ON THE FLOATING SWIMMING BATH
AT CHARING CROSS,
WITH THE MEANS ADOPTED FOR THE FILTRATION
OF THE WATER.

BY MR. EDWARD PERRETT, OF LONDON.

In 1873 Mr. C. W. Whitaker and the Author were appointed Engineers to the Floating Swimming Baths Company, established for the purpose of providing floating baths at any available locality, but especially upon the river Thames. At that time the company proposed to use a plan for floating baths, in which the most noticeable feature was, that when desirable the water should be filtered by passing through charcoal before being delivered into the bath.

It was at once apparent to the author that such means would be quite inefficient and very expensive, and that until a more satisfactory system of filtration could be adopted, the project of providing baths on the Thames or elsewhere, in which filtration of the bathing water should be necessary, must remain in abeyance. After some consideration however it was determined at the instance of the author, to institute a series of experiments in filtration, on a scale sufficiently extended to give reliable results.

Preliminary Experiments on Filtration.—Two descriptions of material were fixed upon for trial, namely Ransome's stone filters and the ordinary bag filters used in sugar factories. The stones used were of various degrees of porosity, and formed into hollow cylinders with one end closed, to give surface; these were placed in the tank containing the water to be filtered, as shown in Fig. 10, Plate 22, the closed end being uppermost, and the open end resting upon a saucer provided with an india-rubber joint and an outlet pipe, which passed through the bottom of the tank, and was there

fitted with a cock. The bags were the ordinary cotton bags used in filtering sugar, each in a netting to prevent distension, and attached by a brass mouthpiece or bell to the bottom of a tank containing the liquid to be filtered, as shown in Fig. 11. The apparatus thus prepared was placed upon a barge moored on the site proposed for the Pimlico Floating Bath, so that no question might subsequently arise as to the quality of the water operated upon, in comparison with that to be thereafter supplied to the projected bath. The water was pumped into the filter tanks direct from the river.

Not to go too fully into detail, it may be stated briefly that the best result obtained by the stone filters, having about 5 sq. ft. of surface, was a yield of fair water amounting in the first 4 min. to 50 gall.; in the next 5 min. to a further 50 gall.; in the following $6\frac{1}{2}$ min. to 50 gall. more, thus reaching 150 gall. in $15\frac{1}{2}$ min.: and so on, until at the end of 30 hours the yield practically ceased, having then amounted to about 1000 gall. of very fair water. Although the performance of these filters was so far highly satisfactory, no ready means of cleaning them for repeated use could be suggested, especially on account of their extreme friability; and the price of new ones being about £1 each, the cost of constant renewal could not be incurred, and it was therefore decided that they could not be adopted.

The trial of the bag filters gave the following result. From one bag, having a surface of about 20 sq. ft., a yield was obtained of 50 gall. in 5 min., a further yield of about 50 gall. in the succeeding 9 min., and a further quantity of 50 gall. in the next 45 min.: making 150 gall. of very clear water in the hour, at the end of which time the delivery practically ceased; the bag had then merely to be removed and washed, and when replaced was again ready for use. As these bags with their sheath are comparatively inexpensive, costing from 5s. to 6s. each, and can be arranged about 5 in. apart from centre to centre, and are durable and readily cleaned, it was considered that sufficient information had been obtained to warrant application being made to the authorities for permission to place floating baths in the river Thames.

But it was still felt that the process of cleaning the bags by taking them down, removing them from the bells, and washing them, was attended with inconvenience and expense which it would be very desirable to overcome or to diminish. Some means was therefore sought for cleaning them without removal from their places; and a further series of experiments was carried out by the author to try the effect of what may be termed a "blow-through" filter, as shown in Fig. 12, Plate 22. This consisted of a modification of the ordinary bag filter, by placing an additional bell at the lower end of each bag, precisely similar to those by which the bags are suspended, the lower bell leading through the bottom or side of the vessel that receives the filtered water, and being provided with a cock. This apparatus, as in the former case, was placed on board a barge moored in the Thames, the water being drawn from the river as before; when the bag, from accumulation of dirt in the interior, gave sign of slackening its yield, say at the end of 15 min. work, the cock upon the lower bell was opened, and the water rushed through the bag, partially cleaning it, so that when the cock was closed again the bag at once recommenced filtering. This experiment was so far successful that it was found by this arrangement one bag will yield about 500 gall. before it need be removed and washed. It should be borne in mind that the water under treatment was heavily charged with extremely fine particles of matter in suspension of a slimy nature, as may be seen by the sample exhibited.

A notable feature arising out of these experiments, and one on which the author would be glad to have the opinion of members of the Institution, is that the water which, in the former series of experiments, had been filtered through the stones, upon being opened after a few weeks, emitted a powerful and very unpleasant smell, though not so strong as that given off by the unfiltered sample; whereas the specimen taken of that which had been filtered through the bags, though opened at the same time, did not then and has not since emitted any odour at all.

Of the samples exhibited, Nos. 1, 2, and 3 were taken at the time the first series of experiments was made; and Nos. 4 and 5 were taken only two days ago.

No. 1.—Thames water	unfiltered	} Taken at Pimlico, 23 October 1873.
No. 2.—	„ „ filtered through the stones	
No. 3.—	„ „ filtered through the bags	
No. 4.—	„ „ unfiltered	} Taken at Charing Cross, 27 April 1875.
No. 5.—	„ „ filtered through the bags	

The growth observable in the filtered water, samples Nos. 2 and 3, became apparent some four or five months after the date of the experiments, up to which time the water was perfectly clear and bright, similar to sample No. 5.

The first series of experiments extended over three weeks, during the whole of which time the men employed on board the barge drank the water from the bag-filter receiving-tanks. No attempt was made to free the water from chemical impurity, as it was believed that the removal of the mud, coupled with the aeration effected by the spreading of the water in an almost imperceptible film over the surface of the bag in the process of filtering, would purify the water sufficiently for all the requirements of bathing. Particulars of the method of applying this system of filtration are given subsequently.

Site of Bath.—Permission was then obtained from the Thames Conservancy Board and the Metropolitan Board of Works for a floating bath to be placed in the recess of the Victoria Embankment, immediately west of the Charing Cross railway bridge,—a site unrivalled in point of position, being exactly opposite the junction of the Victoria Embankment and the new street now being made from Charing Cross, but presenting such engineering difficulties as induced the author to recommend the substitution of one further out in the river, under the shelter of the main pier of the railway bridge; access to the bath could then have been gained from the foot bridge by a spiral staircase terminating in a brow. In that position the bath would have been always afloat, and what is of still greater importance, the water there is much cleaner, containing perhaps less than half as much mud and other impurity as is contained in the water nearer the shore. This recommendation however was not acted upon.

The site selected in the recess of the embankment, Fig. 1, Plate 20, was at that time occupied by a dumby or landing stag for river steamers, but not in use for that purpose. The bottom of this recess is formed by a sloping stone apron, Fig. 4, wide enough to carry the dumby when the tide fell low enough to strand it which happened but rarely, as the dumby drew very little water. This apron was not wide enough however to carry the bath, which projects some 10 or 12 ft. beyond the apron, and draws some 8 ft. of water. The greater width of the bath and the slope of the apron rendered necessary the preparation of a level bed to receive the bath at low water. This was done by driving piles in the river bed about 6 ft. apart from centre to centre, under the line of the outer edge of the bath, with capping from which horizontal timbers also 6 ft. apart run back to the embankment wall in the recess, as shown in Figs. 3 and 4; other timber fixings are arranged as shown in Fig. 4. The gridiron thus forms a level bed for the flat bottom of the bath to rest upon at low water.

Construction of Hull.—The hull of the bath is entirely of wrought iron, and is shown in the sections and plan, Figs. 3 to 5, Plate 20, and the enlarged cross section, Fig. 6, Plate 21. It consists principally of two longitudinal box girders A A, 2 ft. 6 in. wide and 177 ft. long, forming the sides of the bath, with a depth of 10 ft. 6 in. at the centre for a length of 42 ft. 6 in., and 9 ft. depth at each end for a length of 18 ft., and 8 ft. depth for the intermediate lengths, as shown in Fig. 3. These girders are placed 25 ft. apart, connected together at the ends, and further tied by two transverse bulkheads 21 ft. from each end: giving a bathing area B B of 135 ft. length and 25 ft. breadth, and two chambers C C for machinery &c., each 21 ft. $\times$ 25 ft., one at each end of the bath. The whole of the plating is $\frac{1}{4}$ in. thick, with the exception of the keel-plate and garboard-strake, which are $\frac{3}{8}$ in. thick, the bilge-strake, which is $\frac{1}{8}$ in. thick, and the top plates of the girders, which are $\frac{3}{8}$ in. thick. The bathing area amounts to 3375 sq. ft., and when full the bath contains about 150,000 gall. of water.

The water in the bath being filtered, it was necessary to provide a bottom to the hull; this forms a further connection

between the side girders. In cases not requiring the bathing water to be filtered, no bottom would be wanted except for the safety of the bathers. The bathing space is provided with a wooden false bottom, resting on the main frames at the western end, giving a depth of 6 ft. 3 in. of water for a distance of 50 ft., and thence sloping gradually upwards to the eastern end, where the depth of water will be about 2 ft. 6 in., as shown in Fig. 3. These depths may however be increased 8 in. or 9 in. if found desirable.

The occasional grounding of the bath rendered necessary still further connection between the two sides in the 135 ft. length of the bathing space, as at such times the water inside the bath would be some 4 ft. or 5 ft. higher than that outside. To effect this connection, two curved bridges DD, Figs. 4 and 6, are placed near the ends of the 10 ft. 6 in. central part of the side girders, dividing the bathing space into three about equal portions, Fig. 5. These bridges are not arches, but bent girders of exceptional strength: the object of the curvature being to afford an uninterrupted view from end to end of the bath, which could not have been obtained if these connections had been horizontal, as would have been preferable, if they had been considered merely as ties. A bottom having been provided, it was requisite to make it strong enough to bear the upward pressure of the water outside when there is no water inside the bath, as in the progress of the erection of the superstructure, or during repairs &c.; accordingly 7 in. main frames are placed at every 6 ft. with reversed bars, and intermediate frames at every 2 ft.; a rider-plate centre-keelson E and sister-keelsons F are also provided, as shown in Fig. 6. The timbers of the gridiron correspond with the main frames.

The frames in the two end compartments CC are placed 4 ft. apart from centre to centre, with an intercostal keel; and generally the work is of greater rigidity in these portions of the structure. These end compartments are further strengthened by transverse beams, of bulb and double angle-irons, which form the roof or deck of the chambers, and the floor of the rooms above. Along the river side and the ends of the bath the outer skin is carried up to a height equal to that of the deepest part of the girder, 10 ft. 6 in.;

and upon it is placed a horizontal plate 12 in. by $\frac{8}{8}$ in., strengthened at every 3 ft. by a knee, forming a convenient platform on which to erect the superstructure, and also serving to carry the timber fender placed along the outside. The top of the side girders forms the footway round the bathing space, and the floors over the end chambers are raised 1 ft. above the top of the girders.

Mooring.—The question of mooring the structure presented more than ordinary difficulty. Owing to the site being in a recess of the embankment, and close to the steam-boat pier, the bath must be kept in approximately one position; chains therefore could not be used, while at the same time provision had to be made for preventing, in the event of high winds, all the strain falling upon rigid moorings. Another essential consideration was that the bath should be easily and rapidly placed in position, and as readily removed if necessary.

To this end, four cast-iron guides G G, of the section shown in Fig. 9, Plate 22, are bolted vertically to the embankment wall, in the positions indicated in Fig. 5. These guides are 30 ft. high, extending about 8 ft. above high water. In the longitudinal girder of the bath on the embankment side are placed four pairs of T headed bars, corresponding in position with the cast-iron guides G G; the tails of these are screwed and passed through long bosses H H on the inside and outside of the girder, india-rubber washers and gun-metal nuts and lock-nuts J J being put on the screwed ends. In the inner boss, and in the tail of each T bar, is cut a long cotter-way, which, while not interfering with play of the bar endwise, prevents circular movement when cotted up.

When the bath was brought into position, these cotters were withdrawn, the T heads were turned into a vertical position, and thus passed without difficulty into the guides. They were then turned back into their proper horizontal position, thus engaging the cast-iron guides, the cotters were put in, and all was secure. The operation of getting the bath into position occupied but a few minutes from the time of its arrival alongside, and removal could be as easily accomplished. The screws on the tail of the T bars enable a

perfect adjustment to be made, so that each guide shall do its share of duty; the india-rubber washers serve to deaden the shocks that arise from the movement of the bath caused by passing steamers. In the neighbourhood of these guide bars the girder is well strengthened with angle irons and plates to prevent injury to the structure. Stiff adjusting buffers are placed at each end of the bath to prevent motion endwise.

Supply of Water.—The apparatus for supplying the bath with water is arranged in accordance with the experiments already described, and is shown in Figs. 7 and 8, Plate 21: Fig. 7 is a transverse section of the machinery chamber C, which is the one at the eastern or shallow end of the bath, Fig. 3; and Fig. 8 is a corresponding plan. Each bag filter being capable of filtering say 500 gall. of water, and the bath requiring about 150,000 gall. to fill it, 300 bags are wanted for the purpose; and these delivering the water into the bath at the rate of say 500 gall. per minute, the operation will take about 5 hours. Running along each side of the machinery chamber is a shallow tank K, which is divided into compartments, and placed at such a height that the bottom shall be about 1 ft. below the water line of the river when the bath is full and afloat. Into the bottom of each of these tanks are inserted 300 brass bells, the upper portion of each bell being fixed in the tank bottom, and the lower or trumpet-mouthed portion connected to it by a coarse-threaded screwed end. Below these tanks are placed other tanks M to receive the filtered water, each 21 ft. long, 3 ft. wide, and 3 ft. deep, the bottom of the lower tanks being about 5 ft. 6 in. below the bottom of the upper. On the river side the lower tank is provided with a false bottom, Fig. 7, into which are inserted bells similar to those in the upper tank, but inverted; and the space L between the false and real bottoms is divided into compartments, corresponding with those in the upper tank; each of these compartments is provided with a large valve V to draw off its contents. The portion of this lower tank above the false bottom communicates with the pumps, and the upper shallow tank is in communication with the river by means of pipes P passing

through the side girder. On the land side, the upper tank is in communication with the interior of the end of the box girder, which again communicates by the pipe R with the bath. The lower tank on this side has no false bottom, but is in direct communication with the pumps. Filter bags are connected on the river side to the bells in the upper and lower tanks; these bags on the land side are merely suspended from the bells in the upper tank, the lower ends not being open as those on the river side are, as shown in Fig. 7.

Water is admitted from the river at pleasure to any or all of the compartments of the upper tank on the river side, and passing down through the bags fills the space L below the false bottom of the receiving tank, and filters into the latter above the false bottom; thence it is pumped into the bath, while the mud and matter that was in suspension in it settle in the space L under the false bottom or on the sides of the bag itself. When after a time the yield from the bags in any compartment partially ceases, the large valve V in the bottom of that compartment of the tank is opened, and the dirt is swept out by the flow of water into the bilge, whence it is pumped overboard by the donkey pump; the greater portion of the matter adhering to the bags being removed by the rush of water through them, they will recommence filtering as soon as the valve is closed again, though the yield may be somewhat less than before. When, after repeated application of this means of cleansing, the filtration slackens considerably, the bags may be removed by unscrewing the trumpet mouths to which they are secured at top and bottom, and may be released from these trumpet mouths, and washed.

On the land side the water from the bath passing into the end of the box girder may be drawn at pleasure into the upper tank, whence it re-filters through the bags into the lower tank, and is pumped from there back into the bath again: for this purpose it was not thought necessary to provide the blow-through apparatus for cleansing the bags. The water from the bath passes also into the end of the box girder on the river side, so as to balance that in the girder on the land side; and is also admitted into the corresponding

portions of the box girders at the other end of the bath, in order to equalise the strain upon the entire structure and to keep it on an even keel.

The pumping machinery was intended to consist of two of Messrs. Gwynne and Co.'s 7 in. centrifugal pumps, with 3 ft. 6 in. discs, each capable of delivering 750 gall. per min. against a 25 ft. head at 280 rev.; but the contractors for the machinery have at their own risk substituted pumps of their own make to do the same duty, the discs being only 2 ft. 3 in. diameter. The pumps S, Figs. 7 and 8, are arranged to draw either from the filtered-water tanks M, the bath itself, or the bilge; and to deliver either into the bath through the fountains placed in it, Fig. 2, or into the upper filter tanks K, or overboard, as may be required. For first filling the bath the pumps draw from the bilge, into which the water is allowed to enter direct from the river through cocks provided for this purpose. The overflow from the bath passes off through two self-acting subsidisers placed in the chamber C at the western end of the bath. There being abundance of water, a Morton's ejector-condenser is applied to each of the pump cylinders, drawing its supply of water from the bath and delivering into the suction main of the pumps. Steam is supplied by a 14 H. P. semi-fixed boiler of the ordinary type, but with two fire-doors for accommodation in firing. A washing and a rotary rinsing tank are provided for cleansing the bags when they become choked.

An apparatus for raising the temperature of the water in the bath has also been provided; it consists of four fire-tubes, in pairs, placed below the sloping bottom of the bath, and stoked from the machinery room. Each pair of fire-tubes runs into a common flame-box, and the gases are returned through 3 in. tubes to the front, where they go into a common uptake which passes through the dressing room over the machinery room, serving in cool weather, when the water is warmed, to warm this dressing room; the uptake acts also as an air space around the chimney from the steam boiler, serving to prevent this from warming the room in hot weather. It is not proposed to warm the water during the winter, but only to extend the bathing season by heating the water say in May and

October, the temperature of the water in the neighbourhood of the bath being on an average as follows, according to observations made in 1873:—

May	June	July	August	September	October
55°	62°	65°	66°	60°	56°

Superstructure.—It was originally intended that the main ribs of the superstructure of the bath should be of wrought iron, forming in fact continuations of the ribs of the hull; but the appearance of this was not considered suitable to the site. The first design, which is represented in Figs. 1 and 2, Plate 20, was composed principally of cast iron and glass; but owing to its costliness, and to difficulties with the contractor at the outset, causing much delay, it was decided to adopt a plan which could be more readily and cheaply carried out, though less ornamental, and into the construction of which timber should enter more largely; it will retain however the same outline, and present the same general appearance as the former design.

The two domes are each 30 ft. square and 30 ft. high, and are placed 18 ft. from the ends of the bath; the portion between the domes is 20 ft. high, and the rooms over the end chambers are 10 ft. high. The iron columns of the domes are 6 ft. apart, terminating in curved ribs, which are connected together and supported by brackets. In the intermediate portion the columns are placed 12 ft. apart, carrying a roof similar to that of the domes. The curved portion of the roofs is covered with boarding and zinc work; the upper portion is glazed, and provided with continuous louvre ventilators. The roofs over the end chambers are flat and covered with zinc. Wood frames are placed between the iron columns to receive the sashes, which are glazed, like the skylight, with ribbed glass.

The dressing boxes T, Fig. 2, are on the land side only, and are supported on iron brackets; they are so placed as to coincide with the recesses in the embankment wall, Fig. 5. The room over the machinery chamber is formed into a public dressing-room, and that over the opposite end chamber is arranged as a refreshment room,

with plate-glass windows, affording a view over the river. Under the domes are placed the fountains for delivering the water into the bath. The pay office is placed on the floating stage that carries one end of the brows by which the bath is reached from the embankment.

Filtration.—As probably the portion of this paper most likely to be of interest to the members of the Institution is that relating to filtration, it may be desirable to refer to the various methods that have been investigated by the author since the subject has engaged his attention, with the various results arrived at. It may be assumed that water may be filtered through cloth, charcoal, sand, porous stone, &c., with approximately similar results. The question of the most suitable material would appear to resolve itself into the enquiry as to which can be most easily and readily cleansed. For the purposes of baths, the effect of filtering the water through bags was quite satisfactory, but the system in practice for cleaning the bags was very imperfect; and although the method to be adopted in the Charing Cross bath had been decided on and the machinery ordered accordingly, yet the author determined to go further into the question of filter cleansing.

The first filtering apparatus with mechanical means of cleansing that was tried by the author is shown in Fig. 13, Plate 22. The filter cloth being spread over a stationary perforated drum D carried on a vertical spindle in a tank A, the liquid to be filtered was put into the annular space between the drum and the tank, and filtered into the inside of the drum, leaving the dirt on the outside of the cloth, the filtered liquid being drawn away by the self-acting syphon B. When it became necessary to cleanse the filter, the tank cock C was opened, and the liquid in the annular space, into which much of the dirt had settled, was drawn off. The drum was then rapidly revolved, a very little clean water being introduced inside it by the sparger pipe E; the dirt was thrown off, and the cloth became as clean as though it had never been used. The mud &c. ran off through the draw-off cock C, and the filter was ready to start afresh. But although the result of this method was

Y

satisfactory, and the quantity of clean liquid per sq. ft. of filtering surface was largely in excess of that obtained from the bags, yet it was apparent that owing to the size and cost of the apparatus, compared with those of the bags, in relation to the work done, it could not successfully compete with the bags unless means could be devised to accelerate the filtering.

Trial was next made of an apparatus consisting of a rapidly-revolving horizontal disc of thick cloth split horizontally at the edge, one portion of the split edge being turned or dished upwards and the other portion downwards. The liquid to be filtered was discharged upon the disc, at some distance from its centre, in a small stream and under pressure. It was supposed that the momentum of the stream would carry the liquid some way into the cloth or through it, leaving the particles of dirt entangled at or near the upper surface of the disc, and that the filtered liquid would by the centrifugal action be thrown off from the underside, and directed downwards by the under lip of the disc, while the impurities would be flung off from the upper side by the same means. The result of this trial however was not satisfactory, for the liquid when delivered at any appreciable distance from the centre of the disc did not penetrate the cloth in any quantity, and that which did was not clear; the major portion of the liquid was thrown off the disc in a partially cleansed condition, some of its impurity having become entangled in the cloth, but this dirt was also thrown off the edge a few moments later than the liquid.

A further trial of centrifugal filtering and filter cleansing was then made with an apparatus shown in Fig. 14, Plate 22, consisting of a vertical spindle carrying a wire-work basket, to the upper edge of which was attached one end of the filter cloth I; this hung downward inside the basket, and was brought up again to a disc G which was fitted with a nut capable of working up a screw contained within a hollow and slotted prolongation of the vertical spindle; at the top of the screw were fixed a few fan blades H. The liquid to be filtered was run into the annular space formed by the hanging filter cloth I; and the apparatus being put into motion, centrifugal action drove the liquid through the cloth into

the lower chamber J, leaving the impurities inside the cloth. When it was desired to clean the filter, the speed was accelerated; the increased resistance of the air to the fan blades then caused a retardation of the screw, by which the nut attached to the disc was made to ascend, and the cloth being thus turned inside out, as shown dotted at FF, the dirt was thrown off into the upper chamber K. The speed then being reduced, the cloth returned to its original position. The quantity of filtered liquid yielded per sq. ft. of surface was greater than that delivered by the stationary filter shown in Fig. 13, but it was not sufficiently clear for the purpose for which it was wanted. From this circumstance it was gathered that filtration could not be successfully effected while the filtering material was in motion, as the slightest disturbance of the filtering material appeared to be sufficient to permit the passage of enough dirt to make the filtered liquid cloudy; but on the other hand, centrifugal cleansing of the filtering material was found to be thoroughly practicable and successful.

Guided by the above results, it became necessary to devise an apparatus giving ample quiescent filtering surface, and capable of being easily cleansed by centrifugal action. Many plans were considered by the author, but the most suitable that has yet occurred to him is shown in Fig. 15, Plate 22, which is a modification of that shown in Fig. 13, and consists of eight pairs of perforated discs DD bolted together and covered with filter cloth, and carried upon a hollow spindle through which the filtered liquid runs off at B. When it is required to clean, the outside liquid is drawn off at C, and the discs are rapidly rotated, as in the case of the drum in Fig. 13; the cleansing can be assisted by the admission of a little clean water through the central perforated pipe E if required. A filter of this description, with eight pairs of 5 ft. discs, giving a filtering surface of over 500 sq. ft., and cleansed by rotation say every 15 min., would be capable of yielding 10,000 gall. of clean water per hour: the water operated on being similar to the sample No. 1 exhibited.

Mr. PERRETT exhibited the several samples of filtered Thames water referred to in the paper, and also specimens of the stone filter that had been tried, and of the cotton filtering bags and the netting enclosing them. He mentioned that a sample of water taken from the Thames a few days previously at the site of the Charing Cross bath had been found to contain 1-1400th part of its weight of solid matter in suspension. The rate of filtration with the blow-through bag-filter had been found to be 500 gall. from one bag in about five hours, and the gradual choking of the bag by the mud was shown by the fact that the first 100 gall. passed through the filter in 15 min., the second took 22 min., the third 61, the fourth 72, and the fifth 130 min.; the bag being partly cleansed by blowing-through with the unfiltered river water after every 100 gall. was then ready to start filtering again.

Mr. E. A. COWPER enquired what was the rate at which it was intended that the bath water should be changed. The bath was to contain 150,000 gall. of water, and it had been stated that by means of the bag filters the water could be delivered into it at the rate of 500 gall. per min. or 30,000 gall. per hour; but he presumed it was not intended to change the water so frequently as once in every five hours, for if that were done the water would of course be remarkably clean. In the London swimming baths he believed the water was generally changed about three times a week. The number of dressing boxes seemed to him rather small, being apparently only forty-six; in a bath of that description he should certainly think that a hundred might be used in summer, and he hoped the bath would be so popular that the numbers would have to be increased. He enquired whether the engines pumping the water into and out of the bath were non-condensing, or whether they had surface condensers, so as to give clean warm water free from grease; in which case he suggested that the exhaust steam might be easily and economically utilised for taking the chill off the water when it was rather cold, because there was no doubt that swimming baths were more popular if the temperature of the water was raised a few degrees above that of the river, not so as to make it warm, but slightly tepid; and the

exhaust steam from the engine might be applied to that purpose. He felt a great interest in the success of the bath, having himself previously endeavoured to get baths established on the Thames, for which he had proposed to use the water from the water works, bringing it over the bridge on the land side into the bath. That plan he thought would probably have cost rather more than the filtration of the river water, though perhaps the water might have been a little better. The sample exhibited of the river water which had been filtered through bags two days previously had not yet had time to putrify, and certainly looked very clean, and was good enough for bathing, although perhaps not clean enough for drinking; because, after all, filtering through bags was only straining the mud out, and was not such a filtering as through charcoal or fine sand; but the result would be very satisfactory if the water supplied to the bath was always as clean as the sample exhibited. The proportion of solid matter in the water before filtration being 1-1400th, he should be glad to know how much of that was taken out of it by the filtering bags, as the actual effect of the filtering bags was a very interesting question.

He enquired whether there was intended to be any ballast at the bottom of the floating bath. With the straight vertical sides of the structure, there seemed some reason to fear the effect of a lurch over, as the water inside the bath was not confined in boxes or compartments, and consequently did not act as water ballast, but it was open at the surface, and therefore free to move, and if the bath lurched, the water in it would shift. It would not do he supposed to trust to the guides which moored the bath to the embankment, as it was necessary to avoid any strain on the guides, in order that the bath might be able to float freely in all positions.

Mr. H. FAIJA would be glad of some information as to the cost of constructing the bath. It seemed to him that to place a floating swimming bath in such an impure river and supply it with filtered water did away with the main object of such a bath, namely to secure the pleasure of bathing in a running stream, with a safe bottom, shelter from the weather, and conveniences for dressing.

Unless therefore the cost of construction were less than that of erecting a bath on the land, there seemed to be nothing gained by the floating bath; and with the latter the cost of maintenance would be greater. If indeed the river water could be filtered for the bath at a lower cost than water could be supplied on land, the floating bath might be a success; but even then he did not see how it could answer commercially, when the great cost of maintenance was considered.

Mr. E. A. COWPER observed that the rent would be found to be much lower than that of a building on the land, as long as the conservators of the river allowed the floating bath to remain in its present position.

Mr. H. WOODS considered the most important point in connection with the bath was the perfect or nearly perfect filtration given to the water. A considerable amount of ingenuity had been displayed in devising the filters described in the paper; and it appeared to him some improvement might be made if the filter last described (Fig. 15), consisting of a series of pairs of perforated discs covered with filter cloth, were employed as a final filter, after some other means had been used to take off the worst of the mud, which the unfiltered sample of water (No. 1) showed to be very bad indeed. Having himself been interested some years ago in the filtration of water for washing the casks at a brewery, he had employed for many years a plan which on the whole had been perfectly successful for filtering large quantities of water; and he thought it might be simplified and adapted to the filtration of water for large baths, or at all events for taking away a great portion of the impurities, before finally filtering the water through the disc filter shown in Fig. 15, which was certainly a very ingenious contrivance. In the plan that he had employed there were three cast-iron cylinders filled with sponge, the higher portion in each being of a coarse quality and the lower portion fine; and there was the means of pressing the sponge together, so as to increase as required the resistance to the passage of the water through the sponge. The

water was pumped into the top of the first cylinder, and came out at the bottom tolerably clear. Previous to filtration it was nothing like so bad as the No. 1 sample exhibited of Thames water; in fact it was rare, except perhaps in some Lancashire districts, to find water so bad as that. The original water was perhaps about as bad as the sample exhibited of Thames water taken two days ago (No. 4); and after passing through the first vessel, which took off the coarser impurities, it was pumped through the second, from the bottom of which it came out as clear as the best sample exhibited of filtered water (No. 5). The quantity of water pumped through was that delivered by a 5-inch pump with 2 ft. stroke, making about 30 strokes per min. When after a time the water issuing from the second filter began to be somewhat less clear, and was no longer fit for use, the first filter was stopped, and the second was used in its stead for removing the larger quantity of deposit; and the third filter, which was quite fresh, was taken to finish the filtration. The first filter was then cleansed by pumping clean water through it from the bottom upwards, which issuing at the top carried away with it a large quantity of the mud, leaving the filter sufficiently clean to be used again in rotation. When any one of the filters had been thus used so many times that it would no longer yield water pure enough, the sponge was all taken out and washed. That plan had gone on in continuous operation from week to week with very fair results; and it had occurred to him therefore that in the bath now described some such vessels filled with sponge might be used for removing the coarser impurities, and that the disc filter (Fig. 15) might be kept for finishing the filtration of the water pumped into the bath.

Mr. S. C. HOMERSHAM said he had a very high opinion of sponge filters for a rough process of filtering, and had designed one a good many years ago for a brewery at St. Petersburg, which he believed had answered exceedingly well. The water used in the brewery was the water of the Neva, which at certain periods was mixed with very fine sand or silt; and for separating this, filtration through sponge was found to answer better than any other process that

was tried. When it could be avoided however he preferred not to deal with water that required filtering, for he thought such water as a rule was not good for ordinary use, although it might be good enough to bathe in. At the Burton breweries that he had had to do with, he had found that the whole of the water used was spring water pumped from the red sandstone; and this was used not only for brewing, but also even for rinsing the casks containing the fine ale that was sent to India. The use of water from the river Trent was carefully avoided even for cleansing the casks, because if they were rinsed with river water it was found to set the ale fermenting in some unaccountable way; and at those breweries therefore it was essential to use spring water entirely free from all organic impurities.

Mr. H. WOODS said that at the brewery with which he had been connected at Burton, and at which he had employed the sponge filters, particular care was exercised about the water used for brewing, and not only for brewing but also for washing the casks; and for the latter purpose certainly no river water was used until it had been well purified by filtration, and was not less pure than the samples exhibited of filtered water for the bath. Spring water however was there in so great demand for brewing alone, that it was difficult to get a sufficient supply; and at those breweries they certainly could not afford a few years ago to abandon the use of river water for washing the casks. It was for this therefore that the sponge filters had been employed; and it was evident that they must to a certain extent have acted well, because in that particular case it would not have been worth while to filter at all, unless the filtration could be effected in a very thorough manner.

Mr. J. T. THORNEYCROFT observed that in the bottle exhibited of unfiltered Thames water, which had been shaken up a few minutes ago, the greater part of the mud was already settled, principally at the bottom. That was exactly what he had found took place in the Thames at high water and at low water, at which times the water settled itself and a great part of the impurity went down.

This circumstance appeared to him not to have been taken notice of; and he suggested that if there were space to take advantage of it in the floating swimming bath, it might be a benefit for assisting very much in the filtration of the water.

Mr. A. PAGET enquired whether any evidence had been obtained as to the amount of impurity in chemical solution in the water before and after filtration, because he presumed that filtration would remove nothing but solid matter in suspension. It would be interesting to know whether the filtered water was really chemically purer, and to what extent the impurity remained.

Mr. E. EASTON mentioned that on three occasions he had used bag filters for water which contained extraordinarily finely divided particles of clay. One was at St. George's Hospital in London, where a bed of fine running sand had been hit upon in a well, and it was very difficult to get the sand out of the water; bag filters were there used with success, of somewhat the same description and thickness of material as the specimens exhibited from the bath. A much more difficult case had been at Maidstone, where a deep well sunk for the water works yielded water containing particles in such a finely divided state that it did not become clear even after standing three weeks to settle. It was filtered through bags with perfect success, two thicknesses of filtering material being employed, one of which was very like the bags shown from the bath, and the other was of a much finer quality; the filtering was done at the rate of from 40 to 60 gall. per min. from each bag of 4 ft. length and 3 ft. circumference. By an arrangement of cocks at the bottom of the bags, somewhat similar to that shown in the drawings, they were cleaned very readily at periodical intervals, duplicate bags being provided. These examples of the employment of bag filters on a small scale seemed to him to bear testimony to their practical utility for the filtration of water; and he saw no reason therefore why the same plan should not be successfully applied on a larger scale for the purpose proposed in the present paper. He enquired whether the samples exhibited of Thames water which had been taken

eighteen months ago had been kept in the dark, or exposed to the light.

Mr. C. HAWKSLEY suggested that this mode of filtering through bag filters might possibly by a little modification be applied advantageously to the filtration of sewage sludge, by means of some such arrangement as the annular filter shown in Fig. 14. It appeared to him, from the information given in the paper respecting the rate of filtration with the bag filters, that the water was filtered through those filters at about eight times the speed at which it could be filtered through sand in the ordinary way, taking an equal area of surface in each case: though he was not aware whether the filtration was equally perfect.

The PRESIDENT hoped some remarks would be made upon the question raised in the paper, as to why it was that water filtered through the stone filter putrified in so short a time, while that filtered through a bag filter did not. This seemed rather a difficult point to explain. He enquired whether it had been attempted to filter any other substances, such as sugar syrup, by means of the various constructions of filters described in the paper.

Mr. T. HAWKSLEY observed that a misconception prevailed with regard to the operation of what was called filtration, which was generally supposed to produce something analogous to a chemical action upon the water. But in fact filtration proper, as distinguished from mere straining, was neither more nor less than the action of universal gravitation; and the curious way in which filtration was performed might be seen in the simple case of dirty water put into a bottle. It might naturally be supposed that gravitation would carry all the solid particles down to the bottom; but on a careful examination it would be found that a large number of the particles were attracted to the sides of the bottle and adhered to it in a sensible quantity, and that only a portion went to the bottom, though it might be a considerable proportion if the solid matter were very coarse and heavy. In his own experience as regarded the ordinary operation of

filtration through sand, he had found that in that operation particles were taken out from the water which were far smaller than the apertures between the particles of sand; therefore it was not an operation of straining, because if it were so the smaller particles would pass through the larger holes, and would escape being caught; that however was not the case, but the contrary. The real action was that the facets of the sand attracted the particles of suspended matter from the water, and these became deposited and fixed upon the surface of the sand, by the operation of what might be called the attraction of aggregation; and inasmuch as the particles were suspended in a fluid which offered scarcely any resistance to their motion, they were very easily drawn out of it by the attraction. In Cavendish's well-known experiment, when two large globes of lead were freely suspended in proximity to each other, they coalesced; and it was exactly so in the case of the filtration of water, the suspended particles coalesced with the fixed particles, and the water was left clear.

Mr. PERRETT, in reply to the enquiry about the rate of replenishing the water in the bath, said that, though in filling the bath 150,000 gall. could be delivered into it in five hours, it was not intended to renew the water continuously at that rate. No water would enter the filters from the river when the tide had fallen below the level of the inlet pipes to the filter tanks, the height of the orifices of these pipes being fixed so as to avoid drawing any water from the river for a certain period before and after extreme low tide, because at that time the river was more foul, and it was therefore desirable to avoid taking water from it then. During that time the water was drawn from the bath itself, and refiltered by being passed through the filters on the land side, and was then returned into the bath through the fountains, not perhaps so fresh as what came direct from the river, but at any rate refiltered and aerated; and in that way the water in the bath was renewed at a time when otherwise no supply could be obtained.

All the available width of the hull having been required for the bathing area itself, the dressing boxes had been arranged to project

into the two recesses in the embankment, which could not otherwise be used. The number of separate dressing boxes was thus restricted to forty-six only, as those were all that could be got into the two spaces, and none could be allowed to project on the river side of the bath; but there was also the large public dressing room at one end, which could be fitted with separate boxes all round if necessary at any future time.

The heat of the exhaust steam from the engine was utilised for warming the bath, the power of the engine being assisted by the employment of a Morton's ejector-condenser, the whole of the water from which went into the bath; so that the bath water was warmed and an increase of power obtained at the same time.

With respect to the absence of ballast, he had looked upon the hull of the bath as being equivalent to a structure having no bottom; it was constructed of two parallel girders, and the fact of the bottom being added between them did not appear to him to affect the stability of the whole. If there were the possibility of a heavy continuous wind from the land side, lasting long enough to heel the bath over, there might be a liability of its filling and sinking. But there seemed no reason for anticipating such a possibility; and as the guides mooring the bath to the embankment had only 3 in. horizontal play in and out, they would check any excessive tendency to listing.

The cost of the bath, as it was not yet completed, could hardly be stated at present with any certainty. But one item, which in London especially could never be overlooked, was the site, the annual rent of which, had it been on land, would necessarily have been an exceedingly heavy sum, even if such a site could have been obtained at all; and that was one reason why a floating bath was so advantageous. The filtration of the river water would not amount to anything like the expense of a supply from the waterworks mains; and the river water was generally much warmer. The superstructure was no dearer than for a building on land; and though the hull was dearer, he did not think that, taking the structure altogether, it was any dearer than a similar kind of building on land would be, judging from the cost of existing land baths in London independently of their site.

With regard to the suggestion that the water should be allowed to settle and so to clear itself partially before filtration, this was done at all waterworks where the water had to be filtered; and settling would no doubt be very beneficial in the case of the river water supplied to the bath, were it not that, on account of the time taken in settling, a much greater amount of room than was available would be required in order to obtain a sufficient supply of clear water. Additional space would indeed be wanted as large as the bath itself or twice the size, because in the settling it was only the top water that became clear, and it got darker and darker towards the bottom, so that probably not more than half could be drawn off for use, while the bottom portion would have to be pumped back into the river. Even the upper portion that was drawn off would still have to be filtered, because it did not settle so clear in a few hours as to do without filtration; and it had therefore been considered advisable to clear the water wholly by filtration, and not to use settling tanks. Another reason why settling tanks could not have been employed in this particular instance was that the slight motion which the bath would get in floating on the river would be sufficient to destroy the effect of settling.

In reference to the effect upon the water of filtering it through sand or through bags, he should imagine that both materials were about equally good; but he had found that the water from the stone filters putrified within a few weeks and became very offensive. How long the bag filters would last in the bath he did not know; in a sugar factory bags of the same material generally lasted about two years before requiring renewal. With sponge filters there was the disadvantage that in cleaning the sponge by a reverse current a quantity of clean water was consumed merely to cleanse the filter. It seemed preferable to be able to cleanse the filter with dirty water, of which there was an abundance; and this was done in the bag filters by letting a stream of unfiltered river water flow through the inside of the bag. He did not anticipate that any chemical impurities in the water would be removed by filtration through the bags; the only chemical change likely to occur would be the removal of some slight portion of ammonia by the aeration

of the water in filtering and on its delivery into the bath through the fountains. A sample of the water had been submitted to chemical analysis, and a certificate had been received that it was quite fit for bathing, and that it contained less ammonia than previously to being filtered; but he had no information as to the amount of impurity in solution in the water. Practically all the solid matter was taken out of the water by the filtering bags, as after a sample had stood several days the sediment was barely perceptible. The samples exhibited of Thames water which had been taken eighteen months ago had been kept exposed to the light the whole time.

Having borrowed from the sugar manufacture the idea of filtering the water for the bath by means of the bag filters, he had in return made some experiments in the filtration of sugar by the different constructions of cloth filters shown in the drawings, with the view of endeavouring to improve the filtering process in sugar factories. With one of the ordinary bag filters used for filtering sugar, as shown in Fig. 11—the same that he had adopted for filtering the bath water,—he had found that each square foot of surface of the bag was capable of filtering a quantity of liquid containing about $1\frac{1}{2}$ lb. of sugar, before the bag required taking down and cleaning. The bags were usually hung up one day and taken down the next, but two hours was about the time during which they filtered in any useful quantity, the remainder of the time being principally expended in draining the scum in the bags. With the stationary cylindrical filter shown in Fig. 13, in which the internal cylinder or drum of 2 ft. diameter was covered with filtering cloth of the same material as the bag filters, the quantity of liquid filtered per square foot of surface was four times as great as in the bag filters; the reason of the difference he did not know, unless it might possibly be that the cloth being here extended upon the drum, its whole surface was fully exposed to the liquid, while the bags were crumpled up inside the netting, so that perhaps all their surface did not come into play. But although the result was so satisfactory as regarded the filtration of the sugar, the cost of the apparatus was such that even this fourfold increase of efficiency was not sufficient to make it pay.

The next plan, shown in Fig. 14, was a remarkable example of success in its way. When rotated so as to filter by centrifugal action, it was a failure; but it was afterwards tried for quiescent filtering, the liquid being placed in the annular bag formed by the hanging filter cloth, whereby a double extent of filtering surface was obtained in the height. The scum stuck on the inside of the annular bag, and on the completion of the filtration the cloth was turned inside out by the rising of the nut up the screwed shaft when the machine was put in motion, and the scum was thrown off by the centrifugal action. But the cost of an apparatus of this kind was too great to allow of waiting the time necessary to filter the last portion of the liquid, while on the other hand it would not do to throw away the unfiltered liquid; and the plan was a failure on that account.

The filter shown in Fig. 15, if it contained eight pairs of discs 6 ft. diameter, would filter in an hour a quantity of liquid containing about a ton of sugar; but the difficulty attending that plan in the case of sugar was that, in order to rotate the discs for throwing off the scum, the outside liquid would previously have to be drawn off, and in running off would inevitably carry away with it by its motion some of the scum already deposited on the discs. In filtering water, it was of course immaterial how much of the dirt deposited on the discs might be carried away in drawing the outside water off ready for cleansing the filter by rotation; but with sugar such a plan would not be admissible. This difficulty he was endeavouring to meet, though the mode of doing so was not yet perfected. The cleaning of the discs by the centrifugal action was perfectly successful, aided by the injection of a little steam or warm water inside the discs, though that was not always wanted; and with some such construction of filter as this an ample extent of surface could be obtained for the necessary quiescent filtration of sugar.

The PRESIDENT thought it would be a great boon if the efforts now being made by the author of the paper resulted in restoring to the river Thames the floating baths, one of which he (the President)

remembered some forty years ago at Blackfriars Bridge. At that time the river was used for potable purposes; indeed the shipping in the Pool used to get from the Thames their store of water by means of barges, which were fitted with a species of filter; the river water was taken through the filter into a tank, from which it was pumped by hand into the ships' casks; he believed the water was afterwards said to get "sick" for a short time, and then it was all right for a very long voyage. For many years however the Thames had been looked upon as absolutely unfit not only for drinking but even for bathing purposes; if however the author of the paper were successful, as appeared likely to be the case, provided the specimen of filtered river water now exhibited were a sample in detail of what would be obtained in bulk, a great comfort would be restored to London. Looking at the excessive cost of land in any attractive neighbourhood such as that in which the bath was placed, there seemed ample reason to believe that the floating bath might be found, taking every circumstance into consideration, more economical than one on land, even if the structure were more expensive than an ordinary building, which however the author considered it would not be.

The bag filter, intended to be employed for filtering the river water for the bath, he had hitherto looked upon as an ingenious means of getting a large surface in a small space, a crumpled bag of 4 ft. circumference being put into a stocking which was only 1 ft. in circumference; but the results stated to have been obtained in the experiments made with the other forms of cloth filters described in the paper led him now to doubt whether after all the bag so crumpled up was as good a filter as it would be if the surface were all free and fully extended.

Mr. PERRETT mentioned that he had tried an experiment with bags of 6 ft. circumference, put into the same stockings that were used for the 4 ft. bags, and they did not filter half as much again as the smaller bags, on account he presumed of being more crumpled up.

The PRESIDENT observed, with regard to the disc filter shown in Fig. 15, he remembered that the engineer to whom he had been apprenticed, Mr. Hague, who had had a great deal to do with sugar machinery, had devised a filter exactly like it, but without the centrifugal cleaning, which had not occurred to him : in Hague's filter a number of discs, furnished with radii and covered with filter cloth above and below, were strung upon a vertical spindle of a cruciform section. The boss of each disc was a gunmetal collar having holes between the radii, which conveyed the filtered juice into the vertical channels of the cruciform spindle. Mr. Hague introduced these filters as an improvement on the bag filters, his object being to obtain a larger surface in a given space. But these disc filters had to be taken apart after a few hours and washed, and they would not be applicable therefore to the large requirements of a bath. He could not help thinking that the author's suggestion of centrifugal cleaning would render them perfectly suited for bath purposes, and also probably by future improvements for purposes like sugar filtration.

He had been much struck by the extremely clear and lucid explanation given by Mr. Hawksley of the theory of filtration and of the way in which filtration differed from mere straining ; and he wished that Mr. Hawksley or some one else had solved the problem advanced in the paper, why water filtered through the stone filter behaved differently in respect to putrefaction from water filtered through a bag. That was a question which would remain for consideration, and perhaps some day a solution of it would be arrived at.

He moved a vote of thanks to Mr. Perrett for his paper, which was passed.

The PRESIDENT proposed a vote of thanks, which was passed, to the Council of the Institution of Civil Engineers, for their kindness in having again accorded the use of their meeting and council rooms. He knew however he was speaking the views of that body when he said that nothing gave them more pleasure than to render to all cognate institutions meeting in London every facility which their house in Great George Street enabled them to afford.

The Meeting then terminated.

FLOATING SWIMMING BATH.

Fig. 1. Side Elevation.

Fig. 3. Longitudinal Section of Hull.

Fig. 5. Plan of Hull.

Plate 20.
Transverse
Fig. 2. Section
at end.

Fig. 4. Section at centre.

Fig. 6. Transverse Section of Bath.

Fig. 7. Transverse Section of Machinery Room and Filtering Tanks.

Fig. 8. Plan.

(Proceedings Inst. M. E. 1875.)

Fig. 9. Plan of Mooring Guide.

Fig. 13. Stationary Cylindrical Cloth Filter.

Fig. 14. Centrifugal Cloth Filter.

Fig. 10.

Stone Filter.

Fig. 11.

Fig. 12.

Bag Filters.

Fig. 15. Stationary Disc Cloth Filter.