

engines capable of driving the vessel at a speed of from $4\frac{1}{2}$ to 5 miles an hour. They are of the inverted cylinder type, working collectively to 150 horse power. The crane, which resembles shear legs, is designed to lift and swing 50 tons at 25 ft. or 45 tons at 30 ft., and is capable of placing masts over 100 ft. high in a ship of 50 ft. beam and 32 ft. from the top of the bulwarks to the water level. The crane mechanism is controlled by one man from one spot under the direction of the captain. The hull of the vessel is of iron, as is also the framing of the crane, but the jib, which consists of two members circular in section, is made of steel. The vessel can be run alongside a ship while lying at her berth, and can take out or put on board heavy pieces of machinery or guns while the ordinary operations of loading or discharging the ship are going on from the quay. The Leviathan has ample deck room for carrying guns, armor plates, boilers, or pieces of heavy machinery, and is so constructed that it may be used for assisting in the ordinary operations of loading and unloading cargo.

In addition to the power for dealing with the traffic, the huge dock gates have to be opened and closed by hydraulic machinery, and the graving docks are provided with pumping apparatus for pumping out the water when a ship is taken in for repairs. The lock connecting the main dock with the tidal basin is 80 ft. wide and 700 ft. long, divided into two chambers respectively 555 ft. and 145 ft. in length, and there are three pairs of wrought iron, double skinned lock gates, constructed by Messrs. Joseph Clayton and Co., of Preston. Some idea of their size may be formed when we say that each pair weighs nearly 240 tons, the width of each leaf being 49 ft. and the depth from the top of the gates to the sill 44 ft. Water can be pumped out of them at the rate of 650 tons per minute by means of four large centrifugal pumps made by Messrs. Simpson and Co., Pimlico.

Four large dry docks are provided, in which scraping, painting, and repairs can be effected. Two have a depth of 32 ft. and two 27 ft. of water on the sills at ordinary spring tides. These unusual depths will obviate all risk of the detentions so frequently experienced by ships at other dry docks within the port of London. The dry docks are inclosed and divided by caissons. The emptying of the larger pair of dry docks by pumping out 12,000,000 gallons of water can be performed in an hour. There are six caissons, constructed by Messrs. R. and H. Green, of Blackwall, of which those at the south ends of the dry docks were built in position. The other four were constructed at Blackwall. The weight of each caisson is about 240 tons. The boiler house has been constructed to accommodate six boilers; five only have been laid down. Two drainage engines and pumps are provided, and Messrs. Belliss and Co.'s fan arrangement for a forced draught has been adopted. The main dock is 1,800 ft. long and 600 ft. wide, and each of the three branch docks is 1,600 ft. in length, extending from the main dock in a northwesterly direction, the center branch dock being 300 feet wide, while each of the other two has an average width of 250 ft. The depth of the main and branch docks is 38 ft. below Trinity high-water mark. At the quays in the main and branch docks, which are 13,000 ft. in length, 31 steam vessels of the largest size can be berthed for loading or discharging, and the depth of water admits of such vessels being at all times loaded to their full draught alongside the quay without removal to the basin. On the quays of the three branch docks 22 sheds have been erected on piles.

The sheds are each 300 ft. long and 120 feet wide, while the height to the eaves is $12\frac{1}{2}$ feet, and to the apex of the roof 26 feet. Each shed is inclosed by self-coiling steel shutters, of which a total area of 108,000 superficial feet, or $2\frac{1}{2}$ acres, has been used. The floors are of wood, the principals of iron, and the roofs of slate. There is also a dredger, constructed by Messrs. Hunter and English, of which the hull is 101 ft. long and 20 ft. beam, with a draught of 9 ft., which has actually raised 210 cubic yards in an hour of mud or ballast from a depth of 45 ft. There is also ample accommodation in the way of goods junctions and sidings and most complete telegraphic and telephonic arrangements.

It is almost needless to say that the electric light has been employed throughout the whole dock system. The work has been done under the direction of Messrs. R. E. Crompton and Co., of London and Chelmsford, and the general arrangement of the lights has been such that a total of 80 arc lamps of 3,000 candle power each have been placed in various positions on masts or other convenient posts of advantage in the outdoor part of the docks. Many of these posts are 50 ft. high, and there has been no small difficulty in fixing them securely in the marshy soil of which the docks are composed. The incandescent lamps are in nearly every case under cover, and consist in all of 1,362 lamps of 16 to 22 candle power. Five engines and boilers are employed to drive the generating machinery, and they are together capable of a *maximum* output of 500 effective horse power. They are placed in two engine houses, one near the hotel and the other at the opposite end of the docks. There are 16 dynamos of the well-known Crompton type. These machines are of the same kind as those supplied to the ships of the White Star Line, the Royal Gun Factory at Enfield, and for lighting Vienna, and are of the most improved form. They have heavy wrought iron magnets and are put together with great mechanical strength. They are among the most efficient machines that can be had, and visitors will no doubt be struck by their great simplicity of construction. Tests recently published of some large machines of this type made for electric lighting abroad show that they are the most economical machines made.

The fire-extinguishing appliances comprise two land steam fire engines, each capable of throwing a ton and a half of water per minute, one powerful tug fitted with four $1\frac{1}{2}$ in. deliveries, 83 hydrants fitted to the sheds in the main and branch docks with 100 ft. head of water always charged, 2,300 ft. of brigade hose, 900 feet of hose at caissons, and two hose reels with hose ready to run to any spot, with all subsidiary appliances, gear, branches, spanners, etc.

A spacious hotel, called the Tilbury Hotel, has been erected on the river bank of the tidal basin and in immediate communication with the London, Tilbury, and South-end Railway. A row of eight houses has also been constructed for the superintendent and the principal resident officers of the dock company; there are

30 cottages for the foremen, sergeants of police, and others, and six blocks of workmen's dwellings. The railway company propose to run a frequent service of fast trains between Tilbury and Fenchurch Street, which will do the distance in about 35 minutes, so that neither the dock company nor the railway company appear to have omitted any means which would conduce to the success of this great undertaking. — *London Times*.

Our engraving is from the *London Graphic*.

SIBLEY COLLEGE LECTURES.—VII.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

By CHAS. E. EMERY.

TRANSMISSION OF STEAM.

THE nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved, and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and in some respects an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

It is proposed in this paper to discuss:

1. The properties of steam which make it well adapted for a transmission to a distance.

2. The methods adopted to maintain pressure and provide for condensation.

3. The nature of the mechanical devices necessary in a successful street system of steam pipes, with methods of insulation, of supporting and securing the pipes, of overcoming street obstructions, and of making service connections.

4. Methods of measurement; and

Lastly, a statement of precautions necessary in operating long steam pipes, of the causes and prevention of water rams, of the nature of the repairs required to a street system, with general remarks on the whole subject.

The descriptions in most cases refer to the plant and apparatus of the New York Steam Company, designed by the writer, but the same are introduced principally to show the nature of the details required in the practical application of the principles, as time will not permit a full description of this work.

The expression, "a district steam system," is now accepted as referring to a plant in which steam, generated in a central station, is distributed through underground pipes laid in the public streets so that the steam may be taken at will by consumers, "on tap," so to speak, the same as gas and water. Such a plant is in some respects similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of underground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that customers can be accommodated when and where desired, involve many more difficulties and require many modifications in detail, compared with a system where all the property is under one control, where space underground is rarely obstructed or valuable, and where the whole plant, with all its ramifications, may be laid out before the work is commenced.

Dry or saturated steam is well adapted for successful transmission, to a distance, for the simple reason that the temperature always corresponds to the pressure. The laws of thermodynamics show that absolute temperatures and pressures always bear a constant relation. It follows therefore that steam of a given pressure is as valuable at the distance of a mile or more from the boiler in which it is generated as it is at the boiler itself; also that a steam mixed with water, has, when the water is removed, all the properties, and is equally valuable as any other steam of the same pressure. In short, steam does not *deteriorate* the least in transmission, so long as it is steam; that is, has been freed of the water of condensation incident to its transmission. Pressure may be lost, but permit me to repeat, that the steam is as valuable as *any* steam of the same pressure.

The problem of separating steam from water is well understood. Evidently, if a mixture of steam and water be passed through a drum as large as the steam space of the boiler in which the same quantity of steam would ordinarily be generated, the water will be separated by gravity, the same as in the boiler itself. In most cases the pipes themselves act as drums. In any case, by a proper application of principles, it is possible to transmit steam to as great distances as any other fluid. The actual maximum distance must be governed by commercial considerations as to relative cost of piping and stations.

To make the steam efficient, then, it is necessary only to maintain the desired pressure at the ends of the lines, and this depends on the size of the pipes and the loss of pressure that can be permitted. Some embarrassment would result from permitting a very large loss of pressure between the boilers and the ends of the lines. The demands on the various lines are variable, and as it is necessary to keep up the pressure at the boilers sufficiently high to maintain the desired pressure at the end of any one of the branches, the pressure near the ends of the other branches will vary with the demands in such branches. This would require at certain times of the day, at least, a very high pressure at the boilers, and, for safety, the whole plant would have to be constructed to stand this pressure, so that there would be greater liability of leakage, and the first cost as well as the cost of maintenance of the boilers, pipes, and all valves and connections to which the pressure was introduced, would be increased. For these reasons the pipes of the New York Steam Company were proportioned for a loss of pressure of only 10 lb. in a distance of half a mile when the plant was at its full working capacity. All the parts were made of sufficient strength to carry regularly a steam pressure of 100 lb. It was hoped that 60 lb. would be sufficient for all the

purposes required, but many more places were found than was expected in which the apparatus was deficient in size, and required 70 to 80 lb. pressure to do its work efficiently. The standard pressure in the mains has therefore been fixed at 80 lb., the engineers at the boilers being permitted a range of from 77 to 82 lb. to allow for the varying conditions incident to firing and sudden drafts on the boilers due to changes in the demand. The loss of pressure at the present time at the ends of mains $\frac{1}{2}$ of a mile distant by line of pipe from the boiler house is not over 2 lb., for the reason that the pipes are not as yet working to their full capacity. It is a curious fact, also, that occasionally in making synchronous observations it is found that the pressure at the end of the line is *greater* than at the boiler house, which is readily explained by the fact that for these low differences of pressures the velocities are so small that a change of demand on one part of the system may draw down the pressure at the boiler house before the pressure in another direction has had time to adjust itself to that at the source of supply.

The first problem in designing a steam plant is to ascertain the total quantity of steam required and the quantity necessary to supply in detail the several blocks on each of the streets through which the pipes are to be run. In New York this was approximately obtained, first, by collecting the statistics on file in the Police Department with relation to the steam boilers in place in the city, rules being given the computers by which the approximate power of a boiler could be determined from its external dimensions and type, which were the only dimensions taken by the boiler inspectors and reported to the Police Department. The aggregate cubic capacity of all the buildings within the areas which it was expected to heat was also computed approximately from the insurance maps, and this multiplied by a proper factor gave the estimated quantity of steam required to heat that space.

Complete maps on a large scale, showing the house lines, were prepared of each district, on which each boiler was located and marked with the amount of steam it would supply. Similarly, there was written on the ground plan of each building the amount of steam it would require for heating. This preliminary work, though simple in its character, involved a great deal of labor, on account of the number of streets, buildings, and boilers to be considered. When the maps were completed, the first step was to sum the several quantities marked on the buildings for each block. In locations where a boiler was marked, the steam required for heat was summed as before, but deducted from that which the boiler was capable of generating; the remainder, which was also summed in, evidently represented the steam which was required for power purposes in that particular building.

The next step was to sum together the quantities of steam required for the several blocks in the whole district, which at once gave an idea of the capacity of the boilers required and of the mains to be started out from the boiler house. The location of the boiler house having been determined, the next step was to lay down approximately the lines of the principal trunk mains, and indicate an area on the map which each was expected to supply. This enabled the desired capacity of the mains for a particular street to be determined readily by summing the quantities marked on the several blocks which were to be supplied from that street. The total quantity to be carried by the mains as they approached the boiler house was shown by the sum of the various quantities at that point, and evidently equalled the first main sum representing the total quantity of steam to be supplied from that station. In the particular case referred to, the quantity of steam shown to be necessary by this computation was much greater than it was thought expedient to provide for. It was considered that many buildings would not take the steam, and the expense of the undertaking appeared so great that at first it was thought best to not attempt to carry more than $\frac{1}{2}$ the quantity of steam thus computed. This however was afterward changed, and the plant designed to generate and convey substantially one-half of the steam at that time required on the basis stated for the district under consideration. It was well known that lower New York was being rebuilt, and that more steam would be required in the future, but it was not thought expedient to risk the success of the plant by too great an expenditure in the first instance.

The first station of the company was located on Greenwich St., between Dey and Cortlandt Sts. The building was designed to contain 16,000 horse power of boilers of the Babcock & Wilcox type, as will be explained hereafter.

It was expected that this station would supply for a number of years the demands of that part of New York city below Chambers St., but that it would be necessary eventually to have one or two more stations. The property for one was purchased on Front St., near the Battery, and it was anticipated that possibly another would be required in the vicinity of Fulton Ferry. In all, properties were purchased for ten stations in different parts of the city, but of these as yet only the one referred to at Cortlandt and Greenwich Sts., designated "Station B," has been built.

Considerable investigation was made to ascertain the proper formulae for determining the size of pipes required to transmit the steam. The difficulty was not so much in finding formulae, as to decide which were best applicable. As is generally the case, the simplest was finally determined upon, based directly upon the laws of falling bodies, and in form that generally used for the flow of water in pipes, simply substituting for the density of water that of steam at the pressure to be carried. Most of the experiments on the flow of gaseous fluids given in the textbooks refer to air at low pressures and with very small quantities of discharge. There were, however, some experiments on the flow of compressed air in the pipes supplying the drills in the Mont Cenis Tunnel, where the pressure and the quantity of air moved were sufficient to compare favorably with the conditions under which steam was to be transmitted. The only report of these experiments accessible was that given in D. K. Clark's "Handbook for Engineers," which stated the curious conclusion, drawn from the original report, that the quantity of air transmitted was independent of the density. This was of course impossible, as a little consideration will show. Those particular results would correspond well with the formula given in which the density was omitted, for the simple reason that the density was

nearly constant in all the experiments. By substituting numerical values determined from these experiments in the ordinary water formula with a character representing the density introduced, a general formula was obtained in which the constant very curiously and satisfactorily coincided very closely with those given by Wiesbach, in relation to the flow of air at about the same velocity as was expected in the steam pipes. It should be observed that the loss of pressure due to transmission varies also with the density of steam, so that any formula founded on a constant density is not precisely correct. As, however, the loss of pressure was to be restricted to ten pounds, the original formula were based on the average density. At a later date, however, investigations were made in which the variations in pressure were taken into consideration, the formula derived from the water formula being considered a differential formula with relation to the flow of steam. By this means a formula was obtained which, it was believed, well represented the probable facts for all steam pressures and all losses of pressure in transmission. Between the limits of pressure it was expected to use in practice it was found that practically one formula was as exact as the other, so the use of the simpler one was continued in general use. When the slope was introduced into the formula, to wit, 10 lb. per half mile, and the density, which was first fixed at that due to 70 lb., with the expectation of going from 75 lb. down to 65, the formula for the weight of steam discharged per hour reduced at once to

$$W = 87.3 d^{\frac{5}{4}}$$

d , being the inside diameter of pipe in inches. This form results from the fact that the areas of the pipes vary as the squares of their diameters, and the hydraulic mean depths, which are proportioned to the friction as the square roots of the diameters, so the products of the two vary as the $\frac{5}{4}$ power. For strict accuracy, some modifications should have been introduced in the formula, as the friction undoubtedly reduces as the velocity increases, and it is probable also that the friction reduces faster than the hydraulic mean depth. It was not necessary to consider these points, however, as the variations in velocity and density were so small.

In practice it was not found expedient to reduce the pipes as rapidly as the mere conditions of demand according to the maps above referred to would indicate. It was thought that possibly there might be a concentration of demand on certain lines, and it was also desirable to make provision for re-enforcing the pipes near their ends from other stations, should it become necessary. Consequently, in practice, only the lines leading to the boiler house were proportioned by the rule, and the others, as a general thing, were made larger. It was not thought best in the down town streets to lay any steam pipe less than six inches in diameter throughout the length of a long block; and although this was small by calculation for some blocks, still, as it could be fed at both ends, it was considered sufficient, and has since so proved in practice. The above formula was designed to carry the whole capacity of the pipe to its end, whereas in general practice steam is drawn off at intervals, thereby enabling the remaining quantities of steam to be carried along with less relative reduction of pressure. On the whole, therefore, considering the various conditions, it was decided to increase the value of the constant in the formula to an even 100, and the table of the carrying capacity of pipes now used is simply derived by raising the actual internal diameters of the various nominal sizes of pipe in inches to the $\frac{5}{4}$ power, and carrying the decimal point two places to the right.

Some idea of the magnitude of the work of the New York Steam Company can be obtained from the statement that there are already in position from the boiler house one 16 inch pipe, one 15 inch pipe, and one 11 inch pipe, with only part of the capacity of the building yet utilized, and that it is expected to put in in addition two 24 inch pipes, to keep up the pressure at a distance as the demand increases.

The formula shows that the carrying capacities of pipes increase much faster than their areas, and it follows that a material reduction in loss of pressure can be secured by a comparatively small increase in the diameter of the pipes and of the cost of the work.

It is found in practice that steam pipes can be so protected that the loss of condensation will be a very small proportion of their carrying capacity. Experiments were made before the plant of the New York Steam Co. was built, which showed that mineral wool, of ordinary quality, furnished very nearly the same resistance to the passage of heat as the same thickness of hair felt, and that the better qualities were equal or even superior in this respect to hair felt. As mineral wool was non-combustible, quite permanent when kept dry, and not subject to friction, and withal could be manufactured quite cheaply, it was fixed upon as the material to insulate the pipes of the New York Steam Co. In a majority of cases the pipes were suitably supported in the bottom of a trench, brick walls built up at either side, and covered with planking and roofing material, so as to leave a space of from three to four inches about the pipe on all sides in which mineral wool was placed in bulk. In some cases the wool was placed inside a wood casing of pump logs, but this was not considered a part of the regular system, and has not proved as desirable or durable as the other plan. The result of this method of covering has been that with nearly five miles of large pipe, also about two miles of smaller pipes used as services, all under steam continuously, days, nights, and Sundays, there is required but 150 horse-power, each of 30 pounds of water per hour, to supply the condensation in the mains. The mains vary from 16 inches in diameter to 6 inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam.

The water of condensation, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocities in a large pipe graded so as to have a slight descent away from the source of supply, the water in the steam would separate by gravity and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the steam from the top of such a pipe and arranging to blow out the water at intervals from the

bottom, the length of the pipe could be continued indefinitely; no inconveniences would result except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must, however, at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is to a greater or less extent entrained by the current of steam. This is particularly the case when the steam is moving at a high velocity. In practice the up grades in the direction the steam is transmitted are made as sharp and as short as possible; and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long.

This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases arrangements are made to trap out the water of condensation at the bottom of every dip of the pipes, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water is removed automatically by steam traps, and returned to the boiler house through another system of pipes called return water pipes, the details of which, as well as of the traps, will be referred to hereafter.

In laying steam pipes underground it is necessary to observe the following requirements:

1st. The pipe and connections must be of unusual strength and better put together than is customary for the pressure, for the reason that the work is out of sight and cannot be regularly inspected.

2d. The sections of pipe must be sufficiently short to enable them to be readily handled, and if necessary introduced to place through narrow spaces between other pipes already in position.

3d. It is absolutely necessary to secure tight joints, and yet desirable to do this without absolute rigidity, on account of the possible settlement of the soil.

4th. All the joints should be of a character enabling repairs and renewals to be made as required.

5th. The pipes should be supported independently upon the soil, and not be liable to strain from the filling in of the trench, and the street traffic afterward.

6th. Provisions must be made for connections at intervals; and

7th. The expansion devices should be so arranged as to be efficient, and not to interfere with either of the other requirements.

The expansion of small pipes is generally provided for by means of bends and offsets which will spring sufficiently. This method, in its simpler form, is applicable to short lengths only, but if the arrangement be well studied, pipes of any length may be laid on this system. For instance, if it be desired to run a pipe from one end of a long building to another, it may be accomplished by crossing and recrossing a sufficient number of times. No known rules for this kind of work are formulated. The workman is supposed to make the offsets of such a number and with such lateral lengths that expansion will not strain the joints. Frequently, however, insufficient attention is given to this matter, and leaks are developed at important fittings, which it seems impossible to keep in repair, and the work can only be made satisfactory by changing the system to suit the actual conditions. A modification of the offset system, with what are called swinging elbows, forms a much safer method of providing for expansion, but is less used, as more fittings are required, and some little study is necessary to adapt the work to the straight lines and flat grades necessary in a building. It is, however, a very desirable way of laying long pipes of limited size underground, and elsewhere where the grade can be changed as required.

One application of the method may be described as follows: Imagine a main line of horizontal pipe approaching the observer. The nearer end enters an elbow with outlet turned down, in which is screwed a nipple entering another elbow with outlet turned toward the right, into which is screwed a lateral pipe to form an offset of length adapted to the circumstances. The end of this pipe connects with an elbow with outlet turned down, the latter outlet with a nipple, the nipple with an elbow of which the outlet turns toward the left, in which a piece of pipe is connected, which may be of the same length as the first offset. The end of this pipe is again connected with an elbow with outlet turned down, a nipple inserted and connected to another elbow, the outlet of which connects with a pipe, which may have the same general line as the first, but should be located below it sufficiently to allow for the various drops at the nipples in the several elbows. A little study will show that this is a complete swinging joint. The pipe may expand as much as desired, and can do no injury, as it will simply screw or unscrew the nipples in the elbows slightly. Moreover, by arranging the elbows so that the elbows turn down in the direction it is desired to drain the pipe, it will be seen that the expansion does not interfere with the drainage. Evidently it is not necessary to have the direct and return arms of the offset parallel, and if desired these arms may be connected by a pipe in the direction of the original pipes, the connection always being made with two elbows and a nipple.

In this kind of work it is desirable to have the offsets of such length that there will be movement on the threads only the first time that steam is turned on, so that afterward if it be shut off temporarily the elbows will not turn, but simply spring the cross pipes a little, which strain will be relieved when steam is again turned in the pipe. Simple and efficient as this device is, it is very difficult to teach mechanics how to make it. They will think they have a swinging elbow joint if they put two elbows at one end of the lateral pipe, and only one at the other. Many in studying this plan will say, Why not use a return bend where the two lateral pipes join? but on second thought, it will be seen that this defeats the object to be attained.

Swinging elbows are also used to pass obstructions, the cross pipes being inclosed in a yoke in the steam pipe; the steam takes the upper part of the yoke, the

water of condensation the lower, and drainage is not interfered with.

Stuffing boxes or slip joints are frequently used on long lengths of pipe to provide for expansion, though generally on large pipes only. This system answers very well for water pipes or where the steam pressure is low. With high pressure steam the packing has to be very compact to resist the pressure, and great care and some considerable expense are required to keep the stuffing boxes in order and prevent them from leaking. Frequently stuffing boxes are applied without due care in anchoring the pipe. Cases have occurred where pipes were prevented from sliding simply by a lateral connection coming in contact with the side of an opening in a wall or partition. In laying a number of stuffing boxes on a length of pipe without anchorages, the whole pipe may shift to the box which is loosest, and the others not move at all until the first has a very extreme movement, or, as has sometimes happened, is pushed entirely in. Sometimes in cooling such a system the sleeve of one stuffing box is pulled entirely out of the packing.

The original street system of Birdsell Holly, of Lockport, N. Y., provided for the use of stuffing boxes at intervals of 100 feet. These boxes, called "junction boxes," were each secured to one end of a length of 100 feet, and strongly anchored against the wood logs forming the covering of the pipe. The other end of each section was free to move out and in the stuffing box secured to the next section. These stuffing boxes had elongated bodies with outlets, to which connections were made for the various buildings. Simple as were these modifications of Holly's from the customary practice, they contained the basis of really the first practical system for conducting steam in straight lines underground for any desired distance with provision for connecting service pipes at intervals from points that were anchored so as to be stationary. In all cases the services were taken from the junction boxes, and offsets made either in the street or yards to reach the buildings or any part of the same desired. The value of his system is best exemplified by briefly describing a modification of it used by a company in the city of New York, started in opposition to the work of the New York Steam Company, soon after the latter was well under way.

In the case referred to, stuffing boxes were used, but they were located only at the corners of the streets in castings, which also served as crosses to connect with the main street laterals. The consequence was that expansion had to take place for the whole length of the block, and this system was carried out whether the blocks were 100 feet long or 400 feet. The pipes were carried on rollers, so that they would move freely. If mere expansion and contraction had been all that was to be provided for, the system would have worked well enough if properly constructed. In all cases, however, in street work the grade and line must be changed at intervals to avoid obstructions. These were overcome in this particular case, even for pipes eight inches in diameter, by making rigid offsets, sometimes of several feet, with common screw elbows. The friction of the stuffing boxes was so great that leaks soon developed in the elbows of these offsets, and in one or two cases the elbows actually broke, letting the steam freely into the ground, and causing what were termed explosions. Moreover, the pipes, which were supposed to be nearly straight, did not always move freely in the stuffing boxes, from the great difficulty in setting the stuffing boxes exactly in line with the pipe. It was very difficult to keep the stuffing boxes tight, and the manholes in which they were located were so hot that the men became exhausted in attempting to attend to the packing. In this system the services were taken from independent pipes anchored only at the street corners, and running for the length of the block, it being expected that there would be spring enough in the various laterals entering the house to allow for the expansion due to the length of half a block. As, however, some of the blocks were very long, it became necessary to leave considerable space in the boxing around the lateral pipes, particularly near the centers of the blocks. During the early part of the work, when steam was turned on and off frequently, the fitters would sometimes allow for expansion one way and sometimes the other. They were at first accustomed to allow for a movement of the pipe from the nearest street corner as it was heated up. When the pipes were already heated, they thoughtlessly at times left the room on the same side, for which reason, when the pipe was shut off, the contraction would cause the service to strike the boxing, which produced leaks and in some cases rupture.

In one case where connections had been made when the pipe was heated, the service was sheared off as the pipe cooled off, which was not known until steam was again turned on, when the lampblack used for insulation was blown all over the building. In one case of this kind, a break occurred on shutting the pipe off; and in repairing the break, the fitter allowed for contraction instead of expansion, without noting that the pipe he connected to was then cold, and the same service pipe was broken a second time when the street pipe was again heated. The wisdom of Holly in arranging that the fitters should only have distances of half a hundred feet to provide for by offsets, instead of half a block, could not be more forcibly illustrated. It is almost needless to say that the system in which the stuffing boxes were placed only at the street corners proved an utter failure, and its operation was discontinued after a few months' trial.

When the writer was called upon to design a steam system, it appeared to him desirable to avoid the necessity of using either slip joints, with their leaks and expense in care and attention, and it was readily seen that an elaborate system of offsets was not practicable. Experiments were therefore commenced with modifications of what are known as diaphragm joints, in which two annular disks of metal are bolted together through a separating ring at their outer edges, and the inner edges bolted to the ends of the lengths of pipe, or a single disk is bolted at the periphery to a large chamber connected with the pipe on one side, and the center of the disk to the pipe on the other. With these joints the elasticity of the disk permits limited expansion; the movement causing the disks to be dished one way or the other, as may be arranged. All these devices, when made as ordinarily proportioned, proved too stiff and had too limited a range for use in a street system.

A trial was made with cast iron pipe, cast very thin and corrugated very deeply, it being hoped that each pipe could be corrugated sufficiently so that it would safely provide for the expansion of its own length. In such case it was proposed to put in a lining of thin iron to form a smooth passage for the steam. These experiments made it doubtful if the plan would succeed, even if the pipes were corrugated the entire length. Although the cast iron was elastic within a certain limit, the great difficulties in obtaining uniform thicknesses made breaks liable to occur unexpectedly. Experiments with several plates held at the inner and outer edges were more satisfactory, but as ordinarily proportioned were too stiff, and had too little range of movement for the purpose. If the disks were originally dished in one direction with a view of forcing them first flat and then to dish them in the other by pressure, they were of course very much stiffer. Improvements were made by reducing the thickness of the plates and corrugating them annularly, but even when the plates were made of soft steel corrugated annularly as aforesaid, and six inches free space left between the inner and outer flanges, the plates still proved too stiff, so that there was danger of breaking the joints on the pipes to move the expansion joints, and it was not thought practicable to use more than half an inch movement for each of such diaphragms. Diaphragms of this kind were actually dished from one-half inch in one direction to one-half inch in the other, making a movement of one inch, but some parts of the disk developed a tendency to stiffen sooner than the rest, and the movement could not be made back and forth a number of times without disturbing the symmetry of the disk. The improvement due to reducing the thickness was, however, so great that the suggestion came to mind that if the plates could be still further reduced with safety, the available deflection would be inversely as the cube of the thickness, and sufficient movement could be obtained.

A successful expansion joint was finally made by using disks of copper less than one-sixteenth inch thick (0.04 being finally settled upon), corrugated concentrically and supported on radial backing plates which prevented the diaphragm from being distended, to rupture by the pressure.

Elaborate drawings of this device were shown upon the screen, one, called a double variator, having two diaphragms and providing for expansion from two fixed points on either side 50 feet away; the other, called a single variator, having but one diaphragm, and providing for expansion from one direction only. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, these plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it, by means of a special tool illustrated by a drawing. The stems of the valves are extended to the surface of the street, and may be operated through suitable openings in castings placed between the paving stones. At regular intervals of about 50 feet the pipes are connected by means of ball joints, which enable the direction to be changed slightly and take out the strain. Both the ball and plain joint flanges are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface and become absolutely tight, even without the use of paint or putty. Pipes of six inches in diameter or less are screwed into the fittings. Larger pipes (and some have been used as large as 16 inches in diameter) are rolled into the flanges and fittings with an expanding tool. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with boxes, which cover the connecting flanges and terminate in cylinders of metal, which are built in the brickwork surrounding the variators. A number of illustrations were given of the various crosses, tees, and other special fittings required, which are necessarily made of a substantial character to resist permanently the steam pressure of 80 lb. The bodies of the crosses and tees are made globular, to better resist the strains to which they are subjected. Wherever a valve is placed in the pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges in the pipes, and masonry built against the castings with wings well spread out, to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains are run originally, one for steam, the other for the return water of condensation. Generally the latter main is laid lower than the other, so that the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains, through what are called "drop crosses."

The traps used by the New York Steam Company were illustrated. They are of the bucket variety, with valves of different kinds, according to the size, operated directly by a float, or through the intervention of levers. Two forms of regulating valve were described. In one, the Curtis valve, the reduced pressure operates upon a diaphragm, which, through a secondary valve, admits steam to a piston operating the main valve. Another valve was shown in which the reduced pressure acts directly upon a piston connected with the valves and balanced by external weights or springs.

Considerable investigation has been necessary to perfect a meter which would answer all the conditions to be fulfilled in measuring steam. It is evident that if a displacement meter were used, the cylinder development would necessarily equal the piston development, calculated to the points of cut-off of the engines supplied through it. For ordinary slide valve engines, therefore, the meters would have to be practically as large as the engine or run at very much higher speeds, subject to all the difficulties incident to so doing. A small three cylinder engine has been developed for use where very small quantities of steam are required, it being expected to pass the steam at full pressure through the meter, and then reduce the pressure afterward, thus measuring only at the greatest density and the smallest volume. The conditions of use in the district now supplied require, however, another form, yet to be described.

Experiments have been made with meters of the velocimeter type, in which the velocity of the current of steam is registered by a series of indices. Mr. Birdsall Holly designed an instrument of this kind in which the

current of steam struck one edge of a series of floats, like those of a paddle wheel. The jet was controlled by a clapper falling by gravity to reduce the opening to a narrow slit, through which steam passed to strike the wheel, when the quantity of steam passing through was limited. The axis of the paddle wheel was made vertical, and upon the lower end of the shaft was a resistance paddle wheel, which worked in water of condensation collected in the bottom of the case. The steam escaped freely from an opening between the two wheels. This meter has precisely the same kind of variations as any other velocimeter. When passing small quantities of fluid, the slip is very large, and the record is against the supply company. For quantities which may be called moderate to considerable, relative to the size of meter, the rate is remarkably near uniform, when everything is in order. When run to the full capacity of the pipe, the meters are not so accurate. The difficulty with this class of meters lies in keeping the friction constant and preventing wear. There must be some means of carrying the motion of the paddle wheel outside of the case. This is done by driving the axle, which passes through the stuffing box, at reduced speed, by means of gearing inside the case. Notwithstanding this, however, the stuffing box soon gets leaky. The speed of the wheel is quite high, and the bearings wear down rapidly, so that it can safely be stated that the apparatus is not a desirable one for use except at comparatively low pressures and moderate velocities.

The writer, at an early date, made up his mind that a successful meter must be based on the principle of flow through an orifice of known size, and with a known loss of head or difference of pressure. Several methods of doing this were tested. In the meter finally adopted, called a "rate meter," the steam flows through rectangular openings, governed by a valve, operated by a weighted piston balanced on the difference of pressure between the incoming and outgoing steam, the effect of which is that the steam flows through the orifice at a constant difference of pressure. The size of the orifice is regularly registered on a broad paper strip, traversed by clockwork. The result is a diagram showing at any time in the day the quantity of steam used at that time, and the total quantity may be obtained by integrating the chart. When steam is not used, the movable pencil runs on the same line with a stationary one. The paper upon which the meter record is made is printed in divisions of half an inch, numbered from one to twenty-four consecutively, to represent the hours of the day, and in starting the paper, the proper division is set at the corresponding time. The time that steam is turned on is shown by the vertical line made by the movable pencil at the beginning of the diagram, and when it is shut off, by a similar line at the end; and evidently the periods when any particular change is made in the quantity of steam used can be determined from the meter diagrams, as well as the quantity used during the intervals. It was at first considered unfortunate that a reliable meter could not be obtained, which, like a water meter, would show by differences of reading the quantity of steam used for the interval between observations directly without calculation, and without the expense of maintaining a time register at each location, and of integrating the charts afterward. This system, however, proved a blessing in disguise. The greatest difficulty in settling with consumers lies in the fact that employees waste the steam. This is particularly the case during the heating season, when steam for various excuses is left on continuously during nights and Sundays, thus increasing the time of consumption from, say, 60 hours a week to 168 hours. In many cases, too, the rate of consumption keeps uniform during the night as well as during the day, so that it is an easy matter to more than double the bills. The consumers at first naturally lay the blame to the steam of the steam company, but the meter charts have been the means of enabling the company to satisfy consumers when, and to what extent, the increased bills were due to mismanagement on their premises.

The meters and regulating valves are placed in the pipes leading from the streets to the building, and arranged with shut-off and pass-by valves, so that any part of the apparatus may be put in order without stopping the supply of steam to the building.

The lecturer then described a watchman's telltale system, in which a valve in the pipe leading to the consumer was connected electrically with a watchman's box on the exterior of the building. The watchman, being provided with a suitable recording apparatus on his person, visited the several boxes in succession, and by sending an electrical impulse from a portable battery through the watchman's box into the valve, received in turn a record which could be interpreted at the office to show whether or not the valve was open. This apparatus was used while suitable meters were being devised and perfected. Plans were also shown of the boiler house of the company.

The lecturer stated that ten plots of ground, in different parts of the city, were purchased by the New York Steam Company, in the first instance, to be used as boiler stations. There has, however, as yet been but one station built, called "Station B," which is located on Greenwich St., between Cortlandt and Dey Sts.

It was necessary to erect at "Station B" boilers of 16,000 horse-power on an irregularly shaped plot, 75 ft. in width, and on an average less than 120 ft. deep. To obtain proper floor room, the boilers were arranged in four tiers, each tier in a separate story 20 feet high, besides which the plans provide for a fifth story for coal storage and a basement for miscellaneous uses. Each floor is arranged for sixteen boilers of 250 horse-power each, which are placed in two rows, to face a central fire room. There are two chimneys, located between the boilers on the sides of the fire room, as near the center of the building as the shape of the plot permitted.

The whole capacity of the building not being needed at first, the walls were only carried up to an elevation of 88 feet 8 inches, and a temporary roof applied, so that at present there are available only three stories for boilers, and one above for coal storage. The south chimney has been practically completed. The north one was originally extended just above the temporary roof, covered and connected with the other by a sheet iron casing. In the summer of 1885 it was thought desirable to examine the interior of the south chimney and make any necessary repairs to lining, etc., for which reason it was decided to top out the north

chimney with a shaft of practically half the area, which would be sufficient for summer use, while the other chimney was being examined.

There are now in place in the building, and fully connected, 35 boilers, aggregating 8,750 horse-power. Customers were first supplied with steam in April, 1882, since which time the steam pressure has been maintained continuously day and night. The coal is brought from the dock in carts and wagons, and dumped from the rear street into small cars in the basement of the rear buildings. These cars are run back to the elevators, lifted to the top of the main building, run out on tracks over coal bins and dumped, the coal descending by gravity through chutes in front of each alternate column and flowing out as needed on the several fire room floors, close alongside the fronts of the boilers. The ashes pass from the ash pans down chutes in front of intermediate columns to cars in the basement. These cars are hoisted on the elevator to the roof of the rear building, run out on tracks to the front of that building, and the ashes dumped into a chute, from which they are loaded into carts on the street below.

The boilers are of the sectional type, manufactured by the Babcock & Wilcox Company.

From lack of room, a well-established rule was necessarily disregarded, and the lower portions of the chimneys, instead of being independent, were made part of the building, the section of each being rectangular and corresponding closely to the floor space occupied by one of the boilers. Within the building the outside of the chimney walls are vertical, the offsets due to reducing the thickness of walls upward being inside the flue. Above the roof the inside of flue is parallel, and the walls are decreased on the outside, each offset being marked by a belt of granite blocks, forming a water table.

The lining extends only to the roof line, and is put in in sections, supported on the internal offsets. The lower part of each chimney, above the footings, is 32 feet long outside, and 13 feet wide. The flue at the top is 27 feet 10 inches long and 8 feet 4 inches wide. The chimneys are topped out at a height of 220 feet above high water, or 221 feet above their foundations. The tops of chimneys are, therefore, 201 feet above the grates of the lower tier of boilers, but only 141 feet above the grates of the upper tier of boilers.

The foundations of the walls of the building are at the elevation of mean high water, and the chimney and column foundations 1 foot below. An archway is provided through the base of each chimney, as a means of communication between different parts of the basement.

A fixed iron ladder is attached to each chimney, and connected at top with points and at bottom with a cable to form a lightning protector. It was designed to make the top of the south chimney with a projecting platform and iron reticulated balustrade, in which case the chimney would have been 232 feet above high water. It was hoped that by painting the balustrade prominently it would give the effect of a capital to the shaft, without the weight of actual surface projections. For various reasons, however, the top was finished with a granite coping at the elevation of 220 feet above high water, as previously stated, a simple footboard being provided about the chimney, with an iron hand-rail secured in coping stones.

Although the chimney appears slender the narrow way, it is so supported as to have ample weight to resist the overturning moment caused by a wind pressure of fifty pounds per square foot on the area of one flat side.

The shaft erected on the rectangular stump of the north chimney is octagonal in section, with one edge resting on a partition wall built in the center of the lower flue. The walls are reduced from the outside, with a stone water table at each offset. This chimney is provided with a cap constructed of wrought iron plates, supported on cast iron ribs built in the brickwork.

Main steam pipes 16 inches in diameter are arranged in front of each row of boilers on each floor, and connected to two vertical drums, which are in turn connected in the basement to the street mains. By properly adjusting the valves provided, either set of boilers can be connected with or disconnected from either drum. The two drums on each Babcock & Wilcox boiler are yoked together near the rear of the boiler, and from the yoke a wrought iron pipe is carried nearly to the main pipe in front, but at a lower elevation, where it connects with a copper pipe nearly parallel with the main pipe about 8 ft. long, which latter connects with a combined stop and check valve on the main. This bent pipe enables the main connection from the boiler to expand freely. The valve at the connection to the main is a simple metal check, which the steam is obliged to raise in order to reach the main pipe, there being provided, however, a screw from the top which can be set down to hold the check in place and make it a stop valve. When the boiler is in use, the screw is run up, and the steam passes out through the check. This arrangement has the advantage that if any rupture occurs in one boiler, the steam and water only from that one boiler will be blown out, the check valve preventing the steam in the main pipe from entering. In one case, by carelessness, water was allowed to get low in one boiler, and one of the headers was cracked. Through the crack, water issued on the fire, suddenly generating a current of steam sufficient to blow the door open and force part of the fire out upon the floor. The steam and water practically put the fire out; the other boilers supplied the demand, so that there was no fluctuation in pressure observable on the recording gauge, nobody was hurt, and if there had been no person in the building, the boiler would have taken care of itself without doing injury of any kind whatever. It will be seen that had even this slight accident occurred with all the boilers in free communication, there would probably have been so much steam in the room that the stop valve could not have been shut until the steam pressure had dropped, and the consumers of the company been greatly annoyed.

The two drums enable steam to be taken to the street by two routes, so that leaks on either can be repaired during the night without interrupting the supply to the streets. This system of duplication was so important that what is called a donkey system was also put in; that is, there is another system of steam pipes extended around behind the boilers with a small connection from each. These pipes have two connections

independent of the drums, to the main street pipes in front, and one section is connected to one of the drums.

The principal cause of accidents in the operation of large long steam pipes, underground or otherwise, arises from collections of water in the mains, when the pipes are cold or there is no steam circulating. The system previously described, of draining the mains to low points, where the water is removed automatically by steam traps, in connection with the plan of maintaining the pressure continuously, absolutely prevents any serious accumulations of water in the mains of the New York Steam Company, when the same are in use. If, however, a main be shut off for making a large connection not originally provided for, for repairs, or any other reason, intelligent care must be taken in restoring the pressure to prevent the pipes from being injured by what are termed "water rams." Any main which has been out of use for a considerable time is liable to have water in it from the leakage of steam past the connecting valves, and its condensation in the disused pipe. Again, when the main is shut off temporarily, water is likely to be introduced from the return mains through the service connections, particularly in winter, when the heating systems are connected. Check valves are put in the discharges of the traps to prevent this, but they are not always in order. To prevent the possibility of any water entering the steam main in this way, orders are given to shut off all the service connections before shutting off a main.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this in connection with a cloud which forms above the surface will retard rapid condensation, so that in due time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is therefore perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water and so maintained. If, however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water ram. In blowing into a large vessel, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated; and when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks and sometimes rupture the pipe or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is filled with water, one end being open and the steam introduced at the other, a bubble will in due time be formed at the top of the crown, when the water will be forced in by atmospheric pressure from one end, and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always above* the water.

It is evident from the above that it is always desirable in turning steam on an inclined main to introduce it from the top and let the water out at the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end. In a building, the difficulty can of course be prevented by opening drip pipes at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provisions for this should always form part of the plans when it is known that a pipe will have to be heated up in this way. In practice, however, a street system contains so very many absolutely necessary details, that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of a slope may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, and the steam be admitted at the lower end, any water in the main can be driven out of the blow pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited, the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the steam driving back the water. There will be a series of small explosions, which will scarcely be heard, and do

no harm, and the seething wall of water will be continually forced forward and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly and are not liable to be strained; but when steam *must* be turned into the lower end of a descending pipe, which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were so open. Practical engineers who on sea and land have had to do with turning on steam in pipes naturally recoil from turning steam quickly in any pipe, and it is very hard to explain to them the difference. I have had to take a party of men of this kind, state the reasons for action, and in one case I recollect using as an illustration that if a farmer with a pitchfork could get an officer on the run, the latter could not draw his sword, turn, and defend himself, as he would be run through before he came to close quarters. The principle applies to the water in an ascending pipe. The column of water once started, the steam, if the supply be made sufficient, follows it up so closely, and in such volume, that no condensation can take place sufficiently to stop the onward movement. The clearing of a pipe in this way requires nerve and judgment, but I have seen considerable cold water driven up hill out of a 6 inch pipe, 1,400 ft. long, with a difference of elevation at the two ends of fully 20 ft., by letting steam in at the lower end and blowing the water out on the surface of the street through a two inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains 15 and 16 inches in diameter, but I do not consider that it would be safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in at or near the summit. In heating up an 11 inch pipe, only 400 or 500 ft. long, from the bottom, I have had the flange taken off the extreme end, in order to give the water free exit and prevent the possibility of a ram.

The greatest drawback, in a commercial sense, affecting all systems for supplying a fluid under pressure through underground pipes is leakage, with its direct loss of fluid, together with the expenses of inspection and repairs necessary in finding and stopping the leaks. Many gas companies in small cities and villages lose one-third of the quantity of gas generated by leakage. This proportion is generally reduced as the quantity sold is increased, but even old established companies in large cities lose 10 per cent. in this way. Large quantities of water are also wasted in the extended distribution of towns and cities.

The work of the New York Steam Company was particularly well done, with the intention of reducing this loss to a minimum; still, to the surprise of all, the loss from this cause far exceeds that due to condensation. Of necessity there are thousands of joints and many hundreds of valves with packed valve stems to the mile. If most of the valve stems and an occasional joint leaked but a trifle each, the loss in the aggregate would be comparatively large.

It is to be regretted that time has not permitted a more complete description of apparatus necessary in carrying out the principles involved in the transmission of steam, and of the particular details of the work of the New York Steam Company. I have no doubt that now you have heard so much that, in regard to many features, you feel confused rather than enlightened. Nearly every one of the branches of the subject discussed could of itself be made the subject of a special lecture, full of detail, possessing more or less interest to those who might be called upon to engage in work of this class.

I will close the engineering view of the subject by stating that I consider that all the problems are worked out and that all details are mechanically successful; and I am happy to say, also, that the returns on the very large investment of the New York Steam Company are sufficient to invite the attention of capital to new ventures of the same kind.

There is a field for another lecture in a popular view of the questions relating to the uses to which steam

from the streets can be put, and the advantages of this method of supply. I can at this time give but a word to this branch of the subject. It will be understood that steam engines of all kinds and sizes, in any location from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heating either with live or exhaust steam can be done on any scale, but it is also true that nearly all the *cooking* of a family can be done by steam. Nothing is lacking, in fact, but sufficient temperature to brown bread and put the finishing touch, as it may be called, upon broiled meats. Meats may be cooked perfectly with steam heat, but they cannot, in the open air, be so highly heated as to give the particular aroma which pleases the taste. Meat of all kinds can be roasted in an oven jacketed with steam more perfectly than in one heated directly by fire, as the juices of the meat are kept in, and becoming heated aid in cooking the entire mass evenly and thoroughly. Many large restaurants do all their roasting in steam ovens. Boiling of all kinds is very simply performed in jacketed kettles. An *attache* of the New York Steam Company has recently made an invention whereby, by planing the top of a steam table and the bottoms of the vessels to be heated, and using simple clamps, stews can be made and water boiled in vessels not jacketed with steam; the heat being transmitted from below, and the rapidity of heating or violence of the ebullition controlled simply by tightening or loosening the clamps. With steam stoves fitted with these various devices, and having in connection therewith small gas stoves for finishing the broiling of meat, and perhaps gas attachments to the ovens, to brown the bread and cake, housekeepers will be provided with a great boon. With the exceptions named, which do not form a large portion of the work, every operation can be performed by simply regulating a steam valve. By these means the objectionable features of handling coal and ashes will be entirely removed, and provision for doing most of the cooking, as well as complete facilities for heating water, and in winter for warming the building, be provided "on tap," so to speak, the same as gas and water.

Thus the sun's energy of ages past, stored in luxuriant vegetation and buried with it beneath debris due to cosmic changes, may now be redeemed from the bowels of the earth as coal, transmitted to a distance as steam, and bring sunlight to the household by lightening domestic labor. Power, heat, and even actual light may be obtained and manufactures promoted in most inaccessible and contracted places; and, gentlemen, one more subject is now available for the exercise of the talents of the engineers of the future, in their efforts to advance still further the comforts and civilization of mankind.

THE LARGEST GASHOLDER TANKS IN THE WORLD.

WE publish this week an illustration of two gasholder tanks recently constructed from the designs and under the superintendence of Mr. Charles Hunt, M. Inst. C. E., for the Corporation of Birmingham, at their Windsor Street gasworks. They are the largest in existence, being 240 ft. in diameter and 51 ft. deep, and are separated from each other by a wall 7 ft. in thickness. They are constructed wholly of bricks, and made watertight with cement rendering, a $\frac{1}{2}$ in. coating of Portland cement and washed sand being first applied, and finished off with $\frac{1}{4}$ in. of neat cement. The substitution of this for clay puddle as usually employed is estimated to have effected a saving in the work of nearly £6,000. In consequence of the peculiar nature of the soil, which is a drift deposit, consisting of pure sand, sand and loam, with fine drift coal, the work proved to be one of exceptional difficulty, it being found impossible to effectually drain the site. For the latter purpose three pumps had to be employed, two of them reaching down to the new red sandstone, which on the very edge of the site occurs within 59 ft. 6 in. from the surface of the ground, or 85 ft. 6 in. below coping level of tanks, but is nowhere else attainable at any practicable depth. The united pumping from these pumps brought to the surface about 3,000,000 gallons of water daily, the water being kept down to a level of 87 ft. 8 in. below coping level of tanks. In addition to these, several donkey and hand pumps had

THE BIRMINGHAM GASWORKS.—240 FT. GAS HOLDER TANKS.

