fig. 159 is a general plan, and Fig. 160 is a section of the brick conduit D.

Fig. 160.



The Chester Hill conduit of the Boston Waterworks has a gate-house, illustrated by Fig. 161, for the admission of the water from the reservoir. *a* is the reservoir, *bb* are the stop-planks, *cc* the rolling screens, *dd* the gates, *ee* 48-inch pipes, *f* stairs from the upper floor, *gg* are stop-cocks, *h* stairs down to drain pipes, *kk* 20-inch drain pipes, *l* an entrance from below the embankment, and *m* man-hole.

Fig. 159.

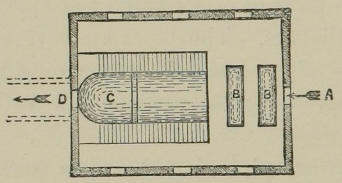
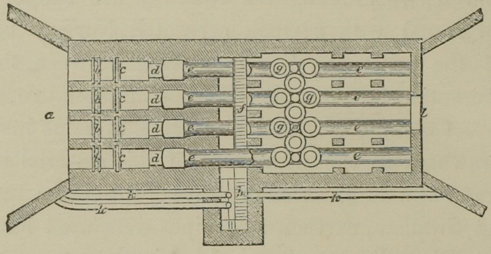


Fig. 161.



On the conduit mains of the Dublin Waterworks a self-acting throttle valve, illustrated on plate 13, is inserted to prevent waste of water, should a fracture occur behind it. Plate 13, fig. 1, is an elevation of part of the main, showing the throttle apparatus, and also a double-faced 33-inch stop valve behind it. Figs. 4, 5, and 6, are enlarged plan elevation and section of the details of the throttling gear, from which its mode of acting is apparent. The disc C, fig. 6, is placed in the centre of the pipe, opposing its area to the current of water against which it is held by the weight of the ball D. When a pipe bursts beyond the valve, and the current is thereby increased by the water finding a free outlet, the excess of pressure against the disc C overcoming the weight of the ball D, causes the lever A to descend. The pin T is thus released, and the weight R causes the wheel E to revolve, and brings the throttle valve M into action, so as to check the flow and consequent waste of water. Fig. 3 is half plan of valve chamber at line of foundation, and plan of surface of road, showing the cover of sluice valve and also cover of ingress to vault containing the valves. Fig. 2 is cross section through the vault.

On plate 14 is shown a similar apparatus as used at the Liverpool Waterworks. The throttle valve M, figs. 1 and 2, is placed on a horizontal spindle in the main, and on the outer end of the spindle is a 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 valve E. A flat disc C, about 18″ diameter, figs. 1, 3, and 4, 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 (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 black line in 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 forward (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 black line in fig. 4, and thereby entirely stopping the passage of the water. The spindle of the throttle valve is placed 1½″ out of the centre of the valve, so that the pressure of the water may assist the weight in closing the valve. To prevent the throttle valve closing suddenly, it is retarded by a piston working in a small cylinder K, the piston rod being connected to the valve 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 stop-cock 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 stop-cock H (fig. 4), so that the discharge outlet from the cylinder K is throttled, and the closing of the valve in the main retarded, owing to the use of the retarding cylinder K and stop-cock H. About three minutes are occupied in shutting the throttle valve M. The force pump L is employed to force the piston down to the bottom of the cylinder, when the whole apparatus is again set in its original working condition.

On the outlet pipe from the various reservoirs of the Liverpool Waterworks a self-acting shut-off valve is placed, illustrated by figs. 5 and 6, plate 14. This is intended to stop the flow of water from the reservoir, should a fracture of one of the pipes take place on the delivery side. The discharge pipe N has a turned-up end, over which is suspended vertically the cylindrical valve P, of an equal diameter. The top of the pipe N and the bottom of the valve P are both faced with brass. In the pipe N is hung, at the end of a long lever, a circular disc C, opposing its flat face to the flow of water from the reservoir, and so weighted at D as to preserve its position so long as the water flows through the pipe at its normal velocity. When, however, a fracture occurs to any pipe on the delivery side of the disc, the flow of the water is accelerated, and the disc C is thrown forwards (fig. 5), this releases the trigger A, and permits the large suspended cylinder P to descend on the orifice of the discharge pipe N, when any further flow of water is effectually prevented. The cylinder P is so weighted at R as to prevent any sudden descent on to the face of the discharge or outlet pipe.

Alarm bells have lately, in many cases, been connected with the valves, so as to warn the attendants.

At the same works a self-acting float-valve is used on the main or pipe line at the upper end of the tunnel, where it terminates in a circular tank of brickwork. Figs. 12 and 13 are plan and vertical section of both tank and pipe. The pipe has a sloping end-piece N, to which is fitted a flap valve M. When any stoppage takes place on the down-stream side, the water rising in the tank causes the floats C to act on the levers A, which rise and shut the flap M. When the water falls in the tank, the floats C also fall, the valve re-opens, and the current runs as before.

For measuring off the compensation water at a stipulated quantity per diem, self-acting gauges are used. Figs. 15 and 16, plate 14, are longitudinal and transverse sections of the gauge, which consists of a cistern fitted with an inlet pipe N from the goit, and a discharge orifice B. A brass plate D, fig. 14, is fixed on the inside of the cistern, with a thin-edged aperture of the size required, so as to give a constant equal flow of water. A beam is placed over the cistern, having a stone float C attached to one end, and a vertical loaded copper cylinder P at the other, both adjusted by screws. The top of the cylinder P is above the high-water level in the goit. This arrangement allows of the passage at the bottom of the cylinder P being regulated by the float C, to correspond with the capacity for discharge of the notch B. The relative levels of the goit and gauge are so adjusted that the gauge must be supplied before any water can pass down the former.

The sluice valves for the 48-inch conduit main of the Manchester Waterworks are opened and shut by worm-wheeled gearing (plate 26, fig. 9). Two men can easily open the 48-inch sluice, one compartment at a time, when the valve is under a head of 80 to 90 feet. But at the reservoirs a small turbine or reaction wheel is used for opening and closing the valves.

The turbine A is geared to the worm wheels B B B, which communicate motion to the valve spindles C C C, by the spur and pinion D. The water driving the turbine flows through the pipe E, and is regulated by a small stop valve F in the service pipe E. A self-acting slide H is connected to levers, which work by tappets upon the valve spindles C, so that when the main sluice valve is either fully opened or closed, the water is shut off from the sluice pipe E, and flows away through the waste pipe K. The hand stop-valve can also be worked by the attendant.

On each line of conduit conveying the water from the reservoirs to Manchester there are placed gauge sluices, which act also as stop-gates. To determine the quantity of water passing through the gauge opening, rods are placed before and behind the sluices B (see figs. 4 to 8). An index A rises with the door of the sluice, showing the vertical extent of the orifice. The index is shown on an enlarged scale in fig. 8. The difference in height of the water before and behind the sluice (that is, the head of water) and the area of the orifice will give the data from which to calculate the amount of water discharged.

A most useful system of gauging is adopted at these works for measuring the amount of compensation water fixed by the Act to be given to the mill-owners below. A general plan of the arrangement made may be seen in referring to fig. 15 which is a plan, and fig. 16 which shows a longitudinal section through the gauge and test basins. From the impounding reservoir the water is allowed to pass into the gauge basin A in quantity controlled by the sluice at E E E. To secure an uniform flow of water under a varying head, the gauge plates B are fitted with slides C, fig. 17, moved by the floats D D, so that the size of the gauging orifice is rendered self-adjusting.

To give entire conviction to the mill-owners that they are receiving their due allowance of water, there is another gauge immediately below by means of which anyone interested in the supply may be at any time satisfied by personal inspection. The water after emerging from the gauging channel is carried by troughs F F across a square test basin H, 30 feet by 10 feet deep. In the bottom of the troughs are placed tumblers K, placed longitudinally and turning on an axis in the centre. This tumbler is a portion of the ordinary flooring of the troughs, the water always passing over it. Fig. 18 shows an enlarged section of it in this position, and in the general plan and section its position is at the letter K also. A lever M is attached to this tumbler, which on being drawn back into the position shown by the dotted lines, figs. 18 and 19, so that the edge of the tumbler just rises above the edge N of the bottom of the trough, is instantly reversed by the stream of water and placed vertically across the trough, when the stop P catches it. The water is now discharged into the basin H for a given length of time, when by raising the stop P by the handle the tumbler is as instantly restored to its normal position and the water thus passes along its course through the trough.

CHAPTER XIII.

DISTRIBUTION OF WATER.

Actual Discharge from Mains, compared with the usual Formulæ—Determination of the Diameters of Water Mains—Corrosion and Furring-up of Mains—Means and Apparatus for Removing Accumulations—Conditions to be observed in Casting Pipes—Apparatus for Testing Pipes with Hydraulic Pressure—Formulæ for Calculating the Thickness of Pipes—Instruments for Gauging the Thickness of Pipes—Various Kinds of Joints—Apparatus for Tapping Mains whilst under Pressure—Safety Valves—Reflux or Stop-back Valves—By-pipes—Sluice Valves—Hydrants and Fire Cocks—Street-watering Apparatus.

HAVING treated of the collection, storage, and purification of water, and also of its conveyance from the source to the town, it will now be necessary to pass to the subject of its distribution.

It will be supposed that the quantity of water required for meeting the demands of the given district has been ascertained, and that the diameters of the pipes for distribution remain to be determined. The theoretic formulæ for these calculations have been given in a former chapter; but it will be well here to make a few remarks concerning discrepancies, which will often be found between the calculated and the actual discharge. These are mostly attributed to inaccuracies in the formulæ, and sometimes to the varying characters of the pipes themselves. In all cases it should be remembered that the test experiments may, and often will, contain slight errors, and since each of the best formulæ is founded on a series of experiments under very carefully ascertained conditions, it is reasonable to believe that sometimes the calculations are more nearly correct than the test experiments themselves. Most of the formulæ usually recognised are for the velocities in or discharges of *straight* pipes, and therefore corrections should be introduced for vertical and horizontal bends, and all variations in diameters; for otherwise the conditions assumed in the calculations will be those giving a larger discharge than that which should be expected. As a rule, however, the standard formulæ give results below the actual discharge, especially with pipes of considerable diameter. The formulæ have mostly been founded on experiments with pipes of comparatively small diameters, and therefore are not necessarily applicable to large pipes. It has been considered that the coating used for the preservation of pipes reduces the friction, and thus increases the discharge; and against this conclusion it has been advanced, that after the first passage of the water has covered with a film the surface of a pipe, the friction is no greater than that of a glazed pipe, since the molecules of water which adhere to the pipe themselves act as a glaze.

Experiments were made in 1870 with the 42-inch main supplying the city of Calcutta with water. Its discharge, as calculated by both Neville's and Downing's formulæ, was 7,450,000 gallons per day, and by Hawksley's and Molesworth's 6,150,000 gallons; whilst the actual discharge as measured at the reservoir was equal to at least 8 million gallons, or an increase of 7·4 per cent. on the quantity computed by Neville's and Downing's formulæ, and 30 per cent. on that by Hawksley's and Molesworth's.

Mr. Bateman's experience shows, in the case of the Glasgow Waterworks, that the actual in excess of the calculated discharge did not continue to the same extent after the works were thoroughly open, and that it gradually diminished. Mr. Rawlinson suggests that this difference arose from the liberated air taken into the pipes by the water; for instance he says: 'You have a pipe 12 inches in diameter, laid on a sharp gradient with the delivery under 200 feet head; you have a valve at the lower end; screw it down and your pipe is full; open the valve and a gush of water comes out at the first, then it absolutely stops, then another gush comes and it goes throbbing on for a considerable time until friction and gravity have balanced each other; but I believe in that pipe you will find a series of vacua, that the water is delivering itself by gushes faster than it can get in, and it is the pull upon the vacuum that causes the water to pulsate.'

Observations on the Edinburgh Water Company's pipes* gave the accompanying results with relation to the formula. The Crawley pipe is 15 inches in diameter and 44,400 feet long; the head is 226 feet above Castle Hill reservoir (= 1 in 196.)

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* Proceedings of Institution of Civil Engineers.

The discharge by formula per minute	294 cubic feet.
Ditto as measured at Castle Hill reservoir	255 ,, ,,

The pipe is thirty years old and much incrustated.

The Coliton pipe, from Clubbie Dean reservoir to Castle Hill, is 16 inches in diameter, was eight or nine years old, and 29,530 feet long, the head being 420 feet (= 1 in 70·5.)

Discharge by formula per minute	575 cubic feet.
As measured at Castle Hill (lowest)	562·5 ,, ,,
Ditto (highest)	600 ,, ,,
Average of fifteen observations	571 ,, ,,

The same pipe, from Larduff cistern to Castle Hill, has a length of 25,765 feet, the head is 230 feet = 1 in 112

Discharge by formula per minute	457 cubic feet.
As measured at Larduff cistern—	
First set of observations	431 ,, ,,
Second ditto	443 ,, ,,
As measured at Castle Hill (lowest)	428·5 ,, ,,
Ditto (highest)	450 ,, ,,
Average of twenty-six observations	440 ,, ,,

The same pipe from Clubbie Dean reservoir to Larduff cistern, length 3,815 feet, fall 184 feet (= 1 in 20·7.)

Discharge by formula per minute	1,063 cubic feet.
Actual discharge	1,215 ,, ,,

A new iron pipe $2\frac{1}{2}$ inches in diameter and 1,150 feet long, with about 11 feet fall, gave on an average about what is due by formula to a pipe $2\frac{1}{4}$ inches in diameter.

That which is known as Darcy's formula (Chapter V., page 80), in pipes of large diameter appears to approach in its results nearer to the actual discharge than any other, and it was the opinion of Professor Rankine, that the resistance decreases to a greater extent in pipes of larger diameter than has been previously supposed. The experiments were made with, and the formula of Darcy deduced from pipes which had been long in use without offering any impediment from incrustation.

Supposing the passage in the mains to be free from incrustation or oxidation (which will shortly be shown to be often serious elements in estimating the discharge), the velocity due to the head, whatever it may be, is diminished by various other causes. Altogether it would seem to be the wisest proceeding to use a formula which gives in excess of the diameter actually required for the time being, since the diameter of the mains must be regulated in consideration of the special requirements of the locality, and its possible future development and increase.

It is the custom of some engineers to make the pipes capable of delivering two-thirds of the whole day's supply in eight hours, or one-half in six hours, that is to say at double the average rate.

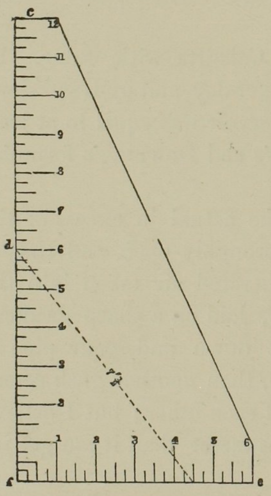
Mr. Hawksley considers a pipe should be large enough to discharge a quarter of the whole quantity in one hour, that is at six times the average rate, and the following formula is recommended by him for adjusting the diameter of pipes for the constant service system.

$$\frac{1}{15}\sqrt[5]{\frac{g^2 b}{h}}=d \qquad g=\sqrt{\frac{(15\,\mathrm{D})^5 h}{b}}$$

g = number of gallons to be delivered per hour.
b = length of the pipe in yards.
h = head in feet.
d= diameter of the pipes in inches.

The following ingenious method, suggested by Mr. George Cockburn, for obtaining approximately the diameter of pipes, will be found serviceable under certain conditions. It is founded on the principle that the areas of squares and circles vary with the squares of their respective diameters or sides, and that the square of the hypothenuse of a right-angled triangle is equal to the sum of the squares of the remaining sides. Required the diameter of a pipe a having the sectional area of two other pipes b and c of different or equal but known diameters; and supposing the pipes b and c to be respectively 6 and $4\frac{1}{2}$ inches in diameter: the diagonal line $c\,d$ will be the required diameter in inches of the pipe a, as shown by fig. 162. Or supposing the diameter of a to be $7\frac{1}{2}$ inches, and that of b $4\frac{1}{2}$ inches; from $4\frac{1}{2}$ inches on the scale take a radius of $7\frac{1}{2}$, and the intersection of the arc with the line $e\,f$ will give the required diameter of a third pipe, the area of which added to b will be equal to the area of a.

FIG. 162.

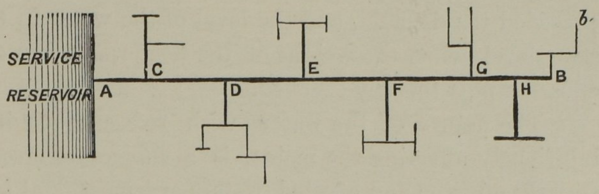


In the poorer neighbourhoods of large cities and towns, where the houses are smaller and the population more dense, the supply which should be provided for domestic purposes will necessitate the introduction of larger mains than in more wealthy districts, where the population is more widely diffused and the requirements of a given area are less. This careful adjustment of the sizes of branch or service mains to the probable demand did not in former years receive the attention it deserved, and even now these matters are very often guessed at in a rough way instead of being carefully estimated.

At Glasgow, in the central part of the city, or in neighbourhoods occupied chiefly by warehouses and factories, and where fires were frequent, the sizes of the mains were regulated more in consideration of the possible demand for water than for the quantity consumed for trade and other purposes; and in other parts of the city they were laid down with reference to the families any given street or district would probably number ultimately.

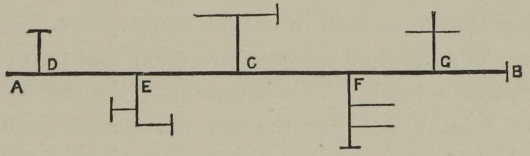
In M. Claudel's system * of proportioning the sizes of mains, A (Fig. 163) represents the point at which the main leaves the service reservoir, and B and *b* the extreme limits to be supplied. The main A B, being the same diameter throughout, should be of sufficient capacity to discharge the required amount at the end of the branch *b*. For the purpose of calculation, the diameter is assumed; the loss of head between A and C being calculated in the ordinary way (see formulæ, Chap. V.) and deducted from the original head will give the effective head at C, which must be sufficient to supply all the ramifications of the branches at C. The water in consequence will be reduced in proportion to the quantity withdrawn at C. In a similar manner the loss of head will be ascertained between C and D. The branches E F and G being treated in the same way, it will be known whether the diameter of the main is sufficient to supply the demands at the extremity of the system. If the head should be in excess at *b*, the diameter may be reduced.

Fig. 163.



In another case, the same authority supposes a main to be receiving water from both ends and supplying it to several branches between A and B (Fig. 164) in definite quantities; some may be only partially and others may be wholly supplied from A, and the same may be the case from B. If it be required that C shall draw from both A and B; then the available head calculating from A must be the same as that calculated from B.

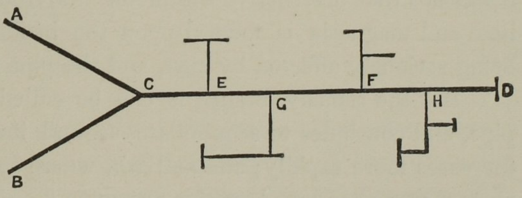
Fig. 164.



M. Claudel then proceeds by approximation, as in the last case, in order to find out if this condition is attained, and assigns some imaginary diameter to A B. The losses of head from the several branches at D E F G being deducted, the effective heads remaining at C will be determined. Should they be unequal, the diameter of the mains must be altered as indicated by the results.

In a third case, suppose the main C D, Fig. 165, to be fed by two pipes A C and B C, the levels at A and B and the quantities to be passed down the respective pipes being known. The diameters assigned to these two pipes must be such that the lines of their vertical declivity shall be coincident in level at the point C. The case may thus be treated as similar to that illustrated by Fig. 163.

Fig. 165.



In supplying a street of unusual width it is often found advantageous to lay two service mains instead of one. The double line is very convenient, too, in streets where the traffic is heavy, as the traffic is then not so much interrupted by laying and repairing the communication pipes. In Melbourne, Australia, this is done in all streets which are more than one chain in width, the pipes being laid on each side; while in streets of less than that width, they are kept as much as possible to the centre.

Under the constant system, the pipes are required to be made larger than under the intermittent, to meet the great fluctuations that take place in the consumption of water in the course of the day, as explained in Chapter XVI. (See also the table on page 120, from which it will be seen, that the greatest consumption took place between ten and twelve in the morning, and two and four in the afternoon.)

Mr. Marten considers that a $\frac{3}{4}$-inch branch main, with a head of 200 feet, would be more than ample to

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* Formules à l'usage de l'Ingénieur.

supply a court containing thirteen houses, and adds that he would not hesitate (with one tap) to supply twenty from the same pipe.

In a paper read before the Institution of Civil Engineers,* on the Bombay Waterworks, by Mr. H. Conybeare, that gentleman described some such arrangement for regulating the supply of water to the hourly varying rate of consumption, as that of the self-acting sluices by means of which the flow is regulated through the filters in Scotch gravitation works. This was effected as follows :—The external orifice of the emission pipe traversing the dam was closed by a flap valve, weighted like the safety valve of a steam-engine. To the end of the valve lever a chain was fastened, which passed upwards over a pulley, and then, descending, was attached to a float rising and falling in a little iron tank, situated underneath the valve. The little tank was connected by a pipe with the pure water basin, and therefore the water in it always stood at the same level as with the pure water in the basin, which was situated immediately below the filter. When the rate of consumption in the town was increased, the level of the water in the pure water basin, and in the tank connected with it fell, and the float of course fell also, and in falling raised the lever attached to the emission valve, and increased the flow of the latter, thereby affording a more plentiful supply through the filters to the pure water basin, until the supply exceeded the demand, and the level of the water in the pure water basin and in the float tank were again at the same level, when the weight of the float was taken off the lever of the emission valve, and the discharge of the emission pipe thereby checked.

The nature of the water with reference to its powers of causing oxidation, incrustation, or otherwise injuriously affecting the mains, is a subject of great importance. It appears from chemical analysis that the slightly alkaline and aërated waters are most fatal to cast iron, and that which is known as the grey cast iron is most easily acted upon by them.

Oxidation, once having set in, goes on with great rapidity, commencing with tubercular formations on the surface, consisting chiefly of oxide of iron often with extraneous matters of organic character ; these tubercles break out, as it were, closer and closer to each other, and ultimately combine to form a thick coating over the surface of the pipe, which not only discolours the water but impedes its passage through the pipes, and seriously diminishes their delivery. An internal coating of linseed oil and litharge, or a wash of hydraulic lime, will delay, but will not ultimately prevent the formation of these tubercles; but in some cases (depending, it must have been, very greatly on the character of the water) the lime whiting has been found on the internal surface of the pipes after they have been in use for many years.

The effect of some waters upon cast iron pipes is to soften them to such an extent that they may be easily cut with a knife. This is especially the case with sea water.

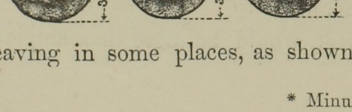
'At Whitehaven the soft water from Lake Ennerdale,' Mr. Rawlinson says, 'acted on the cast iron pipes, and in a very few years those of smaller diameter (3-inch) were all tubercled, corroded, crusted up, and filled with oxidised matter.'

One of the advantages claimed for the constant over the intermittent system is that in a great measure it prevents oxidation. The alternate exposure to moisture and air (occurring of course with worse consequences during a dry season) is one of the most destructive actions to which iron can be exposed, being worse in the case of wrought iron. Soft water, especially that which comes from a peaty soil (usually of an acid character), is excessively destructive to pipes; conglomerated masses of peat and oxide are formed frequently at the joints, when those are badly made. In hard waters the lime is often as great an impediment in the form of deposit, but it has not that destructive action on the iron; for it often happens that a coating of carbonate, or sulphate of lime and magnesia is formed upon the inside of the pipe before there has been sufficient time to allow of its being seriously affected by rust, and the pipe is thus preserved from further oxidation.

But the remedy, if such it can be called, is as bad as the disease, since it diminishes the diameter of the pipe, and continues to accumulate around its sides. When the pipes are constantly charged, this incrustation increases more rapidly; and at Bath, where some of the water is twenty-three degrees of hardness, the constant system was abandoned on this account.

With the very soft and alkaline waters, as much as half-an-inch in diameter is often allowed for oxidation.

Fig 166.



In Yorkshire, the waters are said to be largely affected by hydrous oxide of iron, and the diameters of the pipes are materially diminished with great rapidity.

The waters of Bath, especially those coming from the Winifred Spring, are unusually hard, containing large quantities of earthy salts, and a deposit was formed in the mains of that city, having all the consistency of limestone, leaving in some places, as shown by the sections *b* and *c*, Fig. 166, openings of only 1½ inch diameter in

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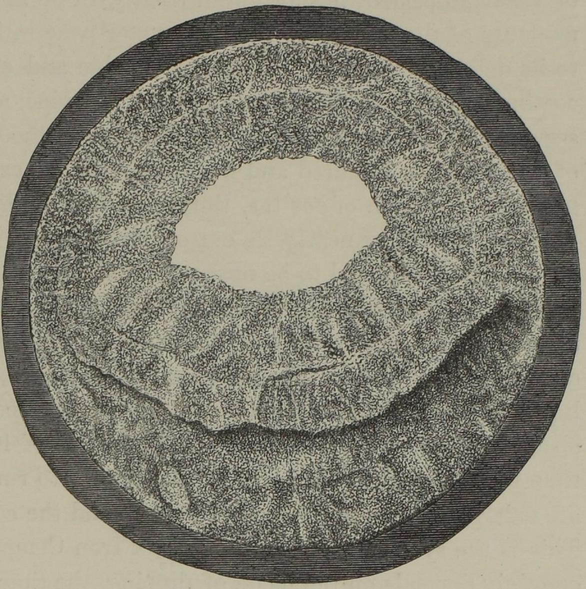
* Minutes of Proceedings of Institution of Civil Engineers, vol. xvii.

that which was once a 6-inch pipe ; the diagram *a* has a somewhat larger opening, being about 2½ inches in width by 1½ in height. Fig. 167 is taken from a photograph, of which *a*, Fig. 166, is a reduction. Dr. Letheby, in his analysis of the Bath water, says 'all the samples were perfectly bright and colourless, even when examined in large volumes, as in a glass tube 2 feet in length, and were even quite free from smell or objectionable flavours.' Each of the samples was tested for ammonia, but the proportion present was extremely small, the largest amounts being in samples B and D (Winifred and Upper Springs), containing respectively 0·008 and 0·009 of a grain, per imperial gallon. The amount of oxygen also required to oxidise where there were traces of organic matter did not exceed 0·036 of a grain per gallon of water. These results show that the waters are remarkably free from organic matter, but they contain large proportions of nitrate of lime, the acid of which has been derived from organic matter that has been oxidised during its passage through the earth. The waters are also extremely hard, from the presence of large quantities of earthy salts, chiefly carbonate and sulphate of lime. On these accounts the waters are objectionable for domestic use, but they do not contain anything that is actually unwholesome.

Fig. 167.



The following are the constituents of the several samples per imperial gallon, as analysed by Dr. Letheby, with the name of the sources from which they were obtained :—

	A	B	C	D	E
Carbonate of Lime and Magnesia . . .	14·38	16·04	13·00	12·60	13·10
Sulphate of Lime	12·49	11·62	7·55	8·13	4·94
Chloride of Sodium (common salt) . . .	3·69	4·31	3·71	2·09	1·32
Nitrate of Lime	11·68	13·52	10·77	5·13	4·31
Silica, Alumina, and Oxide of Iron . . .	0·82	0·91	0·65	0·65	1·00
Organic matter	0·13	0·18	0·00	0·25	0·16
Total per gallon	43·19	46·58	35·68	28·85	24·83
Hardness in degrees	23	28	24	20	18
,, ,, after boiling	13	14·5	10·5	9·5	·8

Mr. Dickenson, marked A, taken from the Reservoir.
Circus Company ,, B ,, ,, ,, Winifred Spring.
,, ,, ,, C ,, ,, ,, Syphon ,,
Calcombe ,, D ,, ,, ,, Upper ,,
,, Lower supply,, E ,, ,, ,, Reservoir.

A very great deal in the prevention of oxidation depends upon the quality of the iron. That pipes should be able at the time of their trial to bear the established test, which would secure them against rupture from the pressure of the water is too often sufficient to satisfy the engineer that his duty of supervision in this respect is complete ; it seems to be forgotten that under certain conditions the material of the pipe itself may be entirely changed. According to the experiments of Mr. Mallet, iron of inferior quality may be converted into plumbago if exposed to the action of foul or salt water. Fifty years ago it was discovered that this effect could be produced by soaking iron in acidulated water. The acid from peaty soil, as before observed, is known to be most destructive to pipes. To avoid oxidation of any kind, as far as possible, the metal should be selected uniformly homogeneous in its surface, close and hard in texture. Impure soft foundry iron rapidly corrodes, the close-grained grey and white iron being less destructible than any other.

Various expedients have been tried from time to time with the view of preventing the corrosive or otherwise injurious effect of water upon the metal of pipes. In 1866 experiments were made by the French navy with a varnish, the invention of M. Crouzière, for the purpose of preserving iron. It consists of a mixture of sulphur, resin, tar, gutta-percha, minum, blanche de ceruse, and turpentine. A plate of iron covered with this varnish was immersed in sea water at Toulon, and on being taken out, twelve months after, was reported to be quite free from rust. Pipes of galvanized iron, dipped in boiling zinc, have been used, but the coating thus formed has been uncertain and unequal, has blistered and come off, and the uncovered places are immediately attacked ; galvanic action also takes place upon the water coming in contact with the zinc and iron, and destroys the latter. A coating of Portland cement has also been tried with no more lasting success, the oxidation taking place either from the moisture of the cement or from the water penetrating behind and peeling it off, thus leaving the surface exposed to its deleterious action. The most durable and effective process appears to be that of Dr. Angus Smith, the coating becoming in fact almost a part of the pipe, and seeming, when properly carried out, very thoroughly to preserve the iron from oxidation. By this process the pipes are taken from the sand, and brought up to a temperature of between four hundred and five hundred degrees Fahrenheit, when they are immersed in a cauldron containing a heated composition of gas tar, Burgundy pitch, oil, and a portion of resin. After being in a certain time, they are lifted vertically, or nearly so, out of the liquid, the surplus composition being allowed to run off. A second process has been applied, said to be more effectual, and attended with less expense and less risk to the pipes, as there was a difficulty in equally heating them; besides the composition coming in contact with highly heated iron was injured and did not adhere as well to the metal as by the process of immersing the pipes cold, which is now most frequently done. In this case they are lowered, cold, dry, and of course free from rust, into a vertical cauldron, the liquid in which is maintained constantly at a temperature of 400°; the cold pipe is then brought gradually up to about the heat of the cauldron. After a bath of half an hour or so, the pipe is slowly taken out of the vessel, time being given for the surplus composition to run off. It is supposed that the pores of the iron in this process are enlarged as the pipes become heated, and the composition entering them is of course retained as the iron cools. This is the system used by the Phœnix Iron Company, at whose works, in Scotland, it was first applied. Much certainly depends on the mode of dipping, the time the pipes are allowed to remain in the dipping pan, and the material. Where the coating by this process appears to have fallen short of its expected result it seems to have arisen either from the difficulty of sufficiently eliminating from the varnish the volatile oils when the dipping pan is first filled, or from the want of proper care being taken that the pipes should be entirely free from rust. The following conditions are specified by an American engineer as necessary to procure by Dr. Smith's process a permanent coating for the pipes :—'Every pipe must be thoroughly dressed, made clean, and free from earth or sand, which clings to the iron in the moulds, hard brushes being used in finishing to remove the loose dust. Every pipe must likewise be entirely free from rust when the varnish is applied. If the pipe cannot be dipped directly after being cleaned, the surface must be oiled with linseed oil to preserve it until it is ready to be coated. No pipe to be dipped after rust has set in.'

The coal-tar pitch is made from coal-tar distilled until the naphtha is entirely removed, and the material deodorised. In England it is distilled till the pitch is about the consistency of wax. The mixture of five or six per cent. of linseed oil is recommended by Dr. Smith. Pitch which becomes hard and brittle when cold will not answer for this purpose.

Pitch of the proper quality having been obtained, it must be carefully heated in a suitable vessel to a temperature of 300° Fahrenheit, and must be maintained at not less than this temperature during the time of dipping. The material will thicken and deteriorate after a number of pipes have been dipped ; fresh pitch must therefore frequently be added, and occasionally the vessel must be entirely emptied of its old contents and refilled with fresh ingredients. The refuse will be hard and brittle, like common pitch. Every pipe must attain a temperature of 300° Fahrenheit before removal from the pan. When this temperature is reached, it may then be slowly taken out and laid upon skids to dry. All pipes of 20 inches and upwards must remain at least thirty minutes in the hot fluid to acquire the necessary temperature.

Whether the pipes are cold or hot when immersed, either operation leaves a fine black varnish all over the surface of the pipe of about the thickness of the thumb nail. A pipe coated by this process was taken up at Manchester in January 1870, after being in constant use for fourteen years, and it was found that externally, to all appearance, it was the same as on the day it was laid down ; on the inside, where the coating had been a little rough and projected, the friction of the water had worn off a portion of the varnish.

The water coming from coal seams is frequently charged with free sulphuric acid, the result of the oxidation of pyrites.

To protect the pipes which bring the water to the surface of the mine Koenigsgruhe from corrosion, they were coated as follows :—They were first for three hours exposed in a bath of hydrochloric acid, then brushed with water, they afterwards received a coating consisting of 34 parts of silica, 15 of borax, and 2 of soda, and were then exposed for ten minutes in a retort to a dull red heat ; after this another coat was put over the inner surface, and the pipes exposed to a white heat for twenty minutes. An enamel was thus formed, uniting well with the iron. This second coating was formed of 34 parts of felspar, 19 of silica, 24 of borax, 16 of oxide of tin, 4 of fluorspar, 9 of soda, and 3 of saltpetre, melted to a mass in a crucible, and ground to a fine paste with a little water. Before the pipes were quite cool, the outside coat was painted with coal tar.

The pipes which were laid down at Torquay by Messrs. Easton, Amos and Sons, were without any protecting composition, and appear to have undergone most rapidly the action of oxidation, due very possibly, to some extent, to the character of the water, thus reducing very considerably the supply; but after having undergone the process of scraping by a method suggested by Mr. Appold (by means of a machine sent through the mains under pressure of the water), the delivery was increased 56 per cent., and by yearly scrapings has been doubled; but after each scraping it declines rapidly about 10 per cent., and in a year 25 per cent.

Fig. 168.

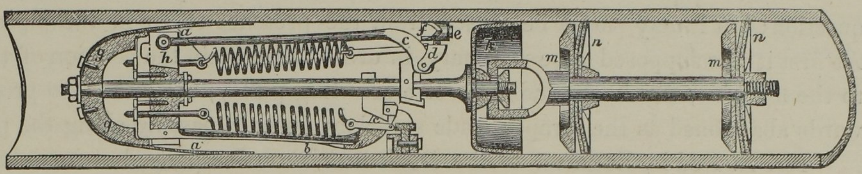
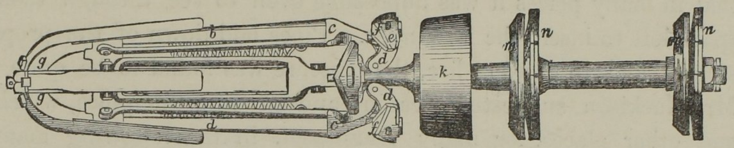
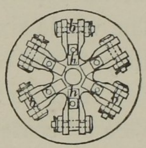


Fig. 169.



The machine just referred to was designed by and made under the direction of Mr. Froude, Mem. Inst. C.E., and will be better understood by the accompanying diagrams. Figs. 168 and 169 represent the machine in section and elevation; *a a* are guide springs which help to centralise the tool in the pipe, as its own weight (about 80lbs.) depresses it slightly out of the centre; *b b*, lifting springs, which elevate the scraper arms *c c* against the sides of the pipe. These springs, when at work, force each scraper against the side of the pipe with a force of about 50 lbs.; moreover they are then in a high state of tension, opening (if released) far beyond their working position, so that a little more or less compression makes but very little difference in the pressure. These conditions, with a spring so limited in breadth and length, could only be fulfilled by utilising the elasticity of steel almost to its extreme limit. It was also necessary that the curvature of the spring in repose should be so adapted to its thickness that when at its work it should become straight. *c c* are the scraping arms of wrought iron, forked so as to play on a pin-joint at their left-hand end. The springs *b b* have their ends under the root of the fork *c c*, and thus elevate it against the side of the pipe. The right-hand end of *c c* is held by a stop, so that it cannot lift more than $\frac{1}{4}$-inch beyond the diameter; *d d* are pieces of wrought iron, of which Fig. 170 is a front view, working with pin joint on end; *d d* are pulled into an erect position by the spiral springs, through the introduction of a connecting link. They stop against a shoulder when erect, the springs being in a high state of tension, almost up to their full duty; *e e* are pieces of gun-metal, which hang with pin-joints on upper ends of *d d*, Fig. 170, and thus form the holders of the knives or scraper edges *f f*. These are screwed to each splayed face of the holder; the splay is adopted to prevent the knives from dropping into bad joints, and is double to prevent lateral stress, the two counteracting each other. The form of the spiral springs is so arranged that it takes a drag of about 65lbs. to begin to force *d d* with its knife, into a position inclined backwards, so that if each scraper were simultaneously to lay hold of some unyielding projection in the pipe, a force of about 400lbs. would, nevertheless, drive the machine ahead, each scraper evading a resistance it cannot overcome. So also the elastic movement of the scraper arms will allow the tool, when set to, say a 10-inch diameter, to go through a 9-inch pipe, each arm having a play of $\frac{1}{2}$-inch; *g g* is a star-shaped gun-metal piece of considerable strength, which carries the guide springs *a a*, and has to bear the hard blows which the tool now and then encounters on reaching a 'door pipe' (or pipe with longitudinal cover held on with bolts and removable), when it may have to be removed, and examined for a start along a fresh length; here occasionally a bank of scrapings is collected, from which the emerging scraper is 'ricochetted' upwards against the flange of the doorway; *h h* is a star-shaped gun-metal piece, which carries the scraping arms *c c*, and elevating springs *b b*, as well as the tail links of the spiral springs; *k* is a kind of 'cup leather,' made of moderately stiff sheet iron; it was originally used as a piston, and lined with leather; but it was found that the cupped form of the piston was liable to set itself fast by pressure of expansion against the sides of the mains; at least phenomena occurred which justified that belief. The quasi-piston was here used simply as a centralising guide with a certain degree of elasticity. The cup was formed by cutting a disc round the edge, and bending up the cut parts, now sufficiently flexible. There are large holes

Fig. 170.



through *k* to discharge the pressure ; *l* is a universal joint, by which the driving-piston rod is flexibly connected with the tool ; *m m* are disc-pistons of plate iron, with a thick chamfered ring rivetted on the outer edge, the chamfer enabling them to slip over any impediment, such as a bad joint ; *n n* are stout leathers cut radially nearly to the centre, the several sections being plated with iron, to give stiffness and hardness, and take the wear against the sides of the pipe. The radial slits let through a portion of the water ; this helps to keep the scrapers clear without practically diminishing the pressure. Fig. 171 is a front view of the radial leathers *n*, and Fig. 172 represents a front view of the machine itself. As the scraper approaches each wash-out, the cock is opened, and the foul water and scrapings ahead of the piston will flow through it to the outlet. A curious fact was noticed in the experiments, namely, the rapid decline of the delivery which continues for a short time after the operation is completed. This has been attributed to the fact of the scrapers smearing, as well as scraping; this creates a smooth surface, the water gradually erodes this surface, and lays bare the rougher one of the pipes. Whether there is sufficient in this to produce the result stated is a doubtful question; but it may partly be caused from the presence of air in the pipes in the manner previously explained. At first it was supposed to be necessary, in order to ascertain the position of the scraper in the pipes, to attach a cord to the machine, which, unwinding over a counting pulley, registered its progress as it went, but this was afterwards abandoned as the scraper made sufficient noise in passing along the pipes to be easily heard above ground.

Fig. 172.

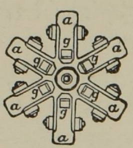
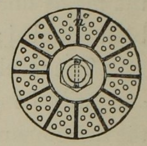


Fig. 171.



Mr. E. Dodds, Engineer to the Durham Water Company, has introduced a self-acting pipe-scraper. The scraper is inserted in the pipe, the water is turned on, which drives the scraper at great speed. At the first experiment 300 yards of pipe were thoroughly cleansed in 2 minutes 20 seconds.

In 1871, Mr. Mackison, the manager of the Dundee Waterworks, successfully cleaned out no less than 10,517 yards of old main service pipe, varying from 2, 2½, to 3 inches in diameter. They were so corroded that in many places it was impossible even to see through them; and, in most cases, there was not sufficient space left to insert the forefinger. Pipes laid down of the proper capacity became utterly inadequate in their supply, and, in cases of fire, the pressure was found to be quite ineffectual To remedy these increasing evils, Mr. Mackison suggested cleaning and scraping the pipes, which had been successfully accomplished at Perth and other places, for many years past, in the following manner:—Spring gouges, with lengths of iron rods screwed into each other, were used. The old pipes being cut, and a length taken out, the water was allowed to run gently towards the opening and against the scraping instruments, carrying with it all the rust and débris out of the pipes into the opening, where the men were working the rods; the water which might accumulate in the opening having to be pumped out into the channels of the street. In some cases, where the pipes were in a straight or nearly a straight line, about 70 yards on each side of the opening could be cleared by the scraper at the same time; where the pipes were on a curve, the scraping could not be accomplished except in short lengths. The whole six miles of the operation was achieved, and the pipes brought up to the full performance of their duty, at the cost of £129; the wages amounting to £84, and the value of the materials to £45.

A great difficulty was experienced by incrustation in the pipes of the Old Dublin Waterworks (which were all coated inside), from the water used there, namely the canal water. Calcareous deposit, composed of lime, earth, and oxide of iron, frequently reduced the bore of the pipes to one-third of their original size; in its dry state it was rather difficult to remove; but when the soft water of the 'Vartry,' which is altogether devoid of lime, was run through the pipe, it acted as a solvent, detaching the deposit from the sides of the pipes, and carrying it along till it was run off at the end plugs or hydrants.

It has been supposed that even oxidation may be caused or increased by the pressure exerted by a head of water upon the inside surface of the main; since in some cases the tubercles of rust have been found to be larger and closer together where the pipe has been subjected to pressure. No thickness of pipe is a guarantee of its security, if its material is liable to be changed by chemical action to a nature unable to resist the pressure required.

Mr. Schott, in his microscopical examinations of fractured iron, arrives at the conclusion that all crystals of iron are in the form of a double pyramid, the axis of which is variable, as compared with the size of the base. The crystals of the coarser kind, as compared with those of the finer qualities of crystalline iron, are of about twice the height. The more uniform the grain, the smaller the crystals, and the flatter the pyramids which form each single element, the better is the quality, the greater the cohesive force, and the finer the surface of the iron. These pyramids become flatter as the proportion of carbon contained in the iron decreases. Consequently, in cast iron, and in the crudest kinds of hard steel, the crystals approach more the cubical form, from which the octahedron proper is derived; and the opposite extreme of wrought iron has its pyramids flattened down to parallel surfaces, or leaves, which in their arrangement produce what is called the fibre of the iron. The highest quality of steel has all its crystals in parallel positions.

All the best cast-iron pipes, except those of the smallest diameters, which are cast at an angle, are now cast in a vertical position, and are therefore more likely to be of uniform thickness than if cast horizontally; as in the latter case the molten iron has a tendency to float or lift the core, and so cause the under side of the pipe to be considerably thicker than the upper ; it being with the latter method no uncommon thing to find the metal of a pipe half as thick again on one side as it is on the other. Where a considerable number of pipes of the same kind are required, it is also customary to use iron patterns, as they are not liable to alter in shape like wooden ones, are more durable, and draw cleaner from the sand.

A good cast-iron pipe should be straight, true in cross section, square on the ends and in the sockets, and the metal of equal thickness all round, with a smooth surface, and free from air bubbles, scoria, or core nails. The latter are used in horizontal cast pipes, to hold the core in position, and after the pipe is cold are hammered up. They are, however, prejudicial, rendering the pipes liable to break at the points where they are inserted. A careful examination of the sockets of small pipes is needed to detect honeycomb ; for after the main is laid and well jointed, serious leakages may occur through honeycombed sockets.

The factor of safety assumed by Professor Rankine for cast-iron water pipes is, that the bursting pressure shall be five times the greatest working pressure. Practically, in small pipes this factor is much exceeded, partly on account of the difficulty of casting sound pipes sufficiently thin, and also from their liability to accident if made no thicker than the theoretical formula requires.

In the United States, pipes are tested to four times the head of water they will be subject to in practice; and the pressure is considered effectual in detecting the mixtures of inferior iron which may be used in the cupola, and will often expose defects which hammering will not betray, if only tested to their working pressure.

The testing of pipes has been the origin of several machines upon various principles. Figs. 173 and 174 illustrate an hydraulic pipe-proving press by Messrs. Tangye Bros., which is here represented as operating upon a flanged pipe. The movable cover A, which is adjusted at first by the hand wheel B, is afterwards, when brought home to the pipe, made quite tight by capstan levers inserted in the openings G. Gasket rings of plaited hemp, or india-rubber washers, are inserted between the pipe and the cover, to prevent leakage. The strain is taken by the horizontal bolts D D. The cock E lets on the water from a tank above into the pipe ; F is an air cock to allow the escape of air while the pipe is filling. A force pump, furnished with a pressure gauge being connected to the inlet pipe, and the pipe to be tested having been filled with water, a very slight working of the pump is all that is required to put on any amount of pressure necessary for the purpose. With a slight modification this machine may be used for socket joints. While the pipe is being tested, and when under the greatest pressure, it should be smartly struck several times along its length, with a hammer of proportionate size. The sound thus produced is, to an experienced person, a good criterion of the quality of the pipe. The hammering also detects many flaws that would otherwise undergo successfully the test of water pressure alone.

Fig. 173.

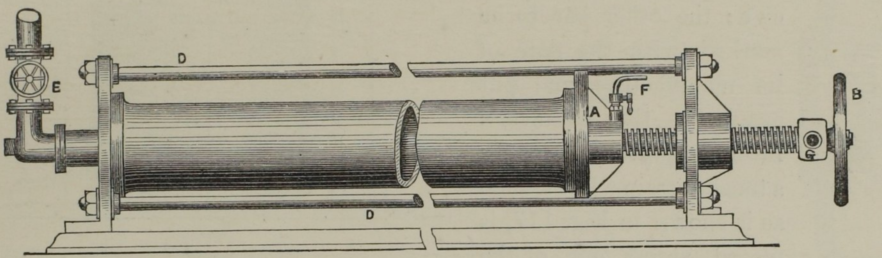
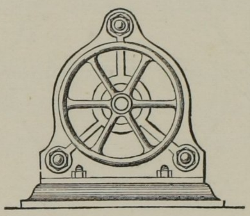


Fig. 174.



An arrangemement has been patented by Mr. Henry Cochrane, of Middlesborough, by which the great pressure brought to bear upon the caps used in closing the ends of the pipes in the ordinary method of testing, and the expense of fastenings sufficiently strong to hold them in their places, are considerably reduced. A core, somewhat less in diameter than the pipe itself, is placed within it, and the water is then forced into the annular space between the two.

Figs. 175 and 176* exhibit an elevation and plan of the testing machine used by Edington and Sons in their foundry at Glasgow. The machine comprises a base plate A, with two side standards B, and a cross head C, together enclosing the circular weights D. These weights are suspended by means of a central vertical bar E ; a part of this bar has a screw cut upon it, and upon this works a nut or internally screwed boss F, which

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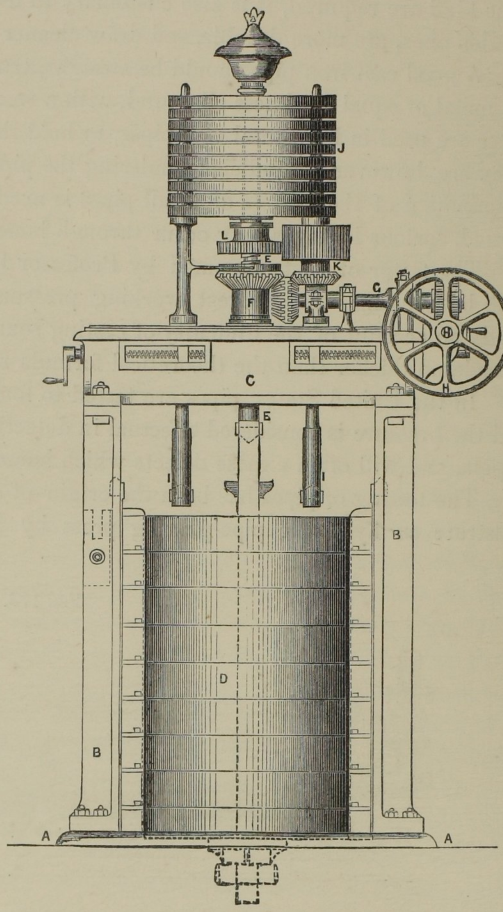
* Memo. of Inst. of Engineers in Scotland, vol. vi.

is formed with bevel teeth, actuated by a bevel wheel on a horizontal shaft G; this last is worked by means of a worm wheel from a transverse shaft H. On the top of the screwed boss F there is a brass index plate, made adjustable to suit the varying thickness of the bars to be tested, this index plate being fixed by means of a thumb screw.

The bar to be tested is placed upon knife edges, in a pair of pendent links I, being passed through a slot in the central bar E.

FIG. 175.



The bar E with the weights D is then lowered by means of the gearing, until the central inverted knife-edge in the top of the slot just bears on the bar, so as to hold it fast, but with little or no actual strain. The index plate is then adjusted, with its zero point at a point of a stationary index finger, and as the operation of lowering the weights goes on, the movement of the index plate supplies an exact indication of the deflection which the bar experiences, and this on an enlarged scale depending on the pitch of the screw. More minute readings may, if necessary, be taken by means of a vernier, or micrometric scale, so that an infinitesimal degree of correctness may be attained. From every composition of metal used for each day's casting in the manufacture of the specified articles, duplicate bars 3 feet 6 inches by 2 inches by 1 inch should be made; one of them is to be tested, having bearings 3 feet apart, and a dead actual weight of, say, 30 cwt.; the other bar to be marked with the date of its manufacture, and put away for the engineer's future inspection. To apply a tensile strain a lever, such as is shown in Fig. 177, is placed across one of the pendent links I, with the inverted knife-edge of the central bar F bearing on one end, and the bar to be tested suspended from the other, being strained between it and a block M, fixed in the side standard B. The pendent link I can be screwed inwards or outwards to vary the position of the fulcrum of the lever, the lever being formed with notches, giving suitable multiples of the strain, or separate levers may be used, giving different multiples.

FIG. 176.

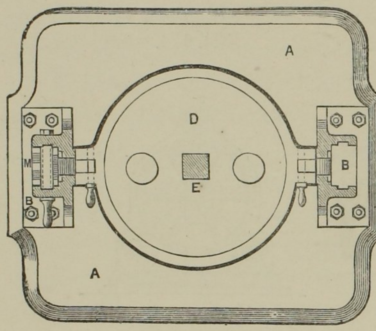
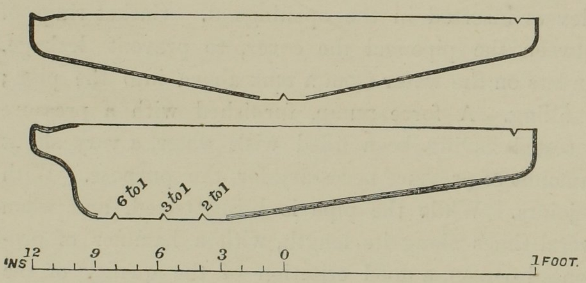


FIG. 177.



The following tests were applied to the cast-iron pipes used for the Paisley Water Works:—

Diameter in inches	Thickness of metal	Head of water	Diameter in inches	Thickness of metal	Head of water
5	$\frac{1}{2}$	600	17	$\frac{3}{4}$	300
8	$\frac{9}{16}$	300	18	$\frac{3}{4}$	300
8	$\frac{5}{8}$	600	18	$\frac{13}{16}$	400
10	$\frac{5}{8}$	300	21	$\frac{13}{16}$	300
10	$\frac{11}{16}$	600	22	1	400
16	$\frac{3}{4}$	300			

They were struck several times smartly with a hammer whilst under pressure, and those which leaked were rejected.

It is often the practice to test pipes twice: once before leaving the foundry, and again either on their arrival on the works or after they are laid and jointed. If the latter method is pursued, it not only tests the safe transit of the pipe, but also detects any leakage occurring from imperfect jointing.

The following formulæ* give the thickness of metal for cast-iron pipes:—

$$P = 0{\cdot}433\ H$$

$$t = 0{\cdot}000054\ H\ d + x$$

$$\text{or } t = 0{\cdot}000125\ P\ d + x$$

Where H = head of water in feet.
P = pressure of water in lbs. per square inch.
d = internal diameter of pipe in inches.
t = thickness of metal in inches.
x = ·37 inch for pipes less than 12 inches in diameter.
= ·5 inch for pipes from 12 to 30 inches.
·6 inch for pipes from 30 to 50 inches.

Mr. Hawksley considers that the thickness of cast-iron pipes should equal $\cdot 18\ \sqrt{d}$ where d = diameter of pipe in inches; or, in other words, the thickness in inches should be equal to about $\frac{1}{5}$th the square root of the diameter in inches.

The theoretical formula for the thickness of metal of circular pipes is usually given as $t = \dfrac{p\ r.}{C - r.}$

t = thickness of metal in inches.
p = pressure in lbs. per square inch.
r = internal radius of pipe in inches.
c = cohesive strength of metal per square inch = 15,000 lbs. for cast iron.

It is often necessary, however, from practical considerations, to make the pipes of thicker metal than that given by the latter formula.

For gauging the thickness of pipes a useful contrivance has been invented by Mr. H. J. King, who has adapted the principle of the common callipers to a most delicate machine for this purpose.

The following description is from a paper read by Mr. J. Page, C.E., by whom certain alterations and improvements have been made:—

FIG. 178.

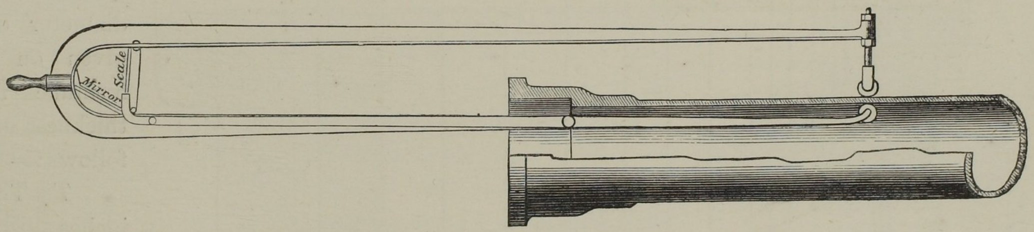
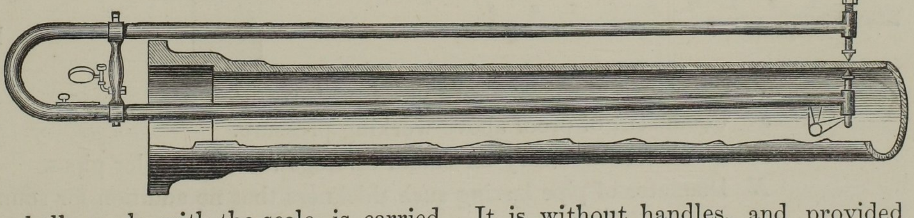


FIG. 179.



'Upon the upper leg of the long callipers, Fig. 178, and at the extreme end, a stud or pin is fitted, carrying a roller which runs upon the top of the pipe. On this stud a thread is cut to allow of adjustment by means of the nuts at the top and bottom of the boss, through which it passes. Upon the lower leg, which is about two-thirds the length of the upper one, a lever works upon a stud at the end. The shorter end of the lever is provided with a small roller, which is kept against the inside of the pipe by the greater weight of the longer end; this end records the thickness of the pipe upon the vertical scale, which is fitted between the two sides of the instrument, and likewise performs the office of a stay. In order to read the scale horizontally, which in practice is found necessary, and to avoid stooping when testing small pipes, a plate of glass is fastened to the frame, at an angle of about 45 degrees, which, reflecting the vertical scale, enables it to be easily read by anyone standing above it. Fig. 179 is a modification of the above, as designed by Mr. Page. It is made of wrought-iron tubing, in which the rod connecting the bell crank with the scale is carried. It is without handles, and provided with a magnifying glass for the purpose of reading the scale. The smaller pair of callipers, Fig. 180, are for the purpose of testing the minimum thickness at the end of a pipe. To do this it is opened by hand, and slipped on to the pipe, the two small steel rollers being kept up by the spiral spring against the inside and

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* Molesworth's Pocket-Book.

It is often the practice to test pipes twice: once before leaving the foundry, and again either on their arrival on the works or after they are laid and jointed. If the latter method is pursued, it not only tests the safe transit of the pipe, but also detects any leakage occurring from imperfect jointing.

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t = thickness of metal in inches.

x = ·37 inch for pipes less than 12 inches in diameter.

= ·5 inch for pipes from 12 to 30 inches.

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The theoretical formula for the thickness of metal of circular pipes is usually given as $t = \dfrac{p\,r.}{C - r.}$

NOTE.

The formula given on page 189—*line* 15 *from top—is inadvertently ascribed to Mr.* H*AWKSLEY*. *It is an old commercial formula, which has been found useful and convenient for foundry purposes, in cases in which a calculation of strength was unimportant.*

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by Mr. H. J. King, who has

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hom certain alterations and

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FIG. 178.

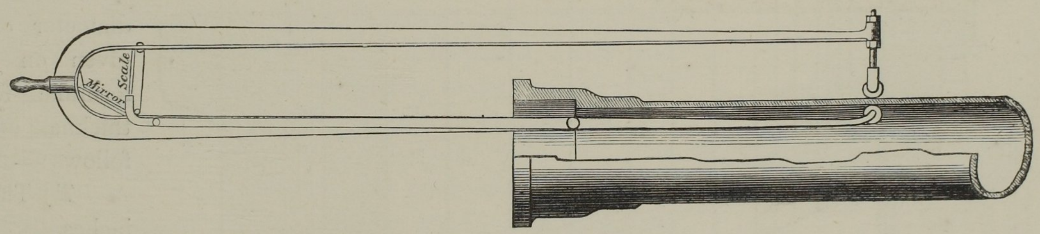
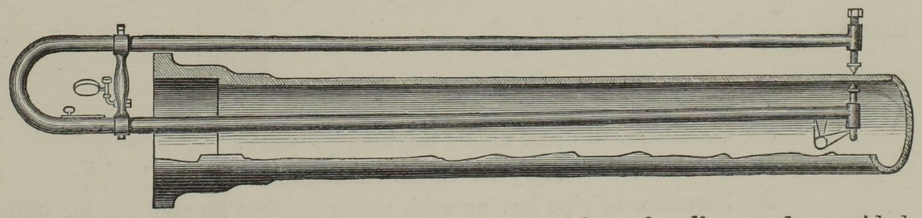


FIG. 179.



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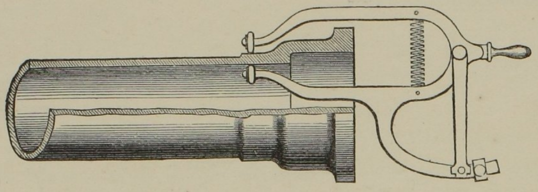
* Molesworth's Pocket-Book.

outside surfaces. It is then run completely round the pipe ; and previous to being taken off an examination is made of the slide on the scale connected to one leg of the callipers; as the surfaces of the two wheels kept up by the spiral spring come nearer together, this slide is gradually pushed back by the arm on the other leg, until the minimum thickness is reached, when it remains stationary until read off. When put on another pipe the slide is pushed up by hand on to the arm, and the process repeated.*

Fig. 180.



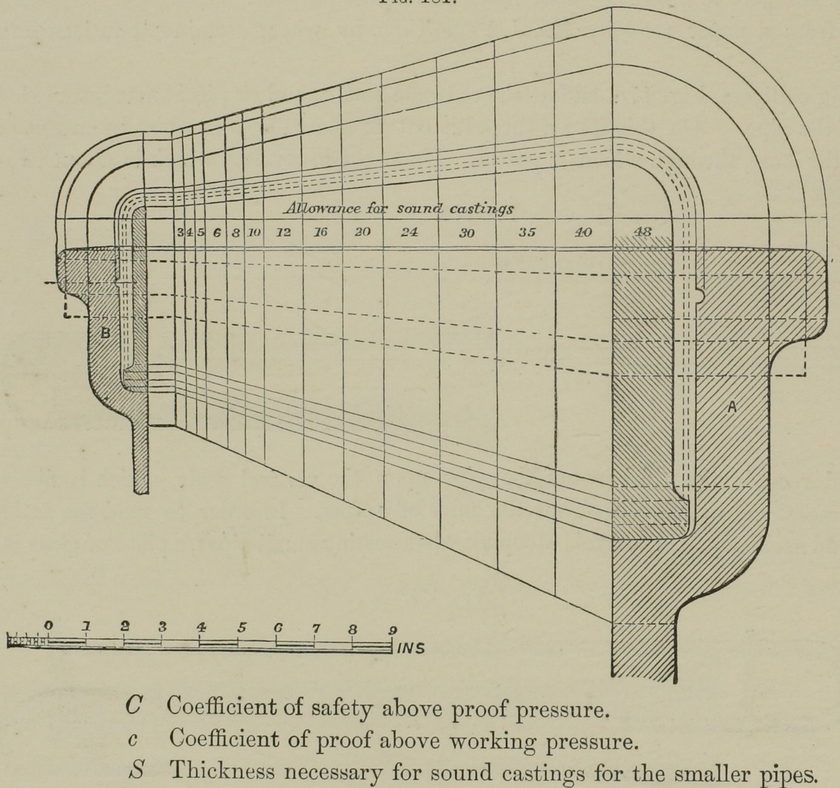
In laying mains care should be taken to place them at such a depth as not to be influenced by change of temperature. M. Girard gives for cast iron an increase in length of ·00000300228 of a foot for every additional degree of Fahrenheit, if the pipes are in the open air. By placing them a certain depth under ground, they may be considered practically independent of any atmospheric changes of temperature. It appears that at the depth of 4 feet in temperate climates the variation is very little; but in countries of extreme cold, water has been found frozen in pipes laid considerably deeper than this.

M. Girard states, as the result of his experiments, that at whatsoever temperature the water enters the line of pipes (if constant in its flow), it will leave it at the same temperature. Other reasons than those just stated necessitate a certain depth for pipes below the surface ; they should be beyond any influence from escape of gas and the injury likely to be incurred by traffic, and yet should not be too deep to prevent easy access to them for repairs.

Various kinds of joints for cast-iron pipes are shown in Fig. 17, Plate 12.

Fig. 181 illustrates the method by which the proportions of the cast-iron pipes used for the distribution of the water of the Washington Waterworks were obtained by their engineer, Captain C. Meigs. The diagram is to a scale of one quarter full size. Of the two sections represented thereon, that marked A refers to a 48-inch pipe, and B to a 3-inch pipe. The intermediate distances between the two sections give the several proportions of various intermediate sizes of pipes. The dimensions in terms of the diameter of the pipes, are also given on the diagram. The formulæ for determining the thickness of the metal is given as follows:—

Fig. 181.



T Thickness of the pipe in inches.

D Diameter of the pipe in inches.

K Tensile strength of cast iron in pounds per square inch.

P Pressure of water in pounds per square inch.

C Coefficient of safety above proof pressure.

c Coefficient of proof above working pressure.

S Thickness necessary for sound castings for the smaller pipes.

N Diameter of pipe having such thickness that no addition for sound casting is necessary.

$\frac{K}{Cc}$ Strength of cast iron in pipe.

$S\left(1-\frac{D}{N}\right)$ Additional thickness for all diameters.

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* Proceedings of the Inst. of Engineers in Scotland, vol. xi. p. 97.

$$T=\frac{P\,D\,C\,c}{2\,K}+S\left(1-\frac{D}{N}\right)$$

When $K=18{,}000$ lbs. then $C=3\frac{3}{4}$, $c=4$.

$N=48''$ $S=\frac{1}{4}''$ $P=75$ lbs.

$\frac{K}{C}=4{,}800$.

$T=0{\cdot}0260416\,D+0{\cdot}25$.

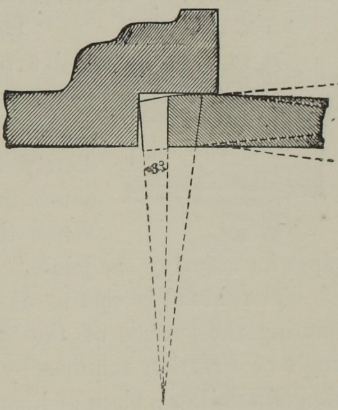
In making the ordinary lead joint several coils of yarn are rammed into the socket by means of a caulking tool; a luting of clay is then laid round the outside of the socket, and the remainder of the space not occupied by the yarn is filled in with molten lead. Sometimes, instead of yarn, strips of cold lead, each of such length as just to encircle the spigot end of the pipe, and sufficiently thick to occupy the space between the outside surface of the spigot and the inside of the socket, are inserted, and driven well home; the remaining space is then filled with molten lead as before, which in both cases is perfectly set up. Many cases occur in practice where it is necessary to use a collar of the kind shown by Fig. 11, Plate 12. The collar serves to join two spigot or plain ends. In mains of large diameters, curved pipes or 'bends' are sometimes replaced by 'cant-collars.' A cant-collar may be described as consisting of two sockets placed back to back, but so that their axes are more or less inclined to one another.

To obtain a certain amount of flexibility in the jointing of pipes, without producing leakage, is a great desideratum in the laying of mains, especially where the soil is liable to subsidence. This is frequently the case in mining districts, where pipes often sink to such an extent that serious leakage takes place, either by fracture, or at the joints.

In the use of turned-and-bored joints, which have of late become so general, various expedients have been tried, in order to effect a sufficient freedom of action; as, for instance, in the use of curved instead of straight turned and bored surfaces (see Fig. 34, Plate 12), as executed at Liverpool. The joints are more likely to 'draw' and leak than the conical joints, as they will not wedge.

The pipes used at Buenos Ayres, Hobart Town, and Sydney (see Figs. 25, 30, and 33, Plate 12) are very long in the joint, and therefore more than usually rigid. Fig. 32, Plate 12, illustrates a joint suggested by Mr. Jno. Downie. The socket has rather less taper than usually given, the breadth of the turned portion of the spigot end being only about equal to the thickness of the pipe at that part, and slightly rounded. It is suggested that by this means a lighter and more efficient joint is obtained, with less likelihood of misfit; as with ordinary bored joints the bearings are very rarely commutual, though in theory they are supposed to be so. Mr. Downie says that one of these joints was driven home at an angle of one inch in three feet, or to a curve of about 200 feet radius, and was tight under 300 feet head of water.*

Fig. 182.



The joint invented by Mr. Williams (Fig. 182) possesses kindred advantages to that suggested by Mr. Downie, and is especially adapted to places where land is liable to settlement, as in the mining districts. According to the angle at which the pipes are united, the spherical exterior of the spigot will be changed; and to any deflection of the line of pipes, therefore, within reasonable limits, the joint will adapt itself without distortion. An experiment was tried at Liverpool with this joint upon five lengths of 44-inch pipes 12 feet long and $1\frac{1}{4}$ inch thick; the joints of the two end pipes were caulked in the usual manner, and the ends closed with iron covers. A pressure of 50 lbs. per square inch was obtained whilst the joints were deflected by means of a screw-jack, until the centre pipe was $13\frac{1}{2}$ inches below the ends. The caulked joints were found to leak very considerably, whilst the patent ones were secure. It should be added that the diameter of the spigot should be slightly in excess of that of the socket, and the union effected under expansion by heat. Fig. 8, Plate 12, illustrates a special ball-and-socket joint, which can be adapted to any curve.

Pipes with turned-and-bored joints can be laid with greater rapidity, and at less cost than can pipes with lead joints.

A French application of india-rubber for jointing, termed the 'système Lavril,' intended for the purpose of adapting the line of pipes to undulating ground, was used at Tunis.

In laying the water mains across the river Schuylkill, at Philadelphia, where its bed was very uneven, Messrs. Ward and Craven's moveable joints were adopted. The socket ends of these pipes are bored to a spherical form the centre of which would be at *a*, as in the accompanying Fig. 183. The spigot end of the pipe is provided

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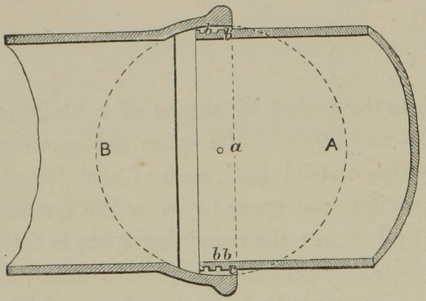
* Engineering, vol. viii. p. 34.

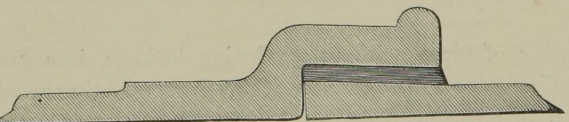
with bands or annulets *b b*; the intervening space *c*, between the spigot and the faucet, is filled up with lead in the ordinary manner. As will be seen by the diagram, a space is left between the end of the spigot and that of the socket, which gives to the joints the latitude they require, to take the form of the river bed. They were jointed on a barge which was moved from its place at every fresh joint, and the line, when paid out, sank joint by joint to the bed of the river. In the case of pipes of large diameter, such as the ones above referred to, it is possible the lead may be sufficiently displaced to cause a leak; this can always be remedied if the pipes are large enough for a man to enter, and caulk them up from the inside. The extreme depth of the river where the main crossed it was 25 feet.

Fig. 183.



A joint designed by Mr. W. C. Homersham is shown in the annexed Fig. 184. It is formed by slightly increasing the diameter of the end of the spigot, and tapering the inside of the socket to the same angle.

Fig. 184.



Several variations of the old caulking process have sprung up from time to time. In laying the Liverpool 36-inch mains, a luting of twine, with a composition of tar and naphtha, was successfully used. Roman cement has been often used with turned and bored joints, as also asphalte, and, to make security doubly secure, even lead.

Fig. 185 represents a butt joint with serrations at the end of each pipe, over which the hollow collar is passed. A cement, consisting of sulphur, gutta-percha, tar, resin, leather, minum, blanche de ceruse, and turpentine, is poured into the space between the casting A and the pipe. This, when set, prevents the separation of the pipes, but they can be removed by the application of heat, which dissolves the cement.

Fig. 185.

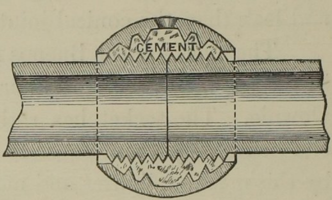


Fig. 186.

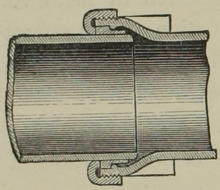
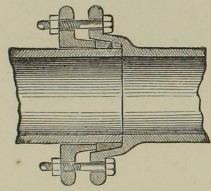


Fig. 186 is another form of joint, the socket of the pipe having a screw thread cast on the outside, upon which a nut is fitted, and by this means the lead or whatever the packing may consist of, can be tightened up. This is a patent of Jean Baptiste Denans, Paris.

Fig. 187 is a joint in which a packing A is tightened up by the means of bolts.

A device for obviating deflection, and the disadvantage of joints in ordinary use, by making the joint rigid and capable of resisting a considerable weight, has been invented by Mr. Barker, and is thus described by the inventor* (Fig. 188):—

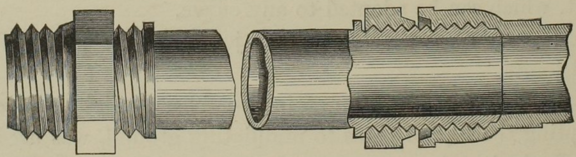
Fig. 187.



'These advantages are obtained by making the pipes with screw and flange spigots cast with a male thread, and the socket with a female thread; by inserting the spigot into the socket and causing the pipes to turn once round, the joint closes, compressing into a recessed channel at the root or end of each of the threads some moist cement, which is immediately confined between the surfaces, and at the same time the taper nose of the spigot enters the conical cavity at the root of the socket, in which is also a collar of moist cement. When the cement sets, the joint is sealed, thereby adding strength and firmness to the pipes for securing the joints.'

The thread is cast to fit easily, or with a 'lash,' so that the screw is used for a fastening grip only for jointing the surface of the 'flange' or lip of the spigot against the mouth of the socket; any deviation of angle or direction requires by the temporary insertion of a nail or a piece of hoop iron on the exterior radius to cause these pipes to sweep any ordinary curve that may be required, the inserted piece of iron being withdrawn prior to the cement setting; these pipes are not weak at the joints, but capable of maintaining their position when any undue strain or concussion affects them at the joint, and are therefore free from the liability to leakage from those causes which so prejudicially affect other pipes. The principle of these new pipes is that by the rigidity of their joints and strength of their formation they are able to bear more than any usual amount of displacement, because

Fig. 188.



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* Engineering, vol. vii. p. 190.

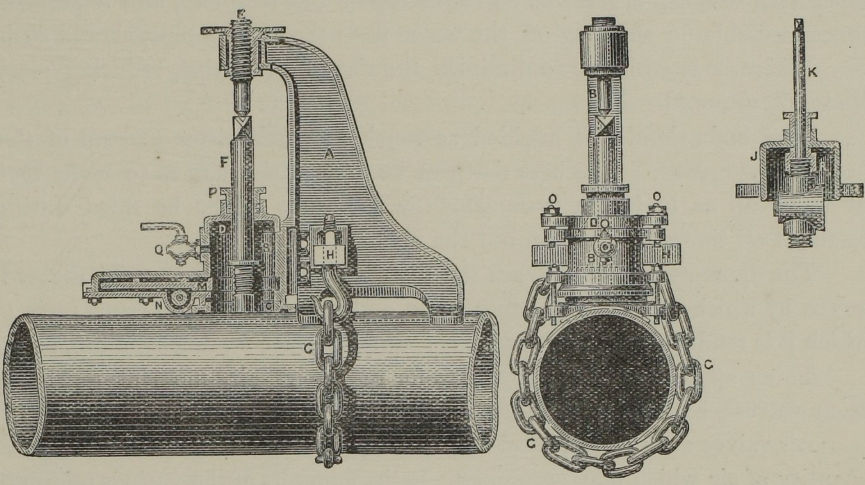
their sensible strength becomes effective to resist it, which no other pipe possesses, also by their continuity of joint any superincumbent weight deflects not only a single pipe, but is transmitted through many lengths, so that each of the new pipes has a smaller amount to sustain. The pipes have been tried with a pressure up to 250 lbs. to the inch without a weep or leakage, and are now in practical work.

Fig. 20, Plate 12, represents a pipe used by Mr. Homersham at Canterbury, bosses being cast at the socket ends for convenience in attaching the services. The manner in which these bosses were utilized will be described presently.

The connection of services and the tapping of mains under pressure therefor have been, up to within the last few years, operations attended with trouble and inconvenience. With an intermittent service the connection could be made when the water was 'off,' but there was always a greater or less waste of water in draining the mains. But with the constant system the inconvenience was particularly great, as the supply from the main, at least between the sluice cocks on either side, had of necessity to be discontinued during the operation.

An ingenious apparatus, illustrated by Fig. 189, was devised by Mr. Alfred Upward, and patented by him May 1st, 1860, to tap mains whilst under pressure.

FIG. 189.



The drill-post A is fixed over the place where the hole is to be drilled, and firmly held by the clamp chain G. Attached to the lower end of this post is the valve chamber B, the escape of water at the joint between it and the pipe being prevented by the india-rubber washer C. The drill F, of the required size, is now put into the chamber, and fixed by means of a gland P. The valve M having been previously opened by means of the pinion spindle N, and the drill cover D with drill spindle, and drill and tap securely fastened to the valve chamber B by the bolts O O (the joint being made by a leather ring sunk in the recess in the valve chamber) the drilling commences in the usual way. As soon as the hole is through, the drill spindle is pressed down till the tap bites, and the hole is tapped. Tapping being complete, the drill spindle drawn up into the chamber, the slide valve M is then closed; the slide valve M is carefully closed by means of the rack spindle N, care being taken to raise the drill so high as not to injure the valve face, and the pet cock Q is then opened to allow the water above the valve to escape, when the setting of screw E and its nuts are removed, the bolts O O loosened, and the drill spindle with its cover displaced.

The cock chamber J, with service tap screwed on the end of the spindle K, is then attached to the valve chamber B by means of the two bolts O O; the slide valve M is opened and the cock screwed into the pipe by means of the spindle K. As soon as it is home the spindle is relieved by a sharp jerk in the opposite direction, and screwed out of the cap R; the pet cock is again opened to let the water out of the valve chamber, the chain C cast loose, and the whole apparatus lifted off, showing the cock perfectly attached to the pipe, and the connection is then complete.

FIG. 190.

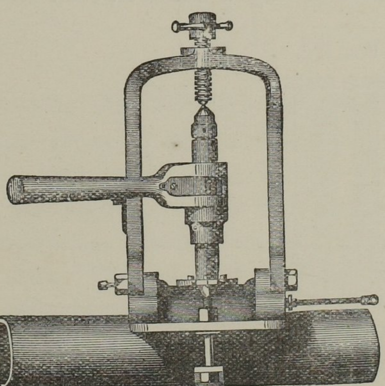
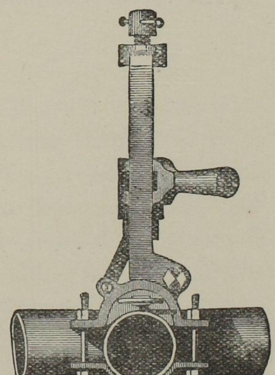


FIG. 191.



By these means a main may be tapped under any head of water, and the service inserted without loss of water, it being only necessary in the above process to properly secure the several joints.

Another system of connection under pressure is that of Mr. George Simmons, and patented by him March 14th, 1861, of a drilling and tapping apparatus for gas and water mains, which the following description in connection with Figs. 190 and 191 will serve to illustrate.

The method pursued at Canterbury, and referred to above, was as follows: A hole was drilled into the boss (Fig. 20, Plate 12), not completely through the metal but within about a quarter of an inch of the interior of the pipe, this thickness being sufficient to support the pressure of the water over the small area of the hole. The hole was then tapped, and a full roundway cock screwed therein. Through the way of the cock a drill was then inserted, and the remainder of the iron penetrated, which being done the drill was rapidly withdrawn, and the cock instantaneously closed with but an insignificant loss of water, and no greater inconvenience to the practised operator.

In the place of the iron plug cock used with Upward's apparatus, Mr. W. Morris, of the Kent Waterworks, uses a straight brass ferrule, screwed internally as well as externally, and containing a screwed plug with a groove on the top to take a screwdriver; the plug being screwed tight down into a seating in the bottom of the ferrule effectually closes the water-way. The ferrule with the plug hard down having been inserted in the main whilst under pressure, there is screwed into it by means of a socket a tee-piece thus ├, and a union or other connection is made between the service pipe and the horizontal arm. The vertical arm of the tee-piece is cut with an internal screw which becomes continuous with that of the ferrule. The plug is then withdrawn, by means of an ordinary screwdriver, into the upper part of the tee-piece and this admits the water from the main to the service pipe. An iron cap is screwed on to the top of the tee-piece, and a permanent joint made. The plug is at all times available for shutting off the water from the service pipe, should such be necessary for repairs or renewals.

Where it is desirable to diminish the size of the mains, reducing pieces, such as that illustrated by Fig 9, Plate 12, are used.

Dead ends should be avoided as much as possible, on account of the water in those portions of the main becoming stagnant. The best that can be done with them is to make them serviceable with scour valves, or to fit them up as hydrants, from which water carts might be filled during the summer; they would also be useful at all times for cleaning out the mains.

The apparatus which govern the distribution of water may be divided into two classes. First, the several means by which the water is admitted to, and regulated in, the trunk main ; and second, the various appliances by which it is rendered accessible to the consumers, either for domestic use, for local purposes, or the extinction of fire.

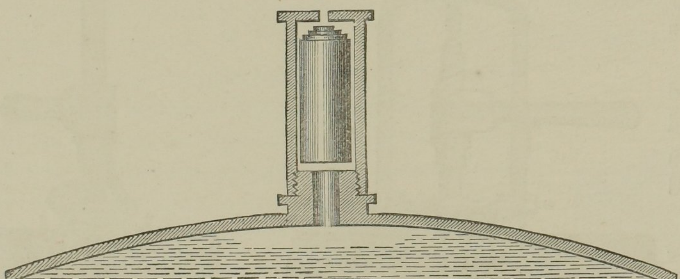
These appliances comprise valves for reservoirs, air, momentum, relief, and reflux valves ; sluice, stop, and scour valves ; hydrants, fire-plugs, stand-pipes, &c.

Air valves are valves placed at certain places on a line of main to prevent its delivery being reduced by the quantity of air which may accumulate at the summits of the various undulations. Very satisfactory air valves are now in general use by most of the water companies, and consist of modifications of Bateman and Moore's ball hydrant or fire cock (Fig. 2, Plate 15). One of these modifications (Fig. 11, Plate 13), is single-acting, and automatically liberates air in large volumes when a main is being charged ; it will not, however, permit any air to escape after once the ball is closed and remains under pressure.

A double-acting valve is one arranged to act both under pressure, and on the charging and re-charging of the main. It consists of a valve of the kind just described placed in connection with a small valve, of construction and action somewhat similar to the larger one, the small valve communicating with the main by a pipe $\frac{1}{8}$ or $\frac{1}{4}$-inch diameter, inserted in the top of the bend leading to the large valve (see Fig. 11, Plate 13). The small ball is too heavy to be sustained against the orifice solely by the pressure upon the small area of the latter. It requires the assistance of its buoyancy; when, therefore, air accumulates in the chamber in the place of water, the ball, no longer supported by the latter, falls away from the opening and allows the air to escape.

Air valves sometimes consist of only a common cock screwed into the highest portions of the main. This system is defective, in so far as it requires some one to look after the cocks, which is expensive ; and in addition there is the possibility of their being neglected. Fig. 192 represents a simple air valve, which may be used for all ordinary purposes.

Fig. 192.



Relief or safety valves should always be fixed in pumping mains, so that the pressure cannot get beyond a fixed maximum should a sluice cock be accidentally or designedly closed, or the flow of water interrupted by any other means. Fig. 10, Plate 13, is a section of a percussion valve, used for the same purpose in the Dublin Waterworks.

Reflux valves are in use on some long pumping mains with a high lift, their object being to shut off the pressure from the lower portion of the mains when the pumps are not working, and also to prevent the higher portion emptying, should a fracture occur in the lower one.

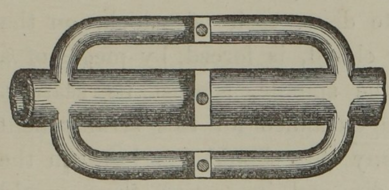
These valves are sometimes used in towns where more than one pressure exists, and where both pressures are at one or more points to the same mains. At the Manchester Waterworks they are placed at the foot of every hill which rises in the same direction as that in which the water is flowing, for the purpose of preventing its return, in case of a pipe being emptied behind the valves.

One of these valves in a 40-inch main is shown on Figs. 24 and 25, Plate 26. The valves are made of leather strengthened by cast-iron plates, and are opened by the water in the direction of its flow.

Figs. 9 and 10, Plate 14, represent a similar valve, used by Mr. Hawksley on the Liverpool mains.

Sluice and stop valves, of which there are many varieties, have exercised the ingenuity of engineers to a considerable extent.

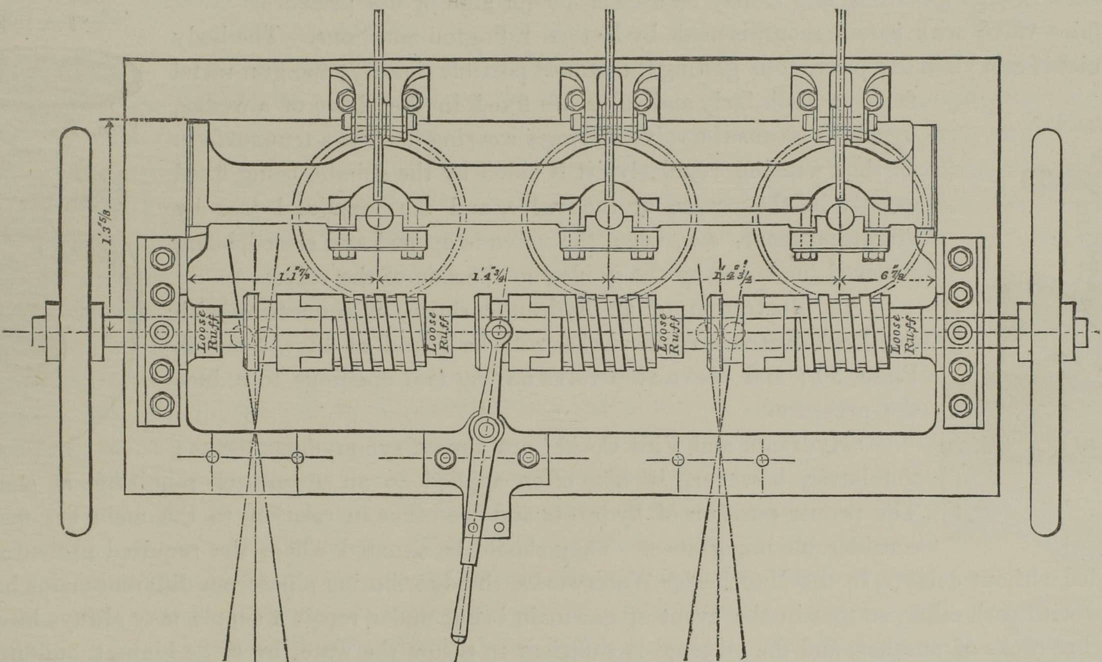
Fig. 193.



Figs. 9 to 13, plate 15, illustrate an ordinary sluice valve, a full description of which will be found in Chapter XVII. Figs. 7 and 8, Plate 13, are sections of a 24-inch single-acting sluice valve, used at Dublin. It is from the design of Mr. John Page, and was manufactured by Thomas Edington and Sons, of Glasgow.

Where the mains are large, and the pressure of the water great, it will be often found difficult, if not impossible, to open the valves by ordinary means. To remedy this by-pass valves are sometimes introduced, as shown by Fig. 193. The smaller valves, which may be opened easily, are opened first, and the pressure against the larger valve having been thus reduced there is no difficulty in opening it.

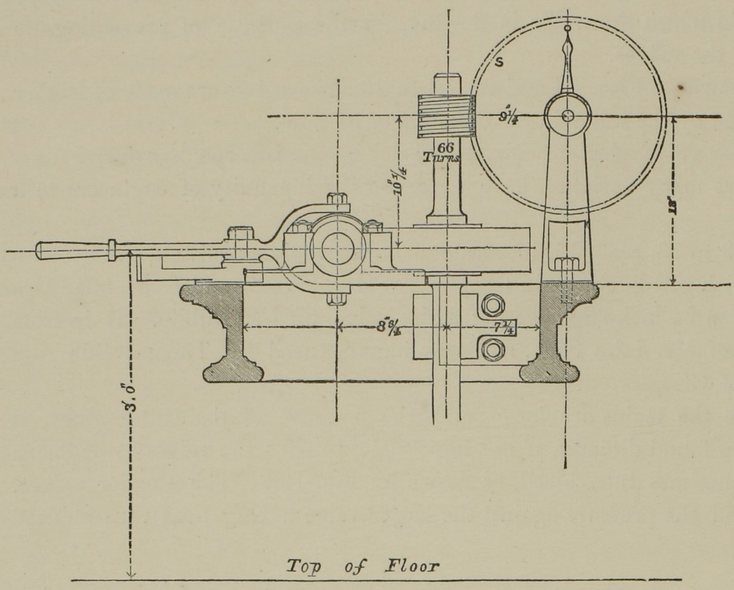
Fig. 194.



In the construction of the Manchester Waterworks, this difficulty was considered of such importance as to cause competition to be invited for the best form of valve—it being a condition that one man should be able to open it. The successful design was that of Sir Wm. Armstrong, Figs. 1, 2, 3, Plate 26. In this valve, which is for a 48-inch main, instead of the sluice being cast all in one piece, it is divided into three segments, each segment being, in fact, a sluice in itself. The centre one, which slides on bars placed across the opening, is made considerably smaller than those on either side. This part is opened first, and the pressure on the others is by this means so reduced that they are easily drawn up. On closing the valve the centre part is shut last. This valve is opened and shut by worm-wheeled gearing (Plate 26, Fig. 9. See description, pages 176 and 177). The same relief is afforded by Mr. Hawksley on the Liverpool main. That gentleman states that when these valves were used not the slightest shock was experienced, and he adds, 'had such been the case, the pipes would undoubtedly have been ruptured; for the length of the column of water and the velocity upon which the force of the concussion was dependent, were both very great.' Fig. 9, Plate 13, is a section of a 27-inch valve on the same principle, used in the Dublin Waterworks. This one has a small air valve placed in the cover.

Page's gearing for working the triple valves, placed at different levels in the Roundwood Towers of the Dublin Waterworks, is shown in the accompanying plan and section Figs. 194 and 195. It is provided with indices and plates, which show to the man working the valves the amount of opening, whether $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$ open or quite closed. The valve has three slides, and by shifting the clutches any one or all of them can be worked at pleasure. As the spindle is turned, the index records the movement of the valve.

Fig. 195.



In Peet's sluice valve (Fig. 196), which is of American origin, the sluice consists of two separate discs, each of which, on the valve being closed, is forced, by means of a wedge on the spindle, against its seating. The advantage claimed for this arrangement is, that if any dirt should get between the face of one disc and its seating, there would still be the other disc to effect the complete closing of the valve.

Warner and Sons' quadrant valve (Fig. 197) is closed by a worm upon the spindle acting upon a ratchet quadrant, and it may be used either for high or low pressure.

A sluice valve with patent scour, is made by Messrs. Edington and Sons. The body of this sluice is cast all in one piece, thus getting the utmost possible rigidity; the gun-metal faces on both body and valve are fixed in the shape of a wedge, by which means the valve is always wearing itself to a true surface. In thus wearing regularly, it is aided by the spindle being fixed exactly in the centre of the valve, and the wear and tear by vibration, scour, &c., when the valve is opened and closed, being received or borne by the guides on the side of the valve.

Fig. 196.

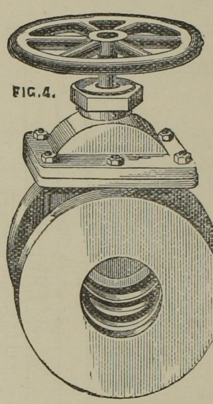
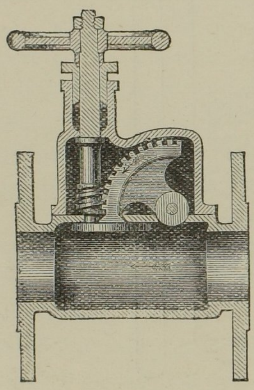


Fig. 197.



An illustration of an hydraulic sluice, in connection with the Lock Katrine Waterworks, will be found at Figs. 1 and 2, Plate 30; and also a stop valve having two openings to reduce the pressure.

'Hydrants and Fire Cocks' are almost synonymous terms; the latter, however, is not often applied to an apparatus requiring a stand-pipe. The proper position of hydrants and fire-cocks in relation to the main are matters of considerable importance. They should be situated where the required pressure can be commanded without delay. In the Manchester Waterworks, the distributing pipes from different mains have been interlaced with each other, so that in the event of one main being under repair a supply may always be obtained from the fire-cocks of another, and the pressure is sufficient to throw the water over the highest building in the city.

One of the hydrants very generally in use is that known as Bateman and Moore's, the invention of one of the former gentleman's pupils, improved upon and patented for him by Mr. Bateman. It consists of a ball A (Fig. 198) floating in water, and closed by the pressure forcing it against an india-rubber seating. As there is no water exposed to the action of the frost on the outlet side of the ball, it cannot become inoperative from that cause, which is a merit claimed for it over other descriptions of hydrants. Fig. 2, Plate 15, shows this to a larger scale. Another reason given for preference to this description of hydrant is, that having no screw or spindle on the fire-cock itself, it cannot get out of order through the spindle breaking or the threads of the screw stripping. This ball hydrant acts as an air valve in both emptying and charging the mains.

Fig. 198.

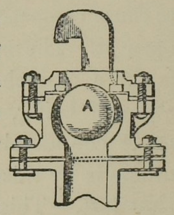


Fig. 199 exhibits a hydrant upon this principle, having a stand-pipe with double revolving discharge outlets attached. When only one outlet is required, the other is fitted with a screw-cap. Both outlets are screwed for connection with the hose.

Against the use of these hydrants it has been advanced that, under high pressure, the india-rubber ball is indented and forced out of shape. To obviate this, metal and wooden balls have sometimes been adopted. (Figs. 2, 3, and 4, Plate 15.) The cheapness of this hydrant is certainly a great recommendation, and its principal defect, which tends to leakage, can be remedied by an occasional addition to the cost. The chief fault of it consists in the liability of the ball, of whatever material it may be made, to lose its spherical form. The hydrant is contained in a cast iron casing and protected when in exposed situations by a cast-iron box (Fig. 200), covered with a loose flap, similar to those in ordinary use. The box cover is made sufficiently large to admit of the thorough repair of the cock without breaking up the roadway.

FIG. 200.

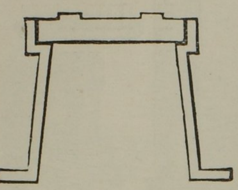
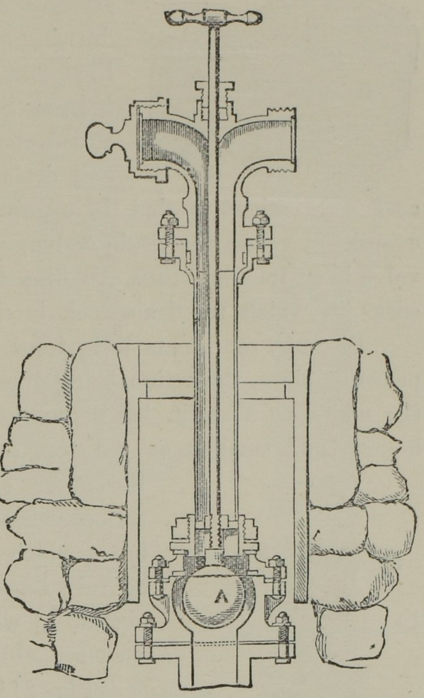
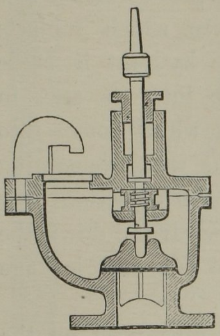


FIG. 199.



More costly, it is true, but of a much more durable character, are the hydrants of Messrs. Simpson and Company (Fig. 201). They consist of a loose-feathered valve with a leather face pressed down by a gun-metal screw on to a gun-metal seating. Like most things of this description, their effective service increases with the cost; it is a question, therefore, of a small outlay at first *plus* the constant repair and constant leakage, against a larger immediate outlay.

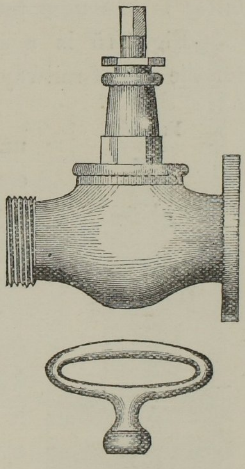
FIG. 201.



Figs. 3 and 4, Plate 15, are sections of Chrimes' hydrant, in which the valve D is a metal disc with a flat face, and closes on an india-rubber or leather seating. The spiral spring R is introduced merely to keep the valve in its place, when there is no pressure in the mains.

The loose valve hydrant has been adopted at a great many places, and consists of a cock similar to Chrimes' loose valve screw-down cock, which is extensively used as a stop and bib cock for houses supplied under constant high pressure, and illustrated in Fig. 202. It may be considered a very efficient fire-cock, but is more costly than the ball hydrant, and not free from the objection of having water congealed on the outlet side of the valve, and also of the screw or spindle being broken while the valve is closed; in either of which cases water could not be obtained.

FIG. 202.



Hydrants, fire-cocks, stand-pipes, and stand-posts are made in a great variety of forms. In some cases, a hose screw is formed on the hydrant itself, and the same is brought flush with the under side of the surface-box or cover, a stand-pipe being dispensed with, and the arrangement being known as a 'flush fire-cock' or 'flushing hydrant'; but this advantage is more than counterbalanced by the risk of the hose screw being out of order, as when so many are exposed underground it is likely that sometimes one or other of them will be found broken or otherwise damaged. This description of fire-cock is also open to the serious objection of leaving water exposed to the action of frost, unless some device is used to avoid it. In some instances, subsidiary or small valves have been introduced on the outlet side of fire-cock valves, with the object of closing automatically when the water is flowing through the principal orifice, and of opening when the fire-cock valve is closed. These are stated not to work with certainty, and have in some places been abandoned and a separate small cock inserted, the spindle of which is fastened in a suitable manner to the fire-cock, and can be turned from the street so as to allow the exposed portion to be drained. The same end is accomplished by Chrimes' patent frost valve fire-cock, which consists of a small lever valve worked by the sluice valve in such a manner that when the sluice valve (which in this case acts as a fire-cock) is closed, the small lever valve is open so as to allow egress to all the water intended to escape. Another plan is to fix a three-way plug cock in such a manner as to open the passage to liberate exposed water when the main passage is closed. Fig. 203 is a representation of Lambert's fire-cock; it is

FIG. 203.

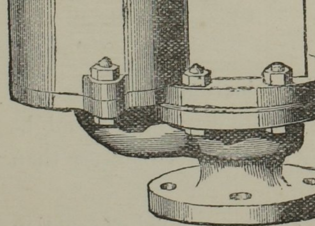


FIG. 204.