A certain number of bars crossing the ring are screwed into the lower part of the dome, which they thus unite to the ring and to the body of the plate iron. At the lower part of the latter are riveted plates and angle iron forming the supporting bed of the upper circle of rotation, G. A lower circle of rotation, H, corresponding to the one above it, is fixed and bedded into concrete.

Between these two rings are placed either conical trucks or balls to reduce the work of rotation to a minimum, which may be effected by men working on the levers of the capstan, V. Three iron ribs at I, with T iron held to the moving structure, support the cheeks of the carriages. Three transverse ribs, J, form, with the first three, the structure of the platform. A floor covers this structure. Two ladders, K, fixed underneath the floor furnish means of communication between the intermediate chamber containing the capstan and that containing the guns. Two movable panels, L, furnish a passage for mounting and dismounting the guns. A brake worked from the interior fixes the position of the cupola during firing. It consists in gear acting on a screw which acts through the medium of a sabot on the rotation circle.

Each carriage is composed of two iron cheeks, O, riveted to the ribs of the floor. These cheeks are strengthened transversely by strong transoms of cast iron or hard steel. Between the cheeks is a cross piece resting on the head of a hydraulic piston which serves to give elevation. The piston is worked by a pump, Q, of gun metal. The gun is held by its trunnions in two grooves, furnishing longitudinal movement in its carriage.

The system rotates on the pivot, S, under the action of the hydraulic press, by means of the bar, T, on which it slides. The recoil is limited by means of a hydraulic brake, of which the cylinders, U, are fixed under the gun. On the intermediate stage and on the center vertical shaft is placed a double capstan, V, acting by means of conical and cylindrical pinions on a toothed arc, X, strongly bolted to the lower part of the moving system. Immediately beneath the racers is the circular graduated scale, Y, for horizontal direction. A needle serves as an indicator. The projectiles are brought into the lower chamber by a gallery. A lift let into the wall and worked from this chamber raises the projectiles into the intermediate chamber, and they are placed either in the niches or in the second lift, E E, which carries them into the body of the turret; this lift, fixed to the ribs of the floor, is worked from the interior of the gun chamber. In order to save time, two lifts are so arranged as to raise a shell during the descent of the empty lift, which ought to take the next shell. The "avant cuirasse," or glacis plate, is made in three pieces: (1) A crown, G G, of cast steel or chilled iron strengthened at the upper edge, and made in eight similar segments; (2) a supporting ring, H H, of cast steel in eight pieces, resting under the upper edge of the crown and bedded in cement; (3) an exterior ("jupon") crinoline or petticoat of thin steel of segments united by strong angle pieces of steel. This forms the continuation or prolongation of the cone of the glacis plate.

Cupola for One Gun of 12 *cm.* (4·72 *in.*), *with Non-recoil Carriage.*—The cylindrical body of the cupola has an exterior diameter of 4·4 m. (14 ft. 5·3 in.), and is composed of nine bars of iron and transoms. The ring, D, is cast in two pieces. It acts as a support to the roof, E. The one and the other are of steel, lead-tempered and annealed. The roof is cast in one single piece; it rests on the walls at F. G and H are two circular racers for turning—the one above and the other beneath. The latter is firmly fixed to the concrete by bolts.

Between the two racers are either metal balls or conical trucks. The rotary movement is supplied by a toothed arc, I, pinned to the racer, H, and engaging with the pinion which is at the extremity of a vertical shaft, to which the movement is communicated by a wheel with axle working upon a double band. Two solid bars, L, of hardened steel, united to th cylindrical body by their extremities, support the cheeks of the carriage. Two small bars, M, constitute, with the two bars, L, the structure of the platform. A movable panel, O, of the platform furnishes a passage for mounting and dismounting the gun. The check, P, worked in the interior of the chamber containing the gun, determines the position of the turret during action. It is composed of a separate wheel, Q, working a screw, which rests by a sabot on the toothed wheel. The carriage is composed of two cheeks, R, whose lower parts are firmly fastened to the principal bars of the platform, and which are united vertically to the cylindrical body by a massive piece of chilled steel, S, in the form of a U, replacing at this point the rib work of iron and transoms of the cylindrical structure. At the upper part these cheeks are united to the ring, D, on one side by strong bolts, and on the other by two cranks or strong legs. The muzzle of the gun passes through a spherical collar piece adjusted to the embrasure. Behind the trunnions the gun is fitted into a jacket, V V¹, whose two pivots run in the grooves of the cheeks. These grooves have as their axis or center the center of the spherical piece, through which passes the chase of the gun. The recoil of the gun is thus prevented, and its shock is mainly transmitted to the upper mass of the movable body of the cupola. The jacket, V, is united at its lower portion by a toothed sector worked by means of gear by the spoked wheel, X. This mechanism constitutes the elevating gear. In order to reduce to as little as possible the work at the wheel, the gun is balanced by a counterpoise, N¹, fastened to the extremity of the chain, O¹. This chain turns upon a drum of spiral form in such a manner that the arm of the lever of the counterpoise varies proportionately to that of the center of gravity of the gun.

At the lower part of H, the racer for the rotation of the turret, is fixed the graduated arc, Y, for pointing. A needle, Z, placed under the platform, determines the angle for this. The projectiles are brought to the lower chamber, A¹, by the gallery, B¹. The niches, D¹, built into the masonry, are intended for a limited store of projectiles. The raising of the charge is effected by a vertical tube, E¹, open on one of its sides, and fixed at its upper end to the platform of the movable body. A lift, F¹, receives the projectile and the charge. It is attached to a support which turns in the open end of the hollow tube. A chain fastened at the upper end of the support raises and lowers the scuttle in passing over the blocks, G¹ and H¹. In the action of the winch, I, lowered upon the shaft of the axle, J¹, which works the endless chain, the scuttle takes a movement and conducts the projectile and the charge in the chamber of the cannon. Communication is effected between one platform and the other by the steps, N. The glacis plate is composed like that of the cupola for two cannons, being of the prolonged form already mentioned.

THE PRALL SYSTEM OF DISTRIBUTING HEAT AND POWER FROM CENTRAL STATIONS.*

By E. D. Meier, Member of Engineers' Club of St. Louis.

Heat is the condition of all life and the foundation of all power. These facts, so clear to the modern engineer, were foreshadowed by the imaginative Greek who invented the myth of Prometheus, that demigod who snatched from Olympus the living fire which was to enable mortal man to become even as the gods themselves. They were the living truths underlying the fire or sun worship of the Parsee race. In this sense the mechanical engineer may lay claim to a spiritual ancestry far antedating that of the proudest monarchs of the world.

We now know, what they darkly felt or imagined, that the sun is, for us at least, the source of all power and the upholder of all life. Not only does he lift up millions upon millions of foot pounds of energy in the vapors which he raises from the sea to feed the water powers of the highlands of our continents, not only does he direct and limit the forces of the winds which still continue to do so much of the world's work; but we know that ages ago with beneficent profusion he stored up for us in the coal measures a limitless supply of force, which we can at will liberate from its long imprisonment and turn to our uses. To-day this antediluvian supply determines by its location and condition where the great hives of modern industry shall be planted. But we must modestly confess that we have not yet learned the A B C of economy in the use of this great gift of nature.

If we will put aside those facts and statements based on the best foreign or the best Eastern coals, and confine ourselves to what lies nearest at hand, which is of course the problem for us to solve, we find that:

The best possibilities in our average Illinois coal are the liberation of 11,580 heat units from each pound of this fuel consumed. We have theoretically necessary to give us one horse power per hour 2,565 heat units. Hence one pound of coal burned per hour should give us 4½ horse power. But we find that our best steam plants, with high pressure engines of the Corliss or an equally economical type, coupled with the best boilers, require three pounds of coal for each horse power per hour, which is equal to 13½ times as much fuel as it should take theoretically. And this may be placed as for our locality the best present possibility in practice, which can only be reached in large plants, where both the engineer in charge and the firemen at boilers are considered, taught, and paid as skilled laborers. In most smaller plants, where a cheap boiler and cheap engine, pipes poorly covered (or perhaps not covered at all), are handled by underpaid and consequently unskillful or careless men, from eight to eleven pounds of coal are used per horse power per hour, which is from 36 to 50 times as much as theoretically necessary, and from 2¾ to 3¾ times as much coal as would be used in plants attaining the practical minimum above stated. But I know of cases where the record shows a consumption of 80 times the theoretical quantity, or six times the quantity of fuel for each hour's run that is actually used in the best class of plants before described. Now since the best types of engines and the best types of boilers, the best types of heaters and all other appliances, cost very much more per unit of power for small plants than for large ones, and since the higher grade of intelligence, in what is one of the highest and most useful branches of manual skill, can only be had for proportionately good pay, it is clear that we cannot expect to develop anything like the economy aforesaid in small plants scattered all over the city, under sidewalks or up in garrets, etc. Furthermore, the principal danger about the steam plants will always be located in the boiler room. And you cannot but regard it as a great mistake that the good old rule which insisted on placing the boilers entirely outside of factory buildings is utterly disregarded in the smaller and larger plants scattered about populous cities for such purposes as heating, cooking, running elevators, printing presses, sewing machines, electric light plants, etc. A recent report of a board of experts consisting of Profs. R. W. Raymond and Geo. Plimpton and Mr. C. C. Martin, C.E., refers to this matter as "the growing danger from steam boilers of all sizes distributed in buildings and under sidewalks, and employed in running elevators, dynamos, printing presses, and other machinery. That destructive accidents from this source have hitherto been few is a gratifying circumstance, which must not be permitted to obscure the fact that the danger is constantly increasing with the number of such boilers and with the growing age of those now in use."

Add to this the danger from conflagrations in the overheating of flues entirely inadequate to the work they are called upon to perform; the cost of bringing in coal and carrying out ashes to and from places narrow, dark and scarcely accessible, and the dirt accompanying this transportation. Consider further the smoke and soot and worse still the invisible gases of combustion which vitiate the air in rooms in which numbers of men, women and children spend their days in labor, and even perceptibly affect the very atmosphere of the streets, and the fact that all these evils grow with the greater concentration of the best part of our population, *i. e.*, the workers, in districts where the height of buildings constantly increases with unchanged width of streets. We have then reasons enough to account for the many attempts which have been made to concentrate the work of producing this heat energy in certain central stations, near the fuel supply and more or less remote from the localities where it is to be utilized. Pittsburg's phenomenal and almost magical transformation by its natural gas supply has necessarily directed our thoughts to the substitution of a gaseous fuel, flowing in constant supply in underground mains under the streets, and distributed right and left alike to manufactories, office buildings, and private residences. There are hundreds of gas producers either seeking for recognition or actively at work on this problem. At the outset it behooves the engineer to inquire into the possible or probable limitations of such a system. The example of the gas light companies teaches us that even with low pressure in the mains, leaks are constant and unavoidable. Increase enormously the quantity of gas required, and we must either use very much larger or a greater number of pipes, or resort to pipes as strong and joints as carefully and securely made as those which gave the Philadelphia Co. in Pittsburg its great success. Pittsburg has not yet eliminated natural gas explosions from its weekly history, although they may no longer create a sensation. But the necessity of the expensive, because thorough, methods of the company aforesaid is acknowledged, and to such methods alone can we look for the prevention of gas explosions. Whether the minor leakage along such lines, causing impregnation of the soil, corrosion of the lead water pipes or of the electric insulators, and possible vitiation to the atmosphere sufficient to intensify if not to create epidemics, may not in course of time show even natural gas to be a not unmixed blessing, we cannot here discuss. The precautions, dimensions, and mechanical contrivances found necessary in Pittsburg's excellent system will no doubt limit the supplying of manufactured fuel gas to certain districts where the quantities are great and the necessities imperative. Furthermore, the fuel gas solves but the first half of the problem in furnishing the fuel in the exact condition in which it can best be burned, while the great multitude of small consumers, who will always create the bulk of the demand, require not this small material, but the manufactured product, *i. e.*, the heat energy itself ready at hand in the smallest subdivision. I am, therefore, convinced that fuel gas when its use becomes general will be distributed direct to certain larger plants, where the best appliances and the most skillful handling can be had, and that from such the live heat energy will be portioned out to the army of small consumers.

Large central steam plants have been and are being successfully operated in favorable localities, and where they have been originally designed and built with great scientific knowledge and practical skill. Where these have been wanting they have failed, always will fail, and ought to fail. They naturally require very large pipes and joints difficult to make and more difficult to keep tight, because not constantly accessible. Steam being very elastic cannot be pumped or forced by mechanical means, but finds its own velocity at the expense of loss of pressure, loss of temperature, and continuous condensation. From these result the always annoying and sometimes dangerous "water hammers" and wet steam and other kindred evils for the consumer. And these evils increase proportionately the larger the demand for heat or power made upon the pipes, so that invariably when most needed the service is least good.

Hot water, *i. e.*, very hot water, a great deal hotter than any one has ever *seen* it, next offers its solution. Water, having the greatest capacity for heat of any known substance (except certain chemical solutions valueless for practical purposes), has been chosen as the measure of specific heat for all substances. A cubic foot of water at 400° F. carries 22,000 heat units, while a cubic foot of steam at the same temperature carries but 682 heat units, *i. e.*, but $\frac{1}{32}$ as much. There is no difficulty in forcing water, under any pressure, through pipes at a speed of ten feet per second. Steam can be made to travel much faster, but many practical considerations limit the safe speed in long pipes to about 60 ft. per second. While no hydraulic engineer would hesitate at pressures in water from 400 to even 1,000 pounds per square inch, I doubt if any steam engineer would have the hardihood to propose supplying a large and complicated network of underground pipes with steam at much more than 100 pounds pressure. If we assume 125 pounds gauge pressure (equal to 140 pounds absolute) as the present practical limit, we find that our cubic foot of steam carries 376 heat units, or about $\frac{1}{60}$ of the quantity held by one cubic foot of water at 400° F. From practical considerations such as these we may then deduce the statement that a steam plant should have five to ten times the pipe area of a hot water plant, *i. e.*, its pipes must have from 2¼ to 3¼ times the diameter of those of the hot water system.

While there have been earlier systems of hot water supply, limited in extent, and some are to this day running with eminent success, the Prall system for supplying heat and power from central stations is, I believe, the first which has been put successfully into service on a large or metropolitan scale. A short description of the system will show where it differs from its precursors in methods and appliances.

We have first a central station with its batteries of boilers of a safety pattern, *i. e.*, constructed with comparatively small shells and small tubes, all with internal pressure, so that all parts of the elastic steel structure shall be in tension, and with a circulation so positive that differences of expansion, which would be caused by differences of temperature, are eliminated. Next, in addition to the ordinary feed pump, we have a pump or a number of pumps for taking the water from the boilers and driving it through a series of street mains carefully wrapped with non-conductors, and placed in an accessible conduit of brick or wood, each of which mains constitutes a complete loop, so that its further end returns directly to the boilers, the egress and ingress nozzles being so placed as to increase the natural circulation of the water in the boiler. At distances prescribed by street and alley crossings, but limited to lengths of 100 to 150 feet, are placed expansion joints, being simply castings, bolted to one end of each section, and to a solid block of foundation, into the further end of which enters through proper stuffing boxes a phosphor-bronze sleeve which forms the initial end of the next section of pipe. These castings are so arranged as to take at the same time the expansion joints of a return main to be afterward described, and the cross connections for the intersecting street or alley. Close to them are also placed stop valves to make it possible to cut out one section at a time for repairs while temporarily supplying the district beyond through the next street main, which thus for the time becomes a by-pass pipe.

In each section is also placed a check valve, being a simple spherical enlargement of the pipe, in which a heavy metal ball is so located that it can roll into and close the conical mouth of the pipe to either side as

* Read May 2, 1888.

soon as the fixed maximum speed of the water is exceeded. In case of accident, therefore, or of malicious injury, the two nearest check valves would shut off the injured section, so that the leakage would simply have the effect of flooding the conduit to a depth of a few inches with water, while the steam formed therefrom would be rapidly dissipated at a very low pressure. An explosion cannot occur here, since, in the opinion of the best experts, a good-sized rupture even of the shell of a boiler, when entirely under the water line, will rarely cause an explosion, since water alone, no matter at what pressure, will not readily attain a dangerous velocity. In the case of our pipe we have cooling influences at hand to reduce the effect of such ruptures, while, in the case of a boiler, additional furnace heat is constantly adding to the pent-up energy. At intervals of about 20 feet a coupling is placed, which at the same time is utilized for supplying service boxes placed at the sidewalk. These couplings have special threads, having the peculiarity that the base of the thread is conical, *i. e.*, runs out, while the crown of the thread is sharp and cylindrical. By this means the weakening of the pipe is diffused over a considerable length, so that experiments have shown it possible to preserve 97 per cent. of the full strength of the pipe. Furthermore, this form of thread can be so forced into the coupling as to actually bed the metal of the pipe into it and make an absolutely tight joint, even under the test pressure of 1,500 pounds.

All pipes before being laid are tested to 4,000 pounds pressure; a certain percentage of them, however, are tested to rupture, which generally requires over 12,000 pounds. Each section when laid is again tested to 1,500 pounds and made tight under this pressure, and finally the whole main is tested to 1,500 pounds per square inch. The entire supply pipe or force main rests on rollers supported on cast iron brackets about fifteen feet apart. The same bracket holds under its arched base a return pipe of double the diameter of the pressure main, which rests and rolls on a small iron trolley supported on the base plate, the whole being bolted down to a brick pier. This larger return pipe also forms a complete loop under the pressure main; it has similar joints, couplings, and expansion sleeves. The whole pipe system, after being tested, is wrapped with an asbestos covering, over which is secured a layer of asbestos cloth painted with water-proof paint. Over this, with a liberal air space between, is placed a brick arch, outside of same another air space and still another brick arch, the outside of which is covered with some water-proof cement. The board of experts before referred to found the loss in temperature of a four-inch hot-water main in Boston to be only four degrees for a length of nearly two miles, and that at a minimum speed of the circulating current of one and a half feet per second. The claim of the Boston company that their entire loss by radiation will not be more than two and a half per cent. on the average therefore seems well founded.

From each coupling in the hot main a one-inch pipe runs to the service box located at or under the sidewalk, where by means of a tee it branches into three openings, each closed by an asbestos-packed cock. From this point to the inside of the house wall, generally a distance of less than ten feet, a small copper supply pipe runs to the converter, copper being used to enable the steam fitters to run their pipe in any direction around obstructions to the point where the converter is most conveniently located. These pipes run generally from one-eighth to three-eighth inches in diameter, one inch being a maximum. The converter is simply a steel vessel taking the place, in the house, of the steam dome, which is not required on the boilers at the station. The small copper service pipe terminates in a pressure-reducing valve screwed by a short nipple against the converter. These valves are controlled very nicely and accurately by electricity. To the top of the converter the steam pipe either for power or for the ordinary steam system of the house is attached, being of the same dimensions as if attached to a local boiler. Each converter is further supplied with a steam gauge to show the pressure at which it is set; at its bottom it connects through a return pipe into the service box, and from that back into the return main. As a further precaution a pop safety valve is placed in a horizontal position at the bottom of the converter, so that in case of excess of pressure by a failure of the reducing valve to do its work, the water can be discharged through the safety valve into the return system. Where ordinary steam-heating plants exist in a house the steam pipe from the top of the converter is simply connected with the same, the connection with the boiler being broken. The same applies to the connection of the system to an existing power plant. Where furnaces or indirect heating or ventilating systems are to be replaced a coil of pipes is substituted, either directly from the main with hot water or from the converter with steam. For cooking, a range is used in which a network of these small hot-water pipes is placed so as to give a constant temperature, sufficient for cooking, baking, etc.; in fact, every operation except broiling, and ranging from 350° to 400° F. It will be seen that by using two converters we may first extract from the hot water sufficient steam at 70 or 80 pounds pressure to drive the power plant of a building, and from this pass the water into a second converter to furnish a further supply of steam at a very low pressure, which may be supplemented by the exhaust from the engines to heat the entire building in the coldest weather. I have above considered only the difference in economy between large, well regulated power plants and small, cheap, local ones. When we come to compare the cost of this system with the cost of fuel for domestic heating and cooking purposes we find that only 10 to 15 per cent. of the heat in the coal is there in practice utilized, as against from 50 to 75 per cent. in steam boiler plants. The Boston Heating Company, which has had this system in use on a large scale during the past winter, estimates for ordinary city houses about 1·1 heat unit per cubic foot per hour. I have found in good examples of steam heating in this city a consumption somewhat larger, but as in my case the buildings were used for offices, where on account of almost constant opening of doors a larger loss of heat may be expected, I believe it to be perfectly safe to figure on 2 heat units per cubic foot per hour as a maximum. Of course, this will be much modified by the circumstances of exposure.

If we consider 5 pounds gauge pressure as ample for steam heating on the average, we find that at this pressure our hot water at 400° F. will give us nearly 20 per cent. of its weight as available steam and still have a large quantity of heat left in the other 80 per cent. for indirect radiation, or for heating water for baths, etc. At the pressure mostly used for pumps, elevators, and small engines about city buildings, say not exceeding 70 pounds, the same water will return us about 10 per cent. of its weight as available steam, the other 90 per cent. being further available for the other purposes above mentioned, and, of course, the exhaust from these engines can be further directly applied for warming, ventilation, etc. Practically then a four-inch pipe would, at a speed not exceeding 10 feet per second, be able to completely supply 50 average stores of 25 feet frontage, 120 feet depth, and three stories of each being heated and each supplied with its own elevator. Since, however, a plant of this kind will always run during the whole 24 hours, and, therefore, the brunt of the fight against cold can be borne by the system during the early morning hours before there is any demand for power, we may reasonably expect to get a result fully 20 per cent. better.

Whenever the plants of heating companies under this Prall system become of sufficient size, a great deal of the water from the return becomes available for condensation at the station, thus reducing the cost of running its own pumps, electric light and fan engines. The water, after all its service has been performed, is thoroughly filtered to remove any grease, grit or dirt it may have picked up in its wanderings, and is then pumped back into the boilers by ordinary feed pumps, passing on through the same pipe and mixing with the water which comes back from the return end of the pressure main. The system has been not inaptly compared by its promoters to the Gulf Stream, which furnishes an example of the great distance to which water can carry heat, thus making the tropical sun of the West Indies exert a genial effect on what would otherwise be the glacial coasts of Northern Europe. When a new main is first put into service, the hot water is pumped through it at a low speed, and this is continued until the conduit and its surroundings are well dried out, and the minimum speed for that main is then fixed by the rule that the last consumer, *i. e.*, the one nearest the station on the return end of the loop, is entitled to a temperature of not less than 390°. When the house connections are afterward all made, while the inflow of the pipes will be at a much greater rate of speed, as long as the return end of the loop maintains this minimum speed the last consumer will be practically as well served as the first. Each station contains apparatus for measuring and recording temperatures and pressures of the boilers, of the outgoing and incoming main, and of the return main. An inspection of the Boston plant in its everyday working must convince the most skeptical that the solution of the heat and power problem of modern municipalities has been found, and that a continuance of the same methods of thoroughness will advance this solution still further, and probably soon fix the limits of such systems in all directions as concisely as they have been fixed for our ordinary gas and water supply. While the great first cost of such a system will in every city limit its first application to the most thickly built-up portion, and therefore to the business section, its advantages will there become so palpably manifest that such central stations will gradually be found supplying the best settled residence districts also, especially since the margin between domestic economy in fuel and that possible in such a station is much greater than that existing between it and ordinary isolated steam power plants in the business section.

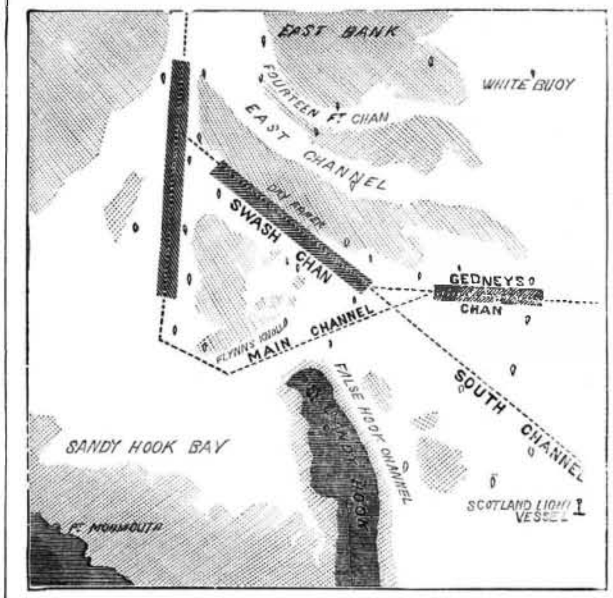
One fact bears strong testimony alike to the correctness of the system and the thoroughness with which the chief engineer of the company, Mr. Arthur V. Abbot, C.E., has done his work in every detail of design and execution. As soon as the first two boilers (Heine patent) were put in position, a steady circulation of warm water was forced throughout the entire main, the temperature gradually increased up to 380°, and next a solution of potash was pumped into the main and circulated for several days to remove all traces of grease and red lead. Then this hot potash water was replaced by fresh warm water until no more signs of contamination existed. During about ten days consumed in this manner, the whole of the line was carefully watched as to leakages and the working of the expansion joints. Thereupon house connections were immediately made and heat and power supplied during the entire winter, without an hour's interruption from any cause whatever, during which time eight more boilers were successively placed in service. Parties using the steam testify to its being unusually dry. When snow was on the ground, there was no sign of its melting faster over the conduit than in other parts of the street, except at the manholes, which are simply covered with two plates with an air space between them. —*Jour. Assn. of Engineering Societies.*

THE IMPROVEMENT OF NEW YORK HARBOR.

One of the most important operations ever conducted by the United States government, from a commercial point of view, is now in process of execution. We allude to the improvement of the channels leading up to New York City from the ocean. In one of his messages to the Board of Aldermen, Mayor Hewitt alludes to this work briefly, emphasizing its great importance to the residents of this city. With the increased length and depth of ocean steamers, it has become very evident during the last few years that something must be done, unless commerce is to be diverted from New York, or, at least, its expansion modified by the restricted depths and widths of the channels. While the question of depth affects the construction of the vessels directly, the narrowness of the channels has rendered necessary quick turning, so that the long type of vessels now in greatest favor for ocean navigation have found great difficulty in getting in and out of the harbor. They have been obliged to arrange their periods of starting by the tide, and very frequently are forced to wait outside of the bar until high water, if they reach it at any other than that period. It has been obvious for many years that some improvement was required, and little prescience was required to see that the necessity for such improvement was increasing in importance.

In 1884, an appropriation of $200,000 was made by Congress under the river and harbor bill, to be devoted to "the improvement of Gedney's channel, New York harbor." In order to work intelligently on so complicated a problem, Col. G. L. Gillespie, of the United States corps of engineers, then in charge of the New York district, was directed to make a survey of the whole harbor of New York. This was done by order of the Secretary of War through the chief of engineers.

The survey was commenced in August and completed in December, 1884, and reflects great credit on Colonel Gillespie, as well from its thoroughness as from the short space of time in which it was done. Soundings were taken by lead line from a tug boat which was kept in constant motion over the ground. Every half minute a sounding was taken and recorded, and every second sounding was located by sextant observations referred to fixed points on shore, whose geographical positions had been determined with great accuracy. With regard to the exactness of this method as compared with rod soundings, comparative tests have been



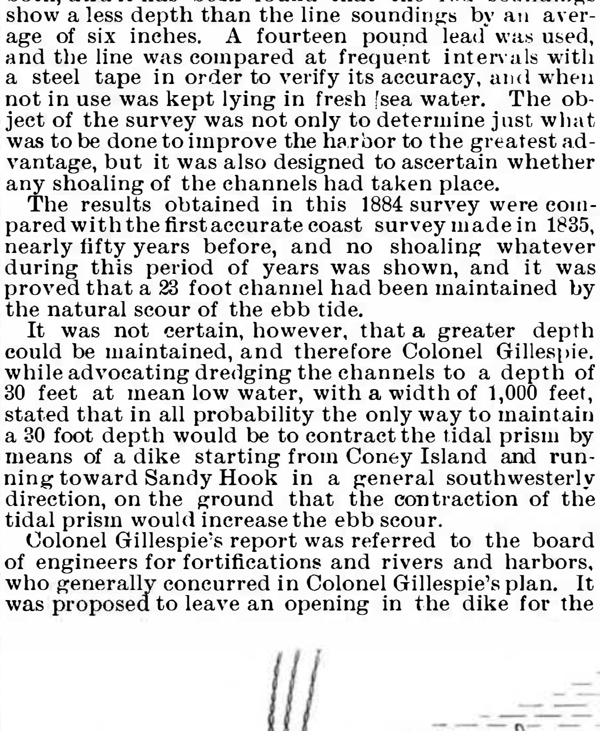
CHANNELS OF NEW YORK BAY.

made where part of the ground has been gone over by both, and it has been found that the rod soundings show a less depth than the line soundings by an average of six inches. A fourteen pound lead was used, and the line was compared at frequent intervals with a steel tape in order to verify its accuracy, and when not in use was kept lying in fresh sea water. The object of the survey was not only to determine just what was to be done to improve the harbor to the greatest advantage, but it was also designed to ascertain whether any shoaling of the channels had taken place.

The results obtained in this 1884 survey were compared with the first accurate coast survey made in 1835, nearly fifty years before, and no shoaling whatever during this period of years was shown, and it was proved that a 23 foot channel had been maintained by the natural scour of the ebb tide.

It was not certain, however, that a greater depth could be maintained, and therefore Colonel Gillespie, while advocating dredging the channels to a depth of 30 feet at mean low water, with a width of 1,000 feet, stated that in all probability the only way to maintain a 30 foot depth would be to contract the tidal prism by means of a dike starting from Coney Island and running toward Sandy Hook in a general southwesterly direction, on the ground that the contraction of the tidal prism would increase the ebb scour.

Colonel Gillespie's report was referred to the board of engineers for fortifications and rivers and harbors, who generally concurred in Colonel Gillespie's plan. It was proposed to leave an opening in the dike for the



DREDGING SCOOP AND SUCTION PIPE.

Coney Island channel, which is, to a large extent, used by the Coney Island and Rockaway steamboats and by oyster smacks and other small vessels from the Great South Bay and other points on the shore of Long Island. Such a dike would close the 14 foot and East channels. But these two are avenues of comparatively little importance, and their closing would be fully justified were the Main channel and Swash channel thereby benefited.

Estimates were made of the expense of improving Gedney's and the Main ship channel, placing it at about $1,000,000; but as this did not allow for the increase of 30 per cent. due to scow measurement of dredgings, because it referred to material in place, the total cost of this estimate rises to $1,370,000.