When the surface of the scum was lifted more than 12 ins. above the water line and there was danger of it overtopping the walls of the tank, the operator was instructed to break up the compacted sludge by means of a long-handled rake worked up and down through the scum, thus liberating the gases which were giving the mass its buoyancy. This operation was only partially successful. Although the sludge when properly broken up settled back to the level of the liquid, within 48 hours it had regained its original position and the process had to be repeated.

As this method involved considerable labor and had to be freqnently repeated, another method was tried. In the operation of septic tanks it has been noticed that rain falling upon scum in an open tank tends to break it up and causes a large portion of the floating matter to sink to the bottom of the tank. The experiment was, therefore, tried of sprinkling the surface of the scum with settled sewage, no water being available at the plant. The water thus applied softens the crust which has formed on top of the scum, giving the gases of decomposition which have collected in the mass a chance to escape. Furthermore, it seems to increase the specific gravity of the floating matter sufficiently to cause it to settle. Even with the application of water a certain amount of stirring has been found to be of value.

At the Moorestown plant the area of the sludge digestion chamber exposed to the atmosphere is approximately 28 per cent of the surface of the settling compartment. It is the author's opinion that the smaller this ratio the more serious will be the trouble from floating sludge on account of the smaller surface from which the gases can escape.

OPERATING RESULTS.

Table I gives the average analytical results of samples of sewage taken at the Moorestown sewage disposal plant, by the New Jersey State Board of Health.

Three separate determinations were made by the State Board, one on May 12, one on June 4 and one on Sept. 10. Composite samples were taken on those days at half-hourly intervals covering the period from 11 a. m. to 2:30 p. m. Only one determination was made on the character of the raw sewage, namely on Sept. 10.

Considerable sedimentation takes places in the grit chamber, far more than is indicated by Table I as the sewage on Sept. 10 was considerably weaker than that taken on the other two days It appears that the grit chamber is entirely unnecessary and should have been abandoned when the old plant was remodeled. Its continued use entails considerable work upon the operator in removing the large quantities of heavier suspended matter which settle out of the sewage in the grit chamber.

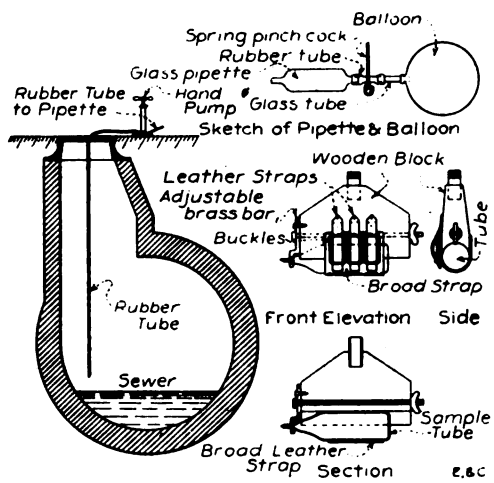
The plant yields an unsually clear effluent, free from sediment and very low in turbidity. The oxidation in the filters is very complete. Tests show the effluent to be non-putrescible during the greater part of the time.

Discharge of Inflammable Wastes Into Sewers—Problem of Prevention—The Pittsburgh Sewer Explosion Investigation.

It is thought that some of the more recent and more violent explosions in sewers were caused by the presence of gasoline vapor. If this belief is well founded it follows that the advent of motor driven vehicles has created a problem in sewer design and maintenance which may prove difficult and expensive to solve. Sewer systems are generally looked upon by the average person as a quick and easy means of disposing of any or all waste matter which can be carried away by the sewer, without any consideration whatsoever of the effect of such discharge, either upon the structure itself, or upon its maintenance and operation. The transition in the mode of travel from horse-driven vehicles to the motor-driven car and auto-truck renders the transportation, handling and use of large quantities of gasoline necessary and it is inevitable that in the handling of this material some will be spilled or wasted either by accident or design, which will find its way into the sewers. The solution of this problem is now occupying the attention of sewerage engineers. The present article, which is taken from a paper by Mr. N. S. Sprague, Superintendent of the Pittsburgh Department of Public Works, before the recent annual convention of the American Society of Municipal Improvements, discusses the discharge of inflammable wastes into sewerage systems and the problem of prevention. The scope of the sewer explosion investigation now being conducted in Pittsburgh is also described.

There are many sources which contribute inflammable wastes in a greater or less degree, ranging from the small and irregular discharges from households and private garages, which may amount to considerable in the aggregate, to the large and intermittent discharges from manufacturing and storage plants and other enterprises which use large quantities of gasoline.

In some cities (Pittsburgh included) the laws relating to the storage of gasoline require



Details of Apparatus for Taking Samples of Air Inside of Sewer. Sewer Explosion Investigation, Pittsburgh, Pa.

the tanks to be buried in the ground. These tanks, which are made of riveted steel plates, vary in capacity from about 50 to 15,000 gals. The purpose of placing them underground is to prevent possible ignition of the gas and protect them in case of a nearby fire. It is not the author's intention to discuss the advisability or the objection to placing gasoline storage tanks underground, but simply to point out the possible danger of gasoline escaping from these tanks and entering the sewers. The thickness of the steel plates of which the tanks are made, 's generally from ⅛ to 3/16 in. and their only protection from corrosion is the application of ordinary structural paint. The tanks are laid directly upon the ground and then covered with earth. Under such conditions, corrosion is rapid. It is also possible, under favorable conditions, that the tanks may suffer injury due to electrolytic action. In any case, there is no opportunity for inspection or repairs and leaks can only be detected by making a comparison of the quantity of gasoline put into the tank with the quantity removed. This information is in the possession of the owners and in case a leak is disclosed by a comparison of the figures, the owners are not likely to volunteer the information to the public authorities.

The possibility of gasoline escaping from the tanks into the ground and finding its way into the sewers may be remote, but with pervious soil or a nearby catch basin or trap, the opportunity for leakage into the sewers is at least present. In certain locations it is quite possible to set these tanks above ground, where ample opportunity for inspection and repairs would be possible. The waste gasoline from households, private garages and shops is so well distributed throughout the lateral sewer system and the average amount discharged at any one time so small that it is quickly dissipated before the formation of explosive vapors can occur. It is therefore to be supposed that the formation of gasoline vapor and other explosive gases present in sewers originates from establishments which are large users or dealers in inflammable materials.

There being in most cases no laws prohibiting the discharge of inflammable wastes into sewers and the danger of such practice not being generally understood, the natural disposition of such wastes is into the sewers. These wastes comprise dirty and used gasoline, benzine, oil, washings from tanks, and refuse from gas plants, paint works, etc. The quantity of these waste products varies according to the magnitude of business and methods employed.

While the discharge of gasoline into the public sewers probably exceeds in quantity any other inflammable waste, yet the discharge of waste products from paint works, oil refineries, gas works, etc., is likely to produce conditions, which, under favorable circumstances, may fill the sewer with explosive gas. Ignition of explosive gases, when present in the sewers, may occur in many different ways —for instance: Sparks from street railway tracks, hot cinders and sparks from locomotives, stacks, etc., which may enter the manholes through the perforations in the covers, or when same are removed for inspection or repairs; also the dropping of matches or lighted cigars into manholes or catch basins; lights and sparks from tools, while making inspection or repairs within the sewer or at chambers, pumping stations or disposal plants.

The problem of preventing sewer explosions would then seem to be a question of either effectually sealing all openings into sewers or excluding or regulating the discharge of inflammable or explosive wastes.

A number of cities have attempted to solve the problem by procuring legislation prohibiting or regulating the discharge of inflammable waste materials into the sewers. Prior to the general use of motor vehicles there were many industrial and business establishments using inflammable and volatile wastes, such as dry cleaning establishments, paint manufactories, gas works, etc. Notwithstanding the fact, explosions in sewers caused by the ignition of gasoline vapor were uncommon. This fact would seem to indicate that the greatly increased use of gasoline due to the growth of the automobile industry has been responsible for many of the recent sewer explosions.

Accepting this theory as a working basis, we must determine whether or not the gasoline is discharging into the sewers in large quantities by a relatively few people or in small quantities by a great number. In the first case the situation is relatively easy to control, while in the latter, it would be difficult. Moreover, it is necessary and important to determine whether the explosive vapor is generated from the accumulative effect of a great number of small discharges or from the discharge of large doses. Past experience has shown that the ordinary means of providing ventilation in sewerage systems has been generally adequate to prevent the collection of explosive gases. If large doses of inflammable wastes are allowed to enter the sewers, other means of ventilation will have to be provided or the sewers sealed. The installation of mechanical ventilation in the sewers throughout the system would remove the gases, but would involve great initial outlay and the cost of maintenance and operation would generally be prohibitive. This scheme would not seem practicable. There is no practical way of providing sufficient ventilation either by mechanical or natural means which would exhaust the air inside the sewer quickly enough to prevent the formation of an explosive compound in case large quantities of gasoline were present in the sewer. With the exclusion of large discharges of gasoline into the sewers, the danger of explosions can be greatly lessened by giving more attention to the improvement of the natural ventilation. This would probably be sufficient to prevent the collection of explosive vapors arising from the normal amount of gasoline discharged into the sewers. To form an explosive mixture a certain amount of air and gas is required. If there is a shortage of gas or an excess of air, no explosion can occur.

It cannot be ignored that many sewer explosions have resulted from the leakage of natural or artificial gas into the sewers. Evidence has been conclusive in a sufficient number of cases to show unmistakably that this is a fact. The prevention of explosions from this source, however, is well within the jurisdiction of public officials and the remedy is the tight construction of sewers and proper laying and location of gas pipes. The remedy in this case consists, therefore, in the enforcement of powers that municipalities at present possess.

Modern sewer design provides for the ventilation and inspection of the structure. The discharge of inflammable wastes into sewer systems would not of itself be a serious matter, or objectionable, were it not for the possibilities of igniting the explosive compounds. Ignition of gases in the sewers could be prevented by sealing all openings, but this would prevent inspection and create impossible working conditions inside the sewer when repairs became necessary. Moreover, the sealing of the sewers would not prevent ignition at chambers, pumping stations and disposal plants. In addition to the foregoing, there are other reasons which would make the sealing of the sewers impracticable and inadvisable.

The exclusion of inflammable wastes from a sewer system brings up the question of how it shall be accomplished. The regulations of the Municipal Explosives Commission of the City of New York, adopted Jan. 3, 1912, require the installation of oil separator traps or similar apparatus. The city of Boston requires a special trap which will prevent the discharge of the objectionable wastes into the sewers, and the city of Chicago has somewhat similar regulations to those of New York, governing this matter.

The efficiency of these devices is dependent upon the attention paid to their operation by the individual. Careless operation or neglect might render them of little value and defeat the purpose for which they were installed. Therefore, frequent inspection should be made by the proper public officers. Their general use on all sewer connections where gasoline or other inflammable waste is discharged would seem prohibitive, if found advisable, on account of the cost. The compulsory installation of devices for removing oil will generally meet with opposition by those affected, which has been recently demonstrated by the passage of an ordinance in New York City repealing the ordinance requiring the installation of oil separators. I am informed that this repealing ordinance was vetoed by the Mayor.

Formulation of legislation directed toward the prohibition of the discharge of inflammable wastes into sewers is at present receiving attention in many cities. That the same may be effectual requires the most careful consideration. It is most desirable that the necessity for such regulations be demonstrated and the efficiency of any devices thoroughly proven before they are required by ordinance.

The writer has examined the regulations of a number of cities and has come to the conclusion that it would be best from the standpoint of enforcement, to have all regulations of this nature contained in a single ordinance which would cover all phases of the discharge of wastes of all descriptions into the sewers. Such an ordinance should contain the following:

(a) Prohibition against the discharge of any inflammable gas, volatile inflammable liquid, inflammable liquid, oil or gas, or any calcium carbide or residue therefrom, or any liquid or other material or substance containing inflammable gas or which would evolve an inflammable gas when in contact with water or sewage.

(b) Regulations as to how sewer connections with establishments from which the fore going wastes emanate may be made. This may or may not require the installation of special traps, separators or similar devices.

(c) Provision for the examination and approval of all intercepting devices and provision for their inspection, maintenance and operation.

(d) Provision with regard to the discharge or placing of obstructing material in any part of the sewer system.

(e) Regulations as to the discharge of steam or hot liquid or gaseous waste into the sewers.

(f) Regulating the location of gas pipes in city streets with reference to the sewer; prohibiting the placing of gas pipes close to or within the masonry of sewers.

(g) Prohibiting connections from manholes, gate boxes, or other apparatus of public service corporations to the sewers, except in an approved manner and when properly trapped.

Legislation alone will not secure or prevent the discharge of these objectionable wastes into sewer systems, but by informing the people of the damage resulting from this practice, the offense will be greatly lessened.

It would appear desirable, in the interest of public safety, where oil separators or similar devices are installed, for the municipality to undertake the final disposition of the residue rather than entrust it to the individual.. The importance of the problem of regulating the discharge of inflammable waste, etc., and the necessity for its strict and effectual regulation has been amply and forcefully demonstrated by recent violent and destructive explosions.

As recent as Sept. 22, 1914, another serious explosion occurred in the sewer on East 42nd St., between 3rd Ave. and East River, New York, making the third explosion in the same sewer within a year. Reports state that the physical damage to the sewer, buildings and street, was not extensive. This is accounted for by the fact that the sewer was a brick lined tunnel in rock about 40 ft. below the street surface. Under less favorable conditions of location and design this result would have been far more serious.

The most disastrous and expensive sewer explosion up to the present time, although entailing no loss of life, occurred at Pittsburgh, on Nov. 25, 1913. This explosion to date has cost the city about $300,000, which may be increased by possible damage suits.

This problem is not confined to the prevention of explosions in the sewers themselves, but may extend to all kinds of sewerage works as shown by the explosion in the screen chamber at East Boston, which occurred June 1st, of this year. In this explosion, which was caused by the presence of gasoline vapor, six lives were lost and three men severely injured.

Without mention of other recent sewer explosions, it is evident from experience covering many cities, that an immediate, effectual and permanent remedy must be found to control the situation. With three explosions in the 42nd St. sewer in New York and two in the 33rd St. sewer in Pittsburgh, all within less than a year of each other, there can be no question but what the conditions inside of all large sewers draining garages, etc., are such as to produce explosions whenever ignition occurs. The safety of the public and the welfare of the community are therefore now dependent more upon good fortune than the certainty of scientific control, hence the public is always exposed to the hidden danger which only requires a chance spark to cause havoc and disaster.

The present situation can be likened to the man sitting on a keg of powder.

SEWER EXPLOSION INVESTIGATION AT PITTSBURGH.

The city of Pittsburgh, immediately after the second explosion, set about to make an investigation and study with a view of preventing a repetition of such disasters. This investigation is being conducted jointly by the city and the local office of the U. S. Bureau of Mines, who have rendered valuable assistance and advice.

The purpose of this investigation, which is still in progress, follows: (1) To locate all possible sources from which gasoline or other explosive wastes might enter the sewers. (2) To determine by a series of examinations and tests the location of the sources where the waste was discharged. (3) The determination of the presence, extent and quantity of vapor within the sewers. (4) Experiments to determine the effect and behavior of gasoline dumped into the sewer in different quantities and at different intervals.

The 33rd St. drainage basin was selected for study because of the number of garages within the basin and the fact that two explosions have already occurred, indicating the discharge of large quantities of explosive waste into the sewer. The 33rd St. drainage basin has an area of 1,642 acres, a population of 53,785, and a total of 417 structures where inflammable and explosive materials are handled. These structures are classified as follows: 295 small garages, not more than two cars, includes private and small business garages; 67 large garages, not less than three cars, includes public garages, repair shops, large business garages, etc.; 12 gasoline storage establishments; 1 dry cleaning establishment; 2 paint shops; 39 business or manufacturing places where inflammable oil or gases are manufactured, used, sold, handled or washed; includes gasoline supply establishments, large automobile establishments where gasoline is stored, sold and used in large quantities.

A map was prepared showing the outline of the basin, the sewer system within and the location of all garages, dry cleaning establishments and other places where inflammable or explosive wastes are likely to be discharged into the sewers. The map will be used in connection with studies to locate the point or points where the discharge of inflammable wastes occur.

Letters of inquiry were sent to all the principal cities in the country with a view of obtaining data and information relative to sewer explosions and what laws or ordinances were in force regulating or controlling the discharge of inflammable or explosive wastes into the sewerage systems. The answers received in reply to those inquiries were compiled and have been printed in pamphlet form and copies furnished to each city supplying information.

Apparatus was designed for securing samples of air within the sewer and for making field tests of same. The apparatus used is shown in the accompanying cut.

The results so far secured in the investigation indicate the presence of gasoline vapor in the sewers of both the 33rd St. and Negley Run systems. This latter system drains an area of about 2,500 acres with a population of about 50,000 and there are considerably less sources from which inflammable wastes are discharged than in the 33rd St. system. Analyses of a series of samples taken on the same day at various points in these systems have shown that gasoline vapor in small amounts is present throughout the sewer system. The gasoline vapor ranges from 0.012 to 0.065 per cent of the volume of sewer air in the sample. While these percentages of gasoline vapor are considerably below the danger mark, which may be taken as 2 per cent, it goes to show that the natural ventilation of these sewer systems is not sufficient to remove the effects of the ordinary or normal discharge of gasoline.

The Negley Run system drains through duplicate outlet sewers for a distance of over a mile, during which distance there are no connections known which could by any possibility discharge gasoline. Above this point, there are a number of large branch sewers of considerable length so that taking these larger sewers of the system together with the many miles of laterals, with the opportunity for ventilation provided, it must follow that natural ventilation would not suffice to remove the effects of the discharge of gasoline in large doses.

It is expected that these experiments will require considerable time before definite conclusions can be reached and preventive measures, based upon them, can be formulated, but it is hoped that some plan or action can be devised which, without imposing hardship or undue expense upon the people, will secure to them freedom from the peril and danger to which they are now constantly exposed.

The Milwaukee Sewerage Problem.

To THE EDITORS: In your issue of Oct. 14, 1914, you printed a portion of a paper entitled "The Milwaukee Sewerage Problem," which I presented at the annual convention of the American Society of Municipal Improvements recently held at Boston. In this paper I stated that the Menominee Sewerage Commission, consisting of Messrs. John W. Alvord, George C. Whipple and Harrison P. Eddy, had recommended that the preliminary treatment of sewage in Milwaukee should consist of chemical precipitation and disinfection. I made an error in this statement which I wish to correct. What this Commission did recommend as a preliminary treatment for the sewage of Milwaukee, was grit chambers, screens and sedimentation tanks for the removal of suspended matters and a disinfecting station—the effluent therefrom to be discharged into the Kinnickinnic River. When this River could no longer provide dilution for sufficient oxidation, the effluent was to be carried through a 13 ft. tunnel under the bottom of Lake Michigan and dispersed on the bottom about 1⅝ miles from the shore. The Commission suggested that, in order to delay for some years the building of this large outfall tunnel, provision might be made for temporarily treating the sewage by chemical precipitation. It further suggested that Imhoff tanks might prove more advantageous than shallow horizontal-flow well baffled tanks, and recommended a careful study be made of the adaptability of these tanks to the conditions in Milwaukee.

In the event that sedimentation, disinfection and dispersion in the lake did not satisfactorily dispose of the sewage, the Commission recommended that the tank effluent be further treated by sprinkling filters.

Very truly yours,

T. CHALKLEY HATTON, Chief Engr.,
Sewerage Commission of Milwaukee.

Milwaukee, Wis., Nov. 9, 1914.

BRIDGES

Design and Construction of the Lower Ganges Bridge in India.

(Staff Article.)

The Lower Ganges Bridge, which is under construction near Sara, India, about 115 miles northeast of Calcutta, will connect the 5-ft. 6-in.-gage system of the Eastern Bengal Railway south of the Ganges River with the railways north of the river. The bridge, which has a total length of about 5,900 ft., consists of fifteen through truss spans of 345 ft. 1½ in. each, center to center of bearings, and symmetrical steel approaches, each of which consists of three 75-ft. deck girder spans.

The piers of the truss spans are spaced 359.1325 ft. on centers, and their caisson foundations extend to a maximum depth of 160 ft. below low water level, the total height of these piers and their foundations being 222 ft. 6 ins. The bridge has a clearance of 40 ft. at high water, the variation between high and low water levels being 31 ft.

A bridge at this site was proposed more than 20 years before its construction was sanctioned in 1908. Proposals put forward by the Eastern Bengal Ry. in 1889 were investigated by a committee and reported feasible. In 1902 Mr. F. J. E. Spring prepared a detailed project, and in 1907 a committee representing commercial interests recommended one of the "Sara" sites, which also had been favored by Mr. Spring. A technical committee appointed in 1908 reported that a bridge could be constructed and advocated a site near Sara. This was followed by the sanction of the Secretary of State to the construction of the bridge at or near Sara and the appointment of Mr. R. R. Gales as engineer-in-chief, at the close of 1908. Earlier proposals projected a single-track bridge with a clearance at high flood level of 33½ ft. and protection works on each bank. Further investigation and experience with the vagaries of the river resulted in the provision, in the final design, for a double-track bridge with a clearance at high water of 40 ft., a public footway, and protection works at Raita and Sara, in addition to more strongly built protection works at the site of the bridge.

APPROACHES AND PROTECTION WORKS.

The portion of the line which includes the bridge and its approaches is about 15 miles long. It starts just north of the Bhairamara station on the Eastern Bengal Ry. (see Fig. 1) and joins the northern section of that railway about three miles north of Gopalpur. From the south (Calcutta) side the approach line to the bridge has a slope of 0.25 per cent for a distance of about 3¼ miles. On the north (Siliguri) side the track is level for 2,000 ft. at Paksey station and then grades downward for about 3¼ miles at a slope of 0.20 per cent. At the abutments the approach banks are 50 ft. high. Figure 2 shows a plan of the protection works at the bridge site and the manner of providing access to them. There are five roads under bridges through the high approach bank and two small culverts for local drainage. There are also four culverts beyond the northern approach grade for local drainage. These culverts are heavily protected against failure during floods. From the Bhairamara station on the south bank to the Ishurdi station on the north bank (see Fig. 1) the railway is double track; beyond these stations it is single track.

The problem of keeping the river to its course through the bridge was the most difficult one which confronted the engineers. The system adopted is that originated by the late Mr. J. R. Bell for rivers with erodible banks. At the bridge site there are two guide banks of the "Bell" embankment type. Each protection embankment is 4,000 ft. long, extending 3,000 ft. above the bridge and 1,000 ft. below it (see Figs. 1 and 2). The ends are curved inward and are heavily pitched with stone. The embankment consists of a core of earth raised 18 ft. above the highest flood level, protected on its river slope with a covering of pitched stone 2 ft. to 3½ ft. thick. From the toe of the slope an apron 4½ to 8½ ft. thick is spread outwards a distance of 150 ft. As the river cuts away the earth from under the outer edge of this span, the stone falls and eventually the entire apron will lie at a slope equal to that of the pitched slope of the bank to a depth of 100 ft.—the maximum known depth of bend scour. It has been possible to make these guide banks shorter than would otherwise have been necessary, due to the existence at Sara (three miles above the bridge on the north bank) and at Raita (seven miles above the bridge on the opposite bank) of benches of clay of considerable extent which form semi-permanent points in the banks of the river (see Fig. 1). To render these points permanent, and thus confine the river to a comparatively straight approach to the bridge, they have been reinforced with pitched-stone guide banks and aprons, each 4,000 ft. long.

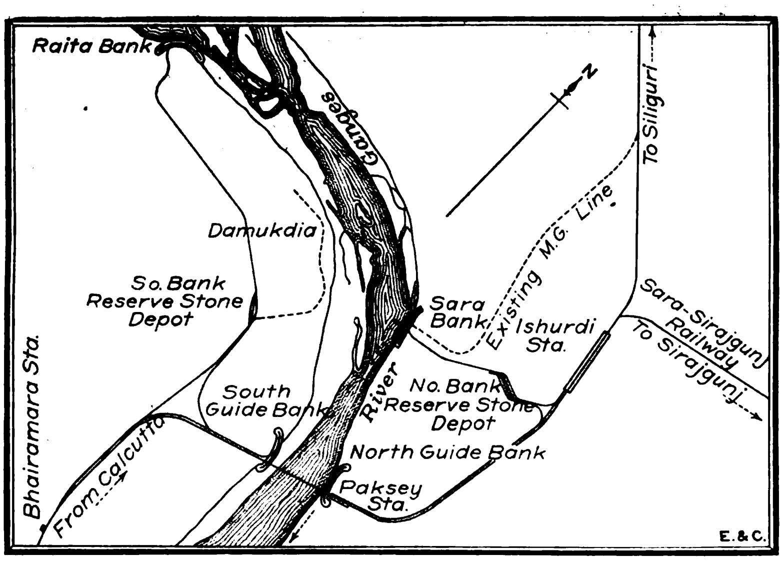


Fig. 1. Site of Lower Ganges Bridge and River Bank Protection Works.

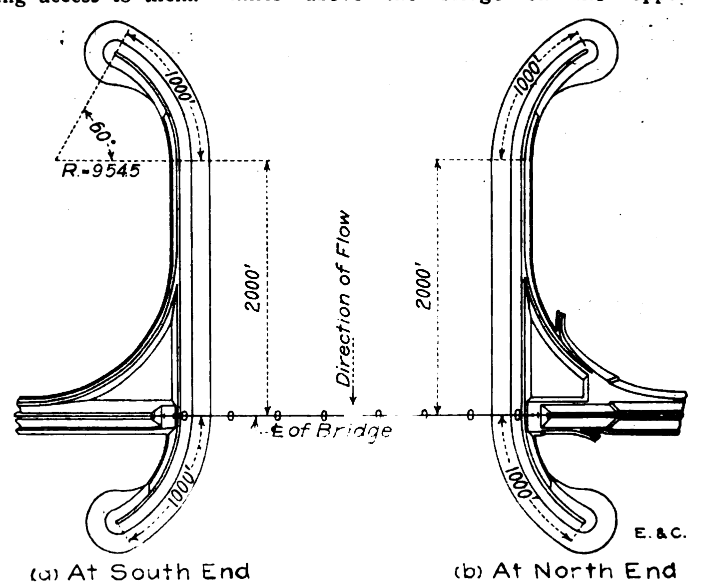


Fig. 2. Plans of Protection Works at North and South Ends of Lower Ganges Bridge—Note Approaches to Protection Works.

SUBSTRUCTURE OF BRIDGE.

Caisson Foundations.—The sixteen main piers are founded on caissons sunk by the