SIALKOT WATER-SUPPLY.

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General Description.

Sialkot is situated in the north-east of the Punjab. The population according to the census of 1901 was 45,574, and of 1911, 47,457; this includes the suburbs of Rangpura and Heranpura to the east, Nekapura and Hamzaghouns to the south-east, and Hajipura to the south-west. As the increase in population has been small, the total was taken as 50,000 for the purposes of the water-supply scheme. In addition to the above, the Civil Lines, including the Police Lines, litigants at the courts, and the proposed Central and Tuberculosis Jails, have been provided for—

	Gallons.
Sialkot City and suburbs, 50,000 at ten gallons per day	500,000
Civil Lines including the Police ...	10,000
900 litigants at the various courts at five gallons a day	4,500
Proposed Central and Tuberculosis Jails 2,000 at fifteen gallons per day ...	30,000
Total ...	544,500

A site to the north-west of the city was selected, and as it was considered advisable to secure extra land for possible extension, 4·62 acres in all were acquired at Rs. 2,519 per acre. The extra land was most necessary, as it was expected that the land surrounding the site would be built upon during the next decade. The wells are close to the city, but no fear of contamination need be entertained as the water is drawn from a deep seated stratum. The highest level from which water is taken is sixty-seven feet below the ground surface, and the average depth of the top of the strainer tubes, from which the supply is taken, is seventy feet.

The supply is drawn from six "Ashford" five inch strainer tubes sunk 122 feet apart. The tubes differ in length to suit the

strata through which they pass, the total length being 350 feet. Each is calculated to yield approximately 11,250 gallons per hour, so that five wells will give 562,500 gallons in a ten hours day, as against 544,500 gallons required. One well will ordinarily be kept in reserve.

The test yield of the five inch strainer tube in well No. 1 at a six foot depression head was 12,963 gallons per hour, and at a four foot depression head 10,761 gallons, and it was on the results of this test that five inch strainer tubes were adopted for the remaining five wells, as a twelve foot head of depression could be pumped if necessary.

The strainer tubes pass through a stratum of coarse sand, in which numerous small stones are found. This stratum is of a thickness varying from about 50 to 60 feet and is 62 to 125 feet below the ground surface. It varies in quality at different depths, but taken as a whole may be described as an excellent water bearing stratum. As can be seen from the section, however, the subsoil differs considerably from the original trial boring, showing how quickly the strata may vary at any site.

The strainer tubes discharge into sumps four feet in diameter, from which the water is drawn by seven inch diameter steel suction pipes, which are carried in brickwork barrels three feet in diameter into the main suction pipe barrel. The suction main increases in size as it passes each well, until it enters the pump sump 39 feet below ground, where it is sixteen inches in diameter at the connection to the pumps. The main suction barrel is at an average depth of 40 feet below ground level, the water level being 41¼ feet below the ground level or 1¼ feet below the floor of the barrel. There is a manhole in the barrel opposite the entrance to each sump. The pumps are in the centre of the barrel's length, which is given a rise of 1 in 300 from both ends. The pumps force the water into the rising main, any amount pumped in excess of the demand being discharged into a brick balancing tank situated in the old fort. This tank holds 303,265 gallons, or a little more than half a day's supply, and this is intended to provide any extra demand on the system during the hours of the greatest draw off. The cast iron distribution mains vary in size from three to fourteen inches, and cover a distance of over 9½ miles.

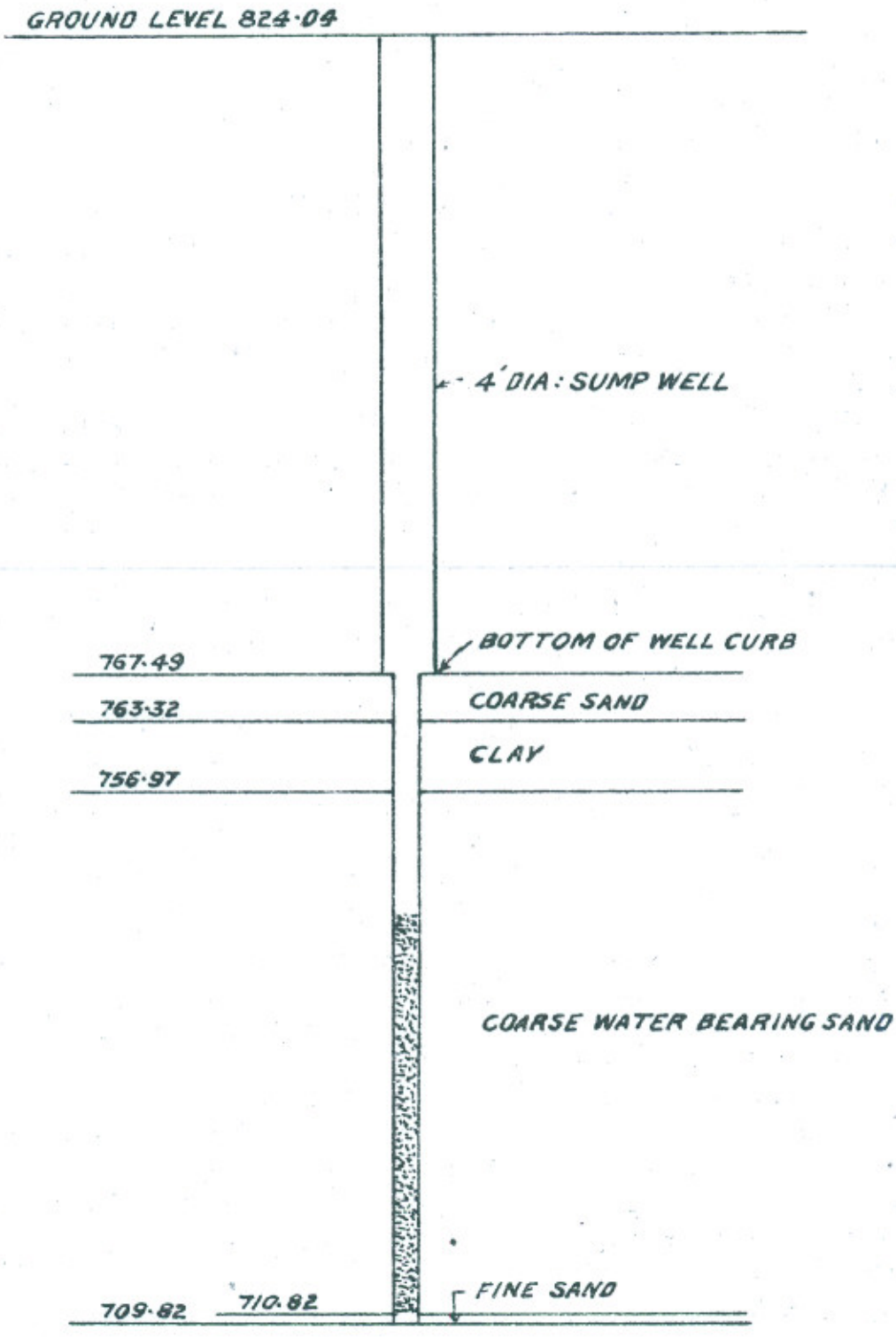
Sump Wells.

The sump wells are constructed of specially moulded bricks set in lime mortar, a vertical cement bond being given the whole

— SIALKOT WATER WORKS —

— SUB-SOIL SECTION OF WELL No I —

— SCALE 20' = 1" —



NOTE:- DOTTED PORTION INDICATES STRAINER TUBES AS ACTUALLY FIXED.

height of the sump as a protection from subsoil water. The diameter of these sumps is four feet, with steining 1½ feet in thickness, while the average depth is 56 feet from the top of the plug to ground level. The brickwork is constructed on kikar wood curbs of 1½ feet depth, and one inch diameter tie rods fifteen feet in length have been provided through the brickwork. The sumps have been plugged at the bottom with four feet of concrete.

Suction Main Barrel.

According to the original design, the invert of the barrel for the suction main was to have been built 29 feet below ground and 12¼ feet above normal water level, but on consideration of the difficulty experienced at the Amballa waterworks, where it was found necessary to subsequently lower the pumps, it was decided to substitute brick for the lime concrete barrel, and to lower it to an average level of only 1¼ feet above water level in order to avoid the possible chance of later on having to lower the pumps and main, owing to a fall in the water level. The actual suction lift on the pumps at the greatest head of twelve feet will only be 19·22 feet, so that any possible fall in the water level cannot affect their capacity. The barrel is constructed of four half-brick rings, and as it had to be laid at water level, cement mortar was used ; no hydraulic lime being obtainable.

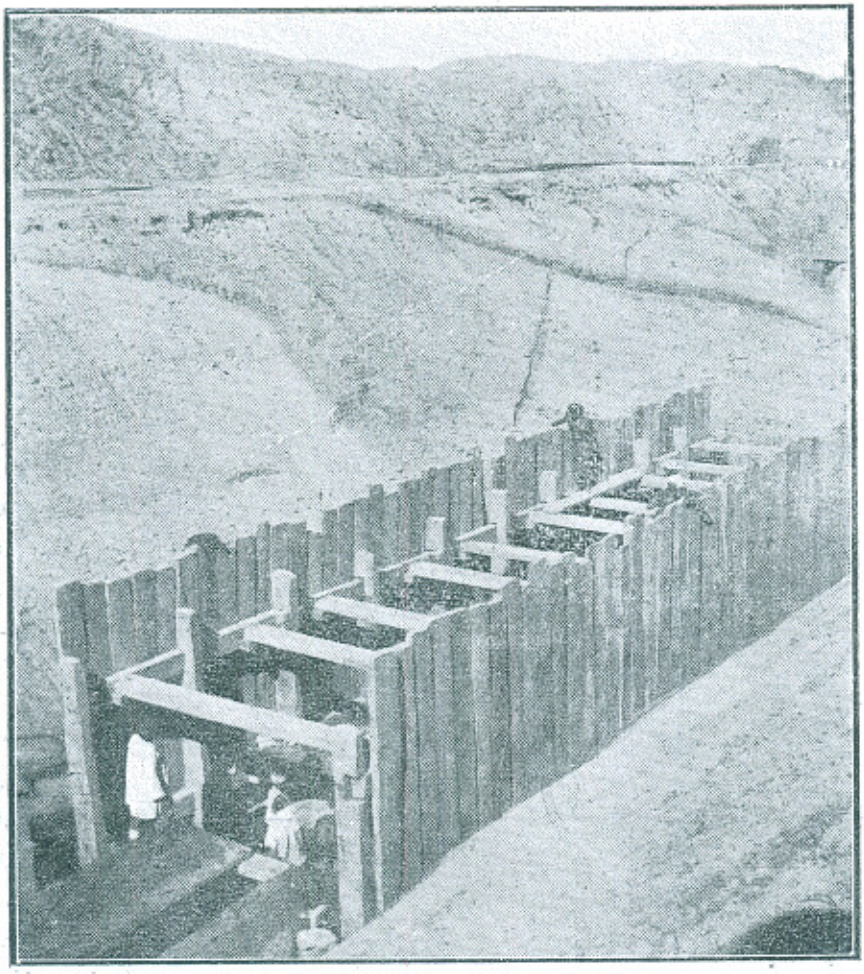
The barrel is four feet internal diameter, thus giving ample room for workmen to examine the suction main. Its construction at a depth of forty feet below ground was the most difficult portion of the whole work. The strata above the bed of the barrel consisted of twenty-one feet of stiff and sandy clay, and below this, twenty feet of fine and coarse sand. For a portion of the trench a layer of kankar lay between the clay and the sand which made the working easier and less dangerous The clay was cut back to a slope of 1 to 1 after several attempts at steeper slopes had been unsuccessful. The lower twenty feet of sand was timbered.

Heavy rain fell during construction, and delays from slips were numerous. The shoring was put into position as follows. The upper stratum of clay having been cut back, the sand was cut down vertically a few feet, and the shoring was then erected in an upright position, by first erecting and bolting together the framework, and then nailing on the planks where they would not stand by themselves. The whole was then gradually sunk by excavating the sand from inside.

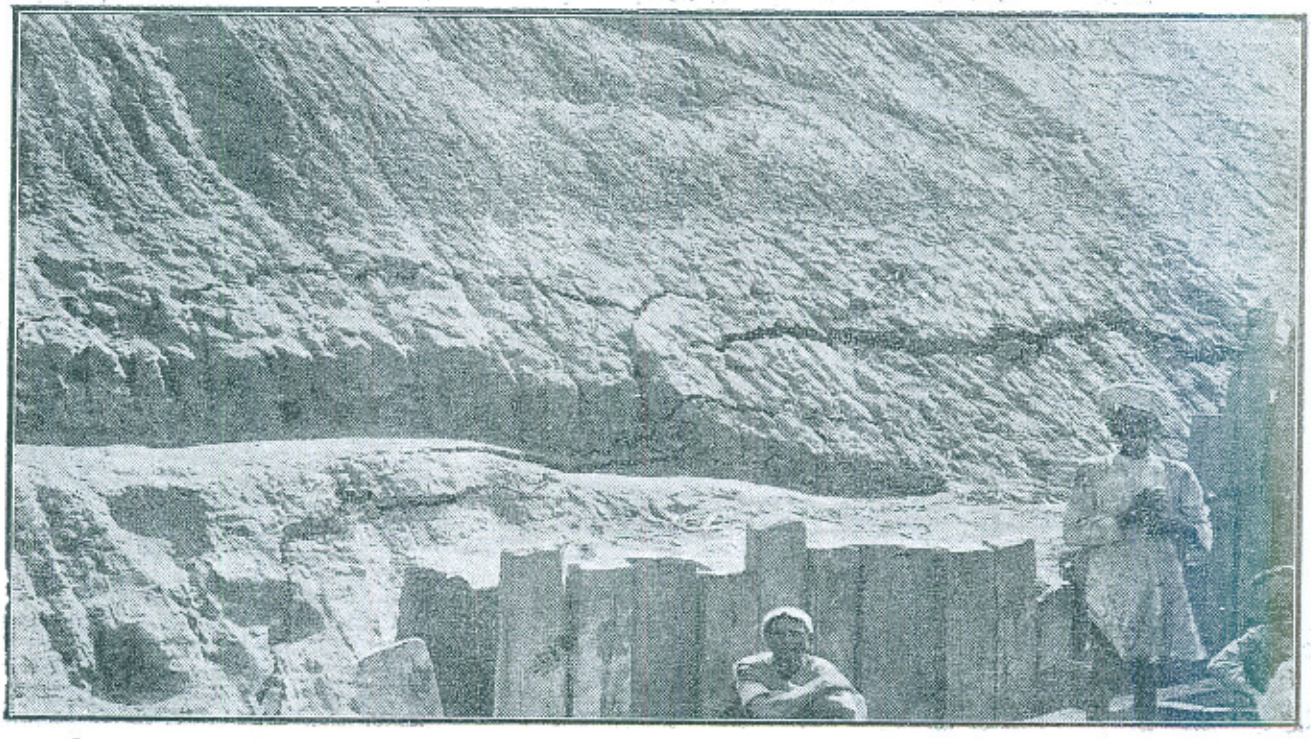
The shoring was bolted together as it was fitted, and thus formed a protection, inside which the men worked free from danger. It was constructed in two heights each of ten feet, and in ten feet lengths, of which three to five lengths were sunk at a time. This took from a week to ten days owing to the confined space the men had to work in. Except at the edges, the upper stratum of stiff clay generally stood firm, and the shoring, having been sunk to its correct depth and packed behind with well watered clay and sand, supported the vertical face of sand and the clay above it. To have shored in the ordinary way by using timbers to suit exact widths of trench would have been costly, and by the method adopted the minimum amount of timber was lost in cutting. The first shoring having been sunk, the second was sunk inside it, until about four to five feet of sand excavation remained to reach the bottom of the concrete foundation where it was found that—the sand being damp—it was possible to work without shoring, and brick pillars were built under the feet of the framed uprights to prevent further sinking. These pillars were one brick square and were carried below the concrete level. The unsupported height of sand was then cut to template to receive the concrete bed for the barrel. It, however, fell in at different points, leaving hollows at the back of the shoring, and where this happened $2\frac{1}{2}$" planks had to be inserted below the lower shoring and the hollow made good by filling in more earth or sand from above. For this purpose earth was found preferable, since, when watered, it swelled and kept the pressure better. Reeds and grass were also used to prevent the sand working through at points.

When the pressure at one side was not taken up sufficiently by the shoring the earth behind would crack, and at times would work into the cutting, displacing the shoring; one side sinking while the other retained its proper position. When this happened it was most difficult to make the shoring safe. Extra planks were filled in at the back to prevent earth falling in over the top of the upper shoring, while the footings of the latter were supported to prevent further sinking. When an extra heavy slip occurred the shoring was strengthened by extra timbering. The earth along the slope almost invariably developed slight cracks when the lower portion subsided, but this was only what might have been expected, as it was almost impossible to get the shoring to take up the proper pressure by simple packing behind. The sinking, however, tended to assist the shoring to take up

SIALKOT WATER-SUPPLY.



Sinking upper shoring into position.



Cracks in earth slopes.

this pressure, provided the sand did not work out below into the trench, and when necessary, earth was packed in again over the portion which had slipped.

The barrel was built in lengths of twenty-five to fifty feet at a time. As each length was completed, the lower shoring, except for the last length which was left in position for connection to the next lot, was opened in sections, and when the complete length had been removed the space was filled up with sand to the level of the bottom of the upper shoring, this being then removed in a similiar way. While the lower shoring was being removed the men worked in comparative safety, as they had the upper shoring to protect them. The great danger was in the removal of this upper shoring, as the earth stratum above, which had cracked, had a tendency to fall off into the trench in great masses. In places some timbers had to be left in the ground, the risk of extraction being too great.

The shoring for the construction of the connecting barrels to the sumps gave considerable trouble, owing to the difficulty of joining up with the main barrel shoring, but this was successfully overcome. While excavating in front of the sumps it was necessary to support them, lest the pressure of the earth behind should crack them, and this was done by wedging the shoring tight against the brickwork. In many cases, particularly in the construction of these connecting barrels, it was found necessary to roof in the shoring for fear of the earth breaking away above and falling into the trench.

The most difficult portion of the work was the construction of the connecting barrel to the engine house, at right angles to the main barrel. This barrel connected into the pump well, and as tunnelling was impossible, it was necessary to carry it through in a minimum width, so as not to unduly disturb the soil for the foundations of the engine house. The cutting was, therefore, taken down vertically, twelve feet in breadth, timbering from the trench being used to support the sides. As the foundations of the engine house, however, were to be $8\frac{1}{2}$ feet below ground, this much was sloped off, allowing three sets of shoring to reach the desired level. Before starting this excavation, the sump for the pumps had been sunk and thus formed a support for one end of the trench, while the excavation of the main barrel had exposed the other end. Great care had to be taken in the extraction of this shoring, which was done in the same manner as in the main trench.

All the filling was done here with sand, as the foundations of the engine house had to be built on it ; and when the filling was in progress a local water-course was turned on to it to ensure proper settlement.

Wells and Guide Pipes.

In all, six tube wells were sunk—five to give the necessary supply of water, and one in reserve. Each well was capable of supplying approximately 11,250 gallons per hour with fifty feet of five inch diameter strainer, and although the strainer was intended by the patentee to be drawn from direct, it was considered advisable to introduce sumps for the following reasons :—

(1). The yield of each well could be tested.
(2). A constant or equal head could be kept on the wells.
(3). Sand would be prevented from entering the distribution mains.
(4). Collection of sand, if any, could be observed in the tubes.
(5). The sumps would facilitate washing out the tubes if they should get blocked with sand.

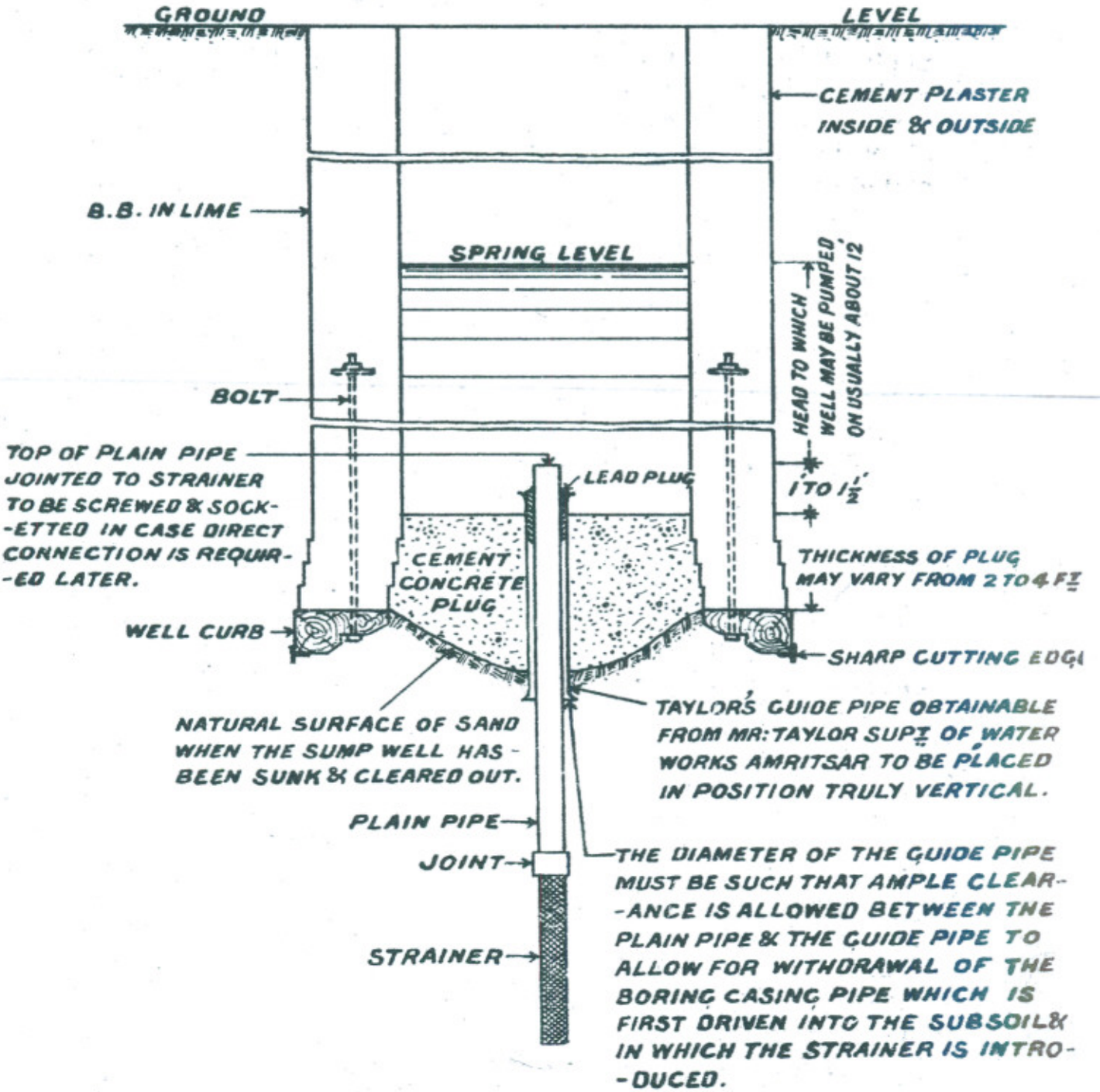
Each strainer tube accordingly delivers into a sump from which the water is pumped into the suction main.

Before sinking the strainer tubes a twelve inch cast iron guide pipe was fixed in the centre of each sump, and the sumps were then plugged at the bottom with about four feet of concrete composed of cement, sand, and $\frac{1}{2}''$-$\frac{3}{4}''$ stone ballast, in the proportions of 1 : $1\frac{1}{4}$; $2\frac{3}{4}$, which was deposited round the pipe by means of a box with a false bottom.

This guide pipe was kept in position by iron cross guides while the concrete was being deposited. As soon, however, as the casing tubes were passed through the guide pipes, it was found that the latter had, in two sumps, got out of plumb, and it was impossible to sink the casing tubes through them. The work had been done under fourteen feet of water, so that it was difficult to see where the guide pipes had actually been placed. The plugs in these sumps had to be drilled through with an iron rail, repeatedly raised, and dropped over the same spot, while a diver removed the debris. The casing tubes were then lowered through the holes and sunk.

While trying to withdraw one of the casing tubes through a guide pipe, which was only slightly out of plumb, a socket fouled the bottom of the guide pipe, and in endeavouring to release it, the

— STANDARD DESIGN —
— FOR —
— CONNECTING STRAINER TUBE INTO SUMP WELL —
— SCALE 4'=1" —



upper portion of the casing tube became detached, owing to the socket not having been properly screwed up, leaving the lower portion stuck in the ground. The same loose joint had fouled the strainer, and as it was impossible to release the latter, the two were being drawn up together.

To free this casing tube, a hollow taper tool was made to screw on to the end of another length of casing tube and large enough to pass over the strainer. A screw thread was cut just above the tapered end, while higher up was a projecting collar. The tapered end permitted the tool being readily inserted, over the strainer, into the fouled casing tube, and while it was being forced down and screwed home the projecting collar, bearing against the inner face of the guide pipe, gradually forced out the casing tube till it was clear of the edge and once more nearly concentric with the guide pipe, when it was easily withdrawn together with the strainer. The latter was only slightly damaged and was re-used.

The lesson to be learnt from these mistakes is that plugging should never be done until the strainer has been sunk and is ready in position. The guide pipe is of no practical use except to allow of the strainer being withdrawn at a later date, if necessary, for renewal or cleaning, without interfering with the plug at the bottom of the sump. The strainer being in position, it is quite easy to slip the guide pipe over it, while the strainer will assist in keeping the guide pipe vertical while the concrete is placed round it. The author would suggest the use of Mr. Taylor's guide pipe, as this can be easily lowered over the head of the strainer, and the lead plug hammered in, after which the concrete can be placed in position. This pipe has the advantage of being curved at the ends, and so preventing the sockets of any tubes which may afterwards be inserted from catching during extraction.

Casing Tubes.

Two patterns of casing tubes were used on the work; namely: socket jointed tubes of $7\frac{1}{8}$" internal diameter at joint, and cressed and screwed jointed tubes of $6\frac{3}{8}$" diameter. The latter are preferable, as there is less friction in driving and extraction and no chance of their catching under the edge of a guide pipe, if one exists. The socket jointed pipes, however, are the stronger tubes, and where the depth is small and no guide pipe exists these are really better. Circumstances must, however, regulate the choice. No difficulty was found in driving or extracting these tubes where the guide pipe was vertical, as the depth was only 88 feet exclusive of the depth of the

sump. The joint ring of a five inch strainer is six inches in diameter, so that for ease in working, a tube eight inches internal diameter is preferable, as it gives more room.

The driving of the casing tubes was carried out with the aid of sleepers loaded with sand bags clamped crosswise on the tube. This loading is only necessary when the tube refuses to go down. To facilitate sinking a sand pump can be used to remove the sand. It was found that not more than four feet of sand rose in any tube during sinking, so that casing never had to be carried much below the depth at which the strainer was to be located, but the quantity of sand in a casing tube depends on the class of strata, and also on the depth to which the boring is taken. In the present case the sand was of good coarse quality, and the deepest boring about 90 feet, so that the casing tubes having been sunk to a few feet below the depth at which the strainer was to be located, the latter could be lowered into position.

Strainer Tubes.

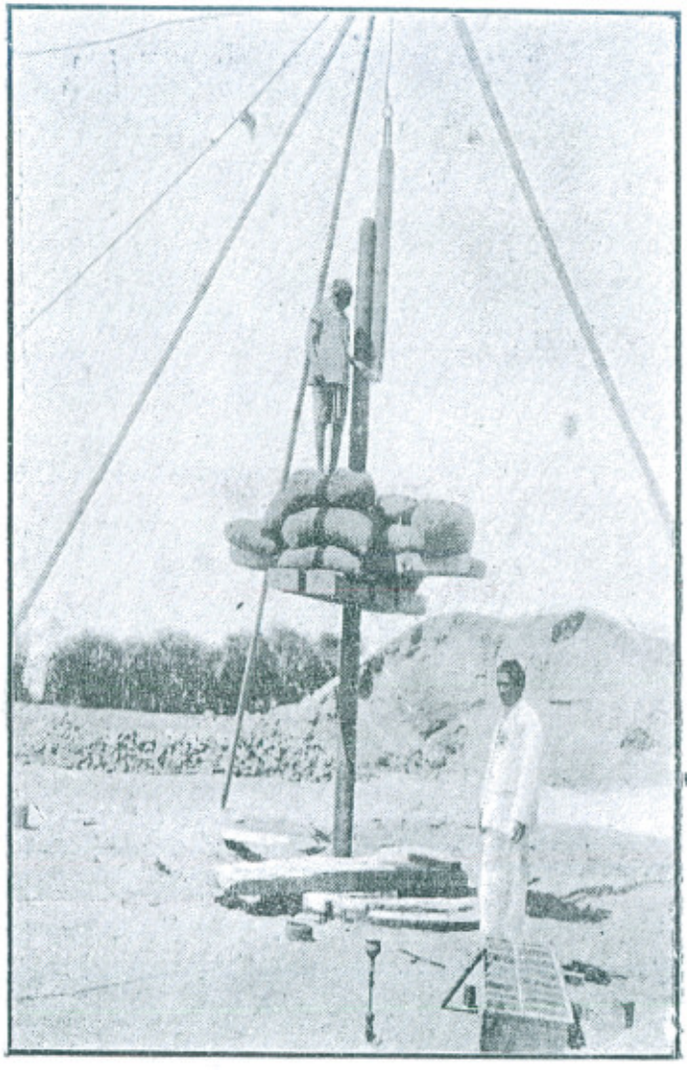
Mr. Ashford describes his strainers as being wound round with fourteen copper wires to the inch, with a spacing between the wires of ·007 of an inch. The section of the wire is as sketched. This gives a flat exterior with a slit between the



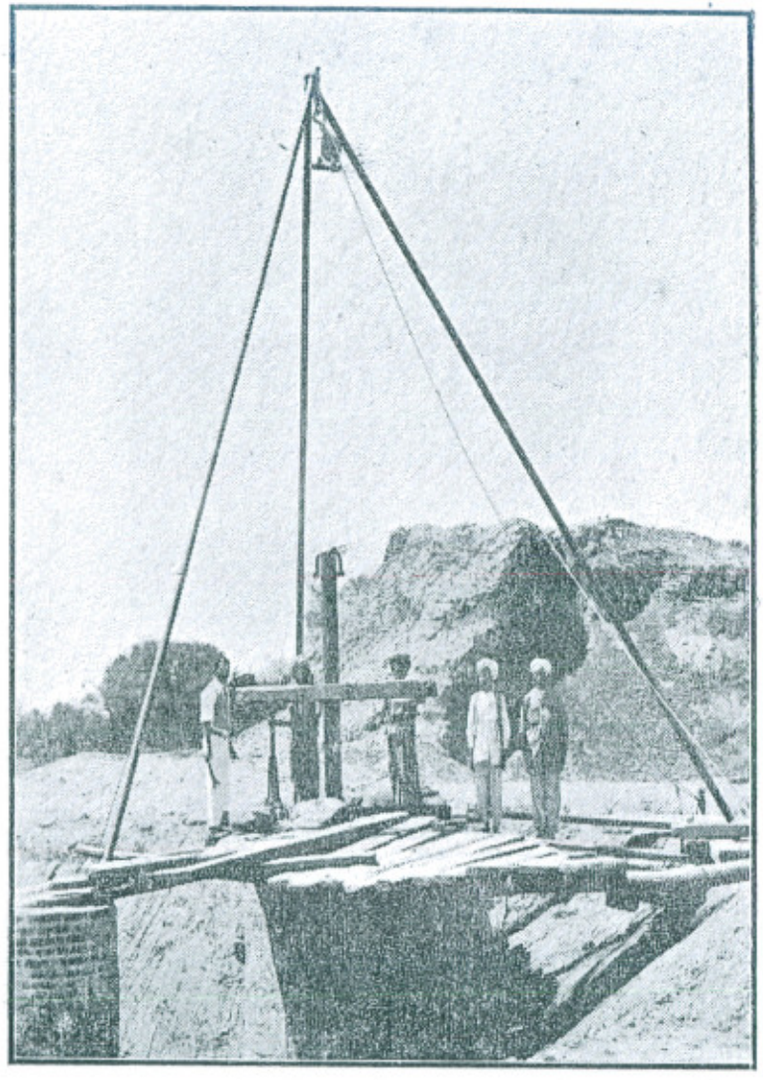
SECTION OF COPPER WIRE

wires opening inwards. The purpose of this design of wire section is to reduce the prospect of choking to a minimum, and experience proves it to be very effective. The joints are made with a split ring ; this joint is slightly flexible and allows for any deviation of the casing tube from the straight, which is sometimes found to occur in sinking. The bottom of the strainer tube is closed by a flange attached by a split ring.

The lowering of these strainers into position was the most important portion of the whole scheme, because the amount of water obtainable depended on their soundness and on the



Sinking the casing tube.



Withdrawing the casing tube.
(A steel wire passes inside the tube to support the strainer and prevent it sinking beyond its proper position.)

accuracy with which they were located with reference to the different strata. The strainers were well wound, but nevertheless the spacing of the wires sometimes opened, and it was very necessary to adjust them with a penknife before lowering. The wires were also sometimes loose, but it was usually possible to tighten them by tapping the centre of the span between their points of support on the framework. Where the spacing could not be adjusted, a little solder had to be used to fill the gaps.

It is important to see that the right end of the strainer is upwards, as there are apertures to allow of the passage of the water in an upward direction, which are only given twice in each five foot length, one lot about half way up and the other a few inches from the top.

Accurate sections having been taken, the correct lengths of strainer were located in the water bearing strata and plain piping interspaced where clay or other undesirable stratum would be encountered.

A wash out system has also been installed, by means of which the tubes can be scoured by forcing the water under pressure in the rising main back through a length of two inch piping to the sumps and thence by a $1\frac{3}{4}$" hose into the strainer tubes.

Withdrawal of Casing Tubes.

The strainer having been lowered into position, the casing tubes were raised by means of screw jacks working against timber clamped to the tubes. During this process, it was found necessary to support the strainer in position by slinging it on a steel wire, but the support was not found necessary after the casing tube had been withdrawn about thirty feet.

Having withdrawn the casing tubes, the space between the guide pipe and the plain pipe was plugged with cement concrete, lowered into position by means of a twelve inch pipe, placed round a temporary five inch pipe attached to the top of the strainer tube at the time of sinking, so as to bring it above the water level in the sump. The concrete was then let down through this twelve inch pipe, until the guide pipe in the concrete plug was nearly filled, when neat cement, made up in muslin bags, was dropped into position over the head of the temporary five inch pipe, thus completing the joint. The temporary pipe was then unscrewed and the top of the strainer plugged with a wooden plug until required.

Recuperation Tests on Well No. 1.

The strainer tube was located in most excellent water bearing strata, of which samples had been sent to the Superintendent of the Central Workshops, Amritsar for test, and his report was most favourable. The strata were of very coarse sand for the most part with large stones measuring up to two by four inches, while the sand was good sharp gritty stuff. In all forty-five feet of strainer were located, and the tests made extended over a week.

As the pumping plant available was unable to reduce the level of the water more than about nine inches, the tests were carried out by plugging the head of the strainer and pumping the water down to about two feet below the level of the head to be tested. The plug was then withdrawn, and the water allowed to rise to the point from which the recuperation was to be calculated. This plugging was done by a diver hammering a wooden plug into the head of the strainer and attaching a bamboo which reached above the water level. As soon as it was required to remove the plug the diver tapped it in order to loosen it while it was held in position by a man above with the bamboo to prevent it being pushed up ; it was then quietly removed, and the water let in. This, however, came in at such a pace that it was difficult to catch the needle on the scale at the right moment and it was allowed to rise slightly before a note was made.

From the recuperation tests given below it will be seen that the recorded yield was considerably in excess of what was anticipated, but these tests cannot be taken as conclusive, as the pumping was not continuous, and therefore the actual yield cannot be definitely calculated ; the figures are in gallons per hour and are very encouraging.

Results of Recuperation Tests.

Head in feet.	1st day.	2nd.	3rd.	4th.	5th.	6th.	Average.
2	5,252	5,302	5,302	5,302	5,519	5,434	5,352
3	7,209	...	...	...	...	..	7,209
4	10,129	9,744	10,276	10,276	10,056	10,868	10,761
5	...	...	...	...	...	...	...
6	...	12,963	...	...	...	...	12,963

A little sediment was drawn during a couple of these tests which, when allowed to deposit in a glass, appeared to be clay. It was not possible owing to its fineness to classify it as sand.

Trial Borings.

A comparison of the original trial boring with the section of the strata in which the tubes were actually located, shews a considerable difference, and the author is of opinion that any trial borings taken should, as far as possible, be on the exact spot where the strainer is to be sunk, and that a complete boring should be made for each well proposed in order to find the best possible strata to locate the tubes.

In the case under consideration it was found that the strata passed through in well No. 6, were not so good as those in well No. 1, and it would have been worth while to have taken extra borings originally, and sunk well No. 6 to the north of No. 1. From the section it can be seen that the strainers were located in a bed of excellent sand over fifty feet in depth, but even in this bed the sand varied considerably in quality. The great difficulty of describing the class of sand can really only be got over in one satisfactory way and that is by testing it for its water bearing capacity, and not by describing it as "coarse sand," "fine sand," etc., etc., which gives no accurate data to work upon, as one person's opinion as to what fine sand is, may not agree with another's.

Reservoir.

It was originally intended to provide a wrought iron tank in the old fort, but this was considered to be objectionable, as the water would be liable to heat up too much in the hot weather. It was, therefore, cancelled in favour of a brick reservoir or, more correctly, a balancing tank, which has been constructed in the ground at the highest point of the fort. This tank was constructed in two compartments, and holds 303,265 gallons, or a little more than half a day's supply. It was built on made earth, which was found to be well consolidated when the excavation was cut. Sand piling was resorted to, in order to make the foundations quite safe, but otherwise the construction of the work does not call for many remarks. The compartments have separate intakes, overflows and scours so that either can be used independently of the other. The overflows and the scours, as soon as they emerge from the slope on the side of the tank, are carried away in a concrete drain and eventually

find their way into one of the city sullage drains. The roof of the tank was constructed of 4½ inch reinforced concrete slabs, one over each compartment, with expanded metal reinforcement ; the concrete being of Sangla stone, etc., in the usual proportions of one cement, two sand, and four stone. An expansion joint was given to allow each slab to expand outwards on all sides, the slab resting on the walls on a thin layer of equal parts of asphalte and coal tar over a layer of cement plaster, thereby allowing the slab a smooth surface for expansion. The interior of the tank was plastered with a half inch layer of cement, in which was mixed eight lbs. of " Medusa " waterproofing compound to each barrel of ement. The result of this waterproofing must be watched, as no information as to its efficacy can be given at present. The tank was covered with twelve inches of earth and the whole turfed, thus ensuring cool drinking water. The site was enclosed by a strong iron railing.

City and Suburbs Distribution.

Owing to the lowering of the level of the balancing tank, it was found necessary to increase the diameter of the mains in the distant portion of the distribution, to make up for a loss of about eighteen feet static head, and the lowest static head in any part of the distribution is now about twenty feet. The size of the mains has been calculated fifteen per cent. in excess of the actual requirements, while in sparsely inhabitated areas twenty-five per cent. has been allowed to provide for any future increase in the population.

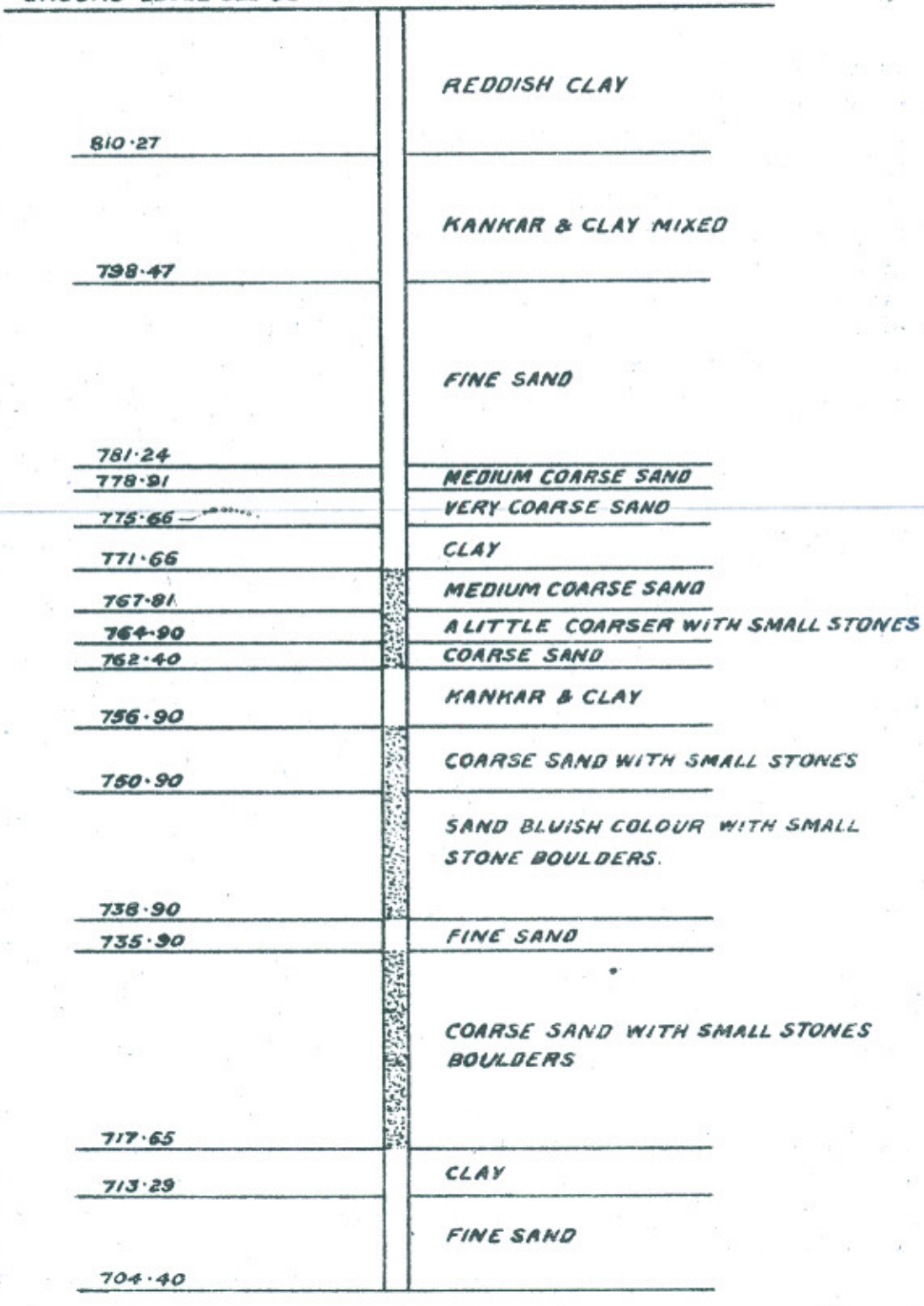
The distribution mains have been calculated to allow of a maximum draw off of forty gallons a minute per thousand of the population. They vary from twelve inches to three inches in diameter, the larger running along the main streets and connecting up by three inch pipes through the principal lanes. The total system covers 9'54 miles.

The rising main, which is nothing more than the main distribution pipe, is twelve inches in diameter up to the point where it takes off to the tank, where it rises up at a steep slope and has been increased to fourteen inches. Any water pumped in excess of the demand is carried into the tank to wait until the demand is in excess of the supply, when it flows back into the distribution system by gravitation.

— SIALKOT WATER WORKS —

— SUB-SOIL SECTION OF ORIGINAL TRIAL BORING —

— SCALE 20'=1" —



NOTE:- DOTTED PORTION INDICATES PROPOSED POSITION OF THE STRAINER TUBES.

Standposts and hydrant standposts have been fitted in the proportion of one to every 344 of the population, there being eighty-four of the former and sixty-seven of the latter, while the hydrants as far as possible have been fitted at the highest points of the streets to allow of flushing the drains on either side. Neat brick in lime and cement platforms have been built under each standpost with a raised platform suitable for resting a ghara or mashk, according as the mahalla in which it is situated is populated by Hindus or Mohammedans.

A certain amount of difficulty was experienced owing to the narrowness of the lanes, in which these posts were fitted, in getting altogether suitable sites, however, the Municipal Committee can always tap the mains and fix additional hydrants if required.

Engine House and Pump Well.

Before the foundations of the engine house could be put in hand, the well for the pumps had to be sunk, but owing to the depth at which it was necessary to place the pumps in order to avoid any possible chance of further lowering at a later date, it was a problem how they could be housed at such a depth (38 feet) below ground. Anything in the shape of a rectangular construction, necessitating either very wide excavation, or else very high shoring, to enable the construction to be put in hand, was objectionable, as this would have undermined the foundations of the engine home to an excessive degree. It was, therefore, decided to use an eighteen foot diameter well. This was sunk with the steining in three thicknesses according to the depth, the lowest 22 feet being 2 feet $7\frac{1}{2}$ inches thick, the next $11\frac{1}{4}$ feet, $2\frac{1}{4}$ feet thick and the top $8\frac{1}{2}$ feet, $1\frac{7}{8}$ feet thick. The excavation, prior to the sinking, was carried down to a depth of 16 feet, which only left $25\frac{1}{2}$ feet of actual sinking. A layer of clay had first to be pierced, but as soon as sand was reached at a depth of about twenty feet below ground the sinking proceeded at a rate of one to two feet a day. The bottom of the curb when sinking was complete, was just below waterlevel.

During the sinking of this massive sump a band of kankar was encountered which threw the steining out of plumb and cracked the brickwork. Excavation, however, had been commenced close to this point for the connecting barrel from the sump to the main barrel, leaving one side of the sump accessible; and the sinkers bored a tunnel from this excavation round the side

of the sump to the obstruction. This was fortunately not far off and, when the kankar was cut away, the sinking proceeded, and the steining gradually closed at the cracks without being materially affected as the work was fresh and in lime mortar. In order to hold the steining together, when the cracks appeared, flat iron bands had been tied round the sump where the cracks were worst, passing at intervals over other iron uprights to distribute the pressure. Besides this, a circular band was laid on top of the brickwork, and over this band two feet of brickwork were laid in cement. When the sinking was finished, the excavated portion around the sump was filled in with sand.

As the walls of the engine house passed close to this made ground, the foundations were laid in cement concrete, reinforced with three old rails on each side, and where the excavation for the connecting barrel had been made, the same precautions were taken. This proved successful in every way and no sign of any settlement was noticed, though the weight per foot on the foundations was about a ton.

The engine room is spacious and airy, being 40¾ feet by 28 feet. Both the engine and the boiler houses are roofed with "Eternit" tiles on one inch planking. The chimney is sixty feet high, has a smoke way of 3·4 square feet, and is capable of steaming both boilers simultaneously.

Pumping Plant.

The pumping plant, supplied by Messrs. James Simpson & Co., consists of duplicate sets of horizontal surface condensing, central exhaust, single cylinder engines, driving vertical double acting Worthington pumps direct, by prolongation of the piston rods through bellcranks. The pumps were placed in the well forty feet below the engine house floor. The principal dimensions are:—

Steam cylinders	21″ diam.
Length of stroke	24″
Main pump plunger	11″ diam.
Length of stroke	18″

The engines run at forty strokes per minute, and each engine and pump is capable of raising 566,000 gallons, in ten hours, against a head of 145 feet. These engines are known as the "Una Flow" type, having steam admission valves of the "drop" type fitted on each end of the cylinders.

The exhaust release is effected through ports in the centre of the cylinder and is controlled by the piston at the proper moment. This arrangement reduces condensation to a minimum as, owing to the steam always flowing in one direction, the exhaust steam passing from the cylinders without coming in contact with the high temperature surfaces at the inlet ends and thus eliminating as far as possible any drop in temperature to the ingoing steam at each stroke, greatly reduces the steam consumption or "duty guarantee", which in these engines is 16 lbs. of steam per pump horse-power per hour. The boilers and superheaters are by Babcock & Wilcox, the boilers having a sheating surface of 401 square feet and the superheaters 70 square feet. The main pumps are of the internal plunger and ring multiple valve type, double acting on both suction and delivery. The economiser has twenty four tubes and is of the standard design manufactured by Messrs. Green and Sons, Ltd.

APPENDIX.

Actual Cost of the Work as compared with Contract Rates.

A note of the cost per foot sunk at which the contractors carried out the work of sinking the last two tubes was made and compares with the contract rates as follows :—

Actual Cost per foot.	Rs.	a.	p.	*Contract Rates per foot.*	Rs.	a.	p.
Sinking the eight inch casing tubes ...	0	15	6	Sinking and extracting the casing tubes together with jointing and lowering the strainer tubes for the first fifty feet ...	7	0	0
Joining and lowering five inch strainer tubes ...	0	4	6	For any additional depth ...	5	0	0
Taking out the eight inch casing tubes ...	0	5	3				
Total cost per foot sunk	1	4	9				

The contractors were paid separately for the carriage of their tools and plant.

The strata passed through at Sialkot were almost all sand, and this accounts for the cheapness of working. The cost of the contractors' foreman is also not included in the above, as he was only on the work for a short time. Working with daily labour his place would be taken by the Sub-Overseer in charge, while the time of completing the work would probably have been much reduced.

Pumping Data.

After nearly a months working of the scheme, recuperation tests made with a two feet head on all wells gave 5,204 gallons an hour as compared with 5,352 gallons obtained during the tests made originally on well No. 1, while at three feet head the yield was 7,532 gallons as compared with 7,209 gallons an hour originally obtained. The depth of sand found in the tubes varied from 5½ inches to 3'—4" the average depth being 1'—5".

Records taken over twenty-two days show the following :—

Average head pumped 3·86 feet.

Average pumping hours daily 4 hours 33 minutes.

Average water pumped daily 232,895 gallons.

Average quantity per hour per well 9,952 gallons.

Average daily consumption in city, etc., 232,213 gallons.

DISCUSSION.

MR. HEARD said that his paper required very little introduction. He had not written it with the intention of dealing with the theory or design of tube wells, about which he had a limited knowledge, while Messrs. Ashford and Brownlie had on previous occasions given them the benefit of their researches in this direction. He had merely dealt with the construction of works, about which at the start he knew very little, in the hope that the experience gained would be of some use to others.

The work was commenced in November 1915, and the opening ceremony was performed by His Honour the Lieutenant-Governor in August 1915. The cost was about five lakhs for a population of 50,000, or about Rs. 10 per head, which was not a large sum.

A serious outbreak of cholera had occurred in 1912 in Sialkot, and it was hoped that a pure water supply had removed all fear of another outbreak. The Commissioner, in his address at the opening ceremony, pointed out that the history of modern India abounded in examples of the benefits conferred on the people by a pure and bountiful water supply. The scheme was the last of a series, which dated back from a considerable number of years, but which, owing to their prohibitive cost, had to be put on one side, one after the other, until the present comparatively cheap system of supply had been evolved.

The Sialkot waterworks were unique in that they were the first large supply to be installed in the Punjab, if not in India, which was entirely dependent on tube wells, although other supplies, such as Ambala and Amritsar, had been augmented by the insertion of strainer tubes in existing percolation wells. Sialkot was extremely fortunate in that the stratum from which the supply was drawn was one of the best hitherto found in the Punjab.

A point he had not touched on in his paper was the cast iron mains. These had been supplied by the Stavely Coal and Iron Company, and a number of the pipes were received in a very rusted and flaked condition. He had, however, been assured by a fellow engineer that this firm coated their pipes with Dr. Angus Smith's solution, but he would like to know the specification to which the firm worked. Again, the correct depths at which to bury mains below ground in order to ensure cool water in the hot weather was a point about which some

that plugging by lowering cement concrete in boxes having false bottoms was not a very reliable method, and a better plan would be to prepare, on the ground, cement concrete blocks eighteen to tweenty-four inches thick, which could then be lowered into the well.

SIRDAR BAHADUR LAHNA SINGH said he found that in the experimental tube borings made at Khushab plugging had not been a success, and the steining was not watertight so that some pollution found its way in. Direct pumping was undoubtedly best where it could be done, but in many cases it was impossible, especially with muddy strata, where the water required straining. Sialkot was fortunately situated over a coarse sand, where the water could not be reduced much below two feet. In other localities, after pumping down to this depth, sand began to come up, and in such cases a sump was essential.

RAI BAHADUR KANHAYA LAL said he was at present engaged on sinking a tube well at Pasrur. He had done similar work at Amritsar, between 1890 and 1903, where the level of the sub-soil water was very near the ground level. When experiments for the water supply were being carried out at Tung Dhab outside Amritsar, there was a conference of doctors and engineers, and the former got the upper hand. The doctors accused the engineers of endeavouring to pump bacterial germs into the population of Amritsar (Laughter). The Chemical and Bacteriological Examiner of the United Provinces had been summoned by the Punjab Government to examine bacteriologically the water of a water-tight well built at Tung Dhab, but he was very much surprised to find the surface water leaking into the well, and considered it useless to analyse the water.

His experience was that wells could not be plugged so as to be made water-tight, and at Pasrur, he contemplated direct pumping from the tubes. The level of the water in the well, he thought, should be lowered from two to twelve feet according to the nature of the sand and the reduction of the head of water at which it began to flow. At Isakhel the people drank not only water that was dirty, but also the sullage from latrines, etc., but of course the people were Pathans (Laughter)—and while they could stand it, nobody else could. The Government had some six years ago collected Rs. 20,000 in a very short space of time for improving the water supply of Isakhel, but the money was still lying with Government and the interest on it was accumulating.

There were many elaborate and expensive schemes, like that at Sialkot, under contemplation, but had the case of the petty zemindar been considered? Ordinary bamboos or wooden tubes, which could be perforated like the models he produced were supplied by nature not by Mr. Ashford (Laughter)—and with these he thought wells could be sunk at a cost of Rs. 50 to Rs. 100, which would meet the case of the poor zemindar.

MR. MILLER BROWNLIE, with reference to the five reasons tabulated at page 76 by the author, thought that the chief reason had been omitted. A certain drawing down took place, and a certain amount of air became intermingled with the water. With direct pumping a certain proportion of air must also be pumped. From tests which had been carried out in America with tube wells, twenty-five per cent. of the efficiency was lost by direct pumping. From the bacteriological point of view a very small sump was all that was necessary. Another point was with reference to the thickness of the brickwork in the sumps, which at Sialkot was eighteen inches.* The depth given in the illustration was approximately fifty feet when the crushing stress on the arched ring would be about seven tons, and he would like to know what crushing stress had been taken to necessitate a thickness of eighteen inches to resist seven tons. He himself had found from experience that nine inch rings were good enough for sixty feet depth, and thought the present design entailed a considerable waste in brickwork. It was always best for a cement concrete plug to be put in after the strainer had been put in. This was the practice in America before 1901, and it was time that the Punjab knew a little about what was done elsewhere in works of this nature. As regards displacement of the wires, the same trouble of slack wires had been experienced in wire wound tubes in America, but this difficulty was overcome many years ago by a method of holding the wire at intervals round the circumference of the tube.

MR. ASHFORD, with reference to Mr. Carne's criticism on the framework, on which the wire was placed, not being screw cut in order to provide a positive space, said that this was the actual method adopted by himself in the first instance. He had discontinued this screw cutting, however, for several reasons, and he did not find it necessary, while it was very costly. To turn the whole of the framework and screw cut it, was

* Pages 72 and 73.

necessarily expensive. If the wire was put on tight there would be no necessity to screw cut. The form of tube well at Sialkot was not the one he was now manufacturing. He did not mean to suggest that the Sialkot well was defective, but he had, he thought, discovered a better system. Six years ago he had sunk one of these wells, and it was still in good order and working without any trouble. He considered masonry sumps to be objectionable, and for some considerable time past he had wished to get away from this arrangement. It was difficult to sink the steining of a deep sump without its cracking, and then there was always the possibility of contamination. Cracks were difficult to plug so as to prevent sand from finding its way into the well. The chief reason for using a masonry sump was to get a reservoir from which to pump, and to enable reciprocating pumps to be used. These pumps had a different action from centrifugal pumps in tube wells, and some of the latest pumps he had designed to work with tube wells gave an efficiency as high as seventy-three per cent.

The whole paper was very interesting, and was a guide and a key-note to future developments. Reference had been made to the experience at Ambala, etc., which led to the placing of low connected tunnels between the sumps at Sialkot. There was, however, rather too great a tendency to base everything on past experience. Tube wells had developed to a very great extent, and to sink a large number such as had been put down at Sialkot, was a mistake, and quite unnecessary. The cost of the tube wells was a very small fraction of the whole, and the greater portion of the money had been spent on brickwork. If they wished to be economical, they should try and reduce the quantity of brickwork that was generally used. The amount of water required at Sialkot was comparatively small, the supply being only about 500,000 gallons per day. Some of his wells had yielded 1,400,000 gallons per day. Why therefore have six wells as at Sialkot, when one would do? This of course would involve less brickwork. The whole area occupied by his well was twenty feet by twenty feet and it gave three times the supply of the Sialkot wells, while the whole expenditure involved in the sinking had come well within Rs. 10,000. He therefore thought that the question of saving brickwork deserved more consideration. He also thought they should consider operating direct from the tube itself. One of his wells had had an infiltration head of twenty-one feet without any trouble from sand. By direct pumping he had no loss of efficiency, or other ill consequences. He further considered that taking into account

the facility and ease with which tubes could be carried, they should be sunk at different points instead of placing the whole of the installation at one place. It would be better to split it up. The pumps could be started up automatically, and the whole system fed from different points, instead of from one. A case of this sort had occurred at Lahore, where one section of the municipal installation was inadequate to meet the supply, and lifting the pipe line and putting down a larger one was contemplated, but at the speaker's suggestion the Municipal Engineer considered distributing the power as described above, and it was very probable that this would be done.

Regarding the poor zemindars to whom Rai Bahadur Kanhaya Lal had referred, he thought they had considered their case and had helped them to get water at a very low cost. They could put down a pumping installation, which would give them water very much more cheaply than could be got from masonry wells, with a tube which would give a discharge of twenty masonry wells at the cost of two such wells. Regarding the supply of drinking water for village populations, he had devised a special tube to be operated by hand, which would give water in small quantities.

BAWA BUDH SINGH drew attention to the margin of safety between the supply needed, *viz.*, 544,500 gallons and the actual yield of the tube wells, *viz.*, 562,500 gallons as shown by experiments. This he considered was rather small, and if one of the wells went wrong, the supply would suffer. The vertical cement bond in the well steining, to which reference had been made in the paper,* presumably meant that the vertical joints were laid in cement, but this would not be sufficient protection against sub-soil water finding its way into the well, by creeping along the horizontal joints. The contract rates for sinking, as given in the appendix, were very high as compared with the actual cost. Had the contractors been given an opportunity for quoting their own rates, or was their tender based on the estimated cost ?

MR. BASHI RAM said that the distribution pipes in a water supply system, in course of time, would get oxidized, unless a hot coat of Dr. Angus Smith's solution had been applied before laying them down, but even then a chemical deposit would form after some years, and a sort of fungus growth appear, which materially reduced the section of the pipe and increased friction, with the result that the discharge was very greatly reduced. To remedy this was a very simple matter provided precautions

*Page 72.

were taken at the outset when the pipe line was being laid. Small, oblong, brickwork chambers six or eight feet long were built on the pipe line three or four miles apart. The fittings of these chambers consisted of a removable length of pipe, connected to the main line with collars, and having two vertical bars on the upper end. Whenever it was desired to clean the pipe the valves were closed so that no water ran through it, the short removable pipe was taken off, and what was called a scraper inserted. The pipe was then again fitted up and the valves opened. The scraper, propelled by a disk or piston behind which the water was admitted, slid through the pipes, scraping all foreign matter in front of it, till arrested at the next chamber on the pipe line, by the two vertical bars already mentioned, when the scrapings were let out through scour valves fitted in the chamber just ahead of the removable pipe. The scraper was then taken out by closing the valves and removing the collar pipe.

No such arrangement had been adopted either at Simla or at Lahore, and some difficulties were now being experienced at the latter station. It would be interesting to learn what means, if any, had been adopted at Sialkot to get over this trouble when it appeared, as it was sure to do in course of time.

MR. LINDLEY pointed out that as European practice finds it more economical to incur the higher initial cost of a gravity supply than to maintain a pumping plant, and as Sialkot was more favourably placed than the average Indian city for getting a supply from the foot hills of the Himalayas, it would be of interest to record the reasons that made a pumped supply preferable in this case. The supply allowed, of ten gallons per head per day, seemed low compared with the supplies of thirty gallons and upwards given in European and American practice, even allowing for the fact that the latter include the requirements of water-borne sewage schemes. How had this figure been fixed?

In placing pumping galleries or sumps in a sub-soil water-table, it was necessary to guard against some masking others by being on the lines of flow, instead of across them: had any observations of the water-table been made before fixing the sites of the wells, as none were mentioned?

MR. MORRIS asked with reference to the six tube wells having been spaced 122 feet apart, how this distance had been fixed, and had it since been found that the circle of influence of one well interfered with that of the next? If

this were the case, then the yield of each well would be less than the yield of a single well. It would be also interesting to know if any difficulty had been experienced in getting the shoring to sink, and if so, was it loaded in any way, as it appeared to be very light. It was also not clear from the description how the lower shoring was got in without interfering with the upper shoring. A sketch shewing the lay out of the wells, barrels and engine house would be useful.

MR. HEARD in replying to the criticisms said that as regards contamination, he could only say that the site had been selected after due consideration by the Sanitary Engineer and his staff, and he had done nothing beyond constructing the wells. Of the six wells, five were actually giving the supply, while the sixth was held in reserve. As regards the value of the sump, he personally thought that a combined system might be adopted, by which water could be drawn by direct pumping, but which could be disconnected when necessary.

The eighteen inch steining used in the sump wells was more or less the standard thickness of steining which was required to enable a well to be sunk without cracking. As regards the brick barrel, he did not take out any calculations, as it was not his design ; the original design was a concrete barrel eighteen inches in thickness and the brick barrel had been substituted as easier to construct forty feet below ground level. The tubes were loaded to make them sink.

He was inclined to agree with Mr. Ashford's remarks about the waste of brickwork. At the same time he would like to point out that the Sialkot water supply scheme was the first large scheme of its kind, and consequently could hardly be expected to be free from some such mistakes. It had, however, achieved the object for which it had been constructed.

It would be sound policy to locate tube wells as near as possible to the point at which the water was to be supplied. At Pasrur the tubes were to have been sunk half a mile from the city, but at his suggestion they were being sunk close to the town.

Regarding the possibility of a failure of the supply at Sialkot, the required supply could now be got with an average head of only three feet ; there was, however, provision for pumping up to a twelve feet head, if necessary, so that there was ample margin.

Regarding a possible growth of fungi and any necessity for scraping the pipes, the waterworks at Sialkot were new, and the pipes clean before they had been put down, all foreign matter having been removed. The possibility of fungi taking root was a matter which would be considered when the time came.

As to the remarks by Mr. Lindley on gravity supply, Sialkot was itself on a hill, and therefore the supply could not be provided by gravity.

In reply to Mr. Morris, the wells were in a straight line with the engine house opposite the centre of the line. Pumping tests shewed that their circles of influence overlapped to some extent. There had been no difficulty in sinking the shoring, but the sand gave trouble when any excavation was made under the shoring to allow it to sink. The shoring was not loaded, but any section inclined to stick was driven down with a hammer. The lower shoring was constructed inside the upper, so that the cross pieces would not interfere with its sinking.

COLONEL CRA'STER brought the discussion to a close by thanking the author of the paper and the members for the very lively and interesting discussion which had taken place.

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