MECHANICAL FILTER INSTALLATION AT JAMMU.

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Preliminary—Outline of the scheme—Raw water—Raw water pumps—Inlet controller—Measuring and chemical mixing gear—Mixing trough—Settling tanks—Filters—Outlet controller and inspection box—Washing the filters—Compressed air and wash water pump plant—Method of washing a filter—Clear water tanks—Clear water pumps—Construction and cost—Test and operation—Guarantee.

Preliminary.

Jammu, as is probably well known, is the winter capital of His Highness the Maharaja of Jammu and Kashmir. About twenty-five miles from Sialkot, the town, which is the terminus of a branch line of the North-Western Railway, has, according to the last census, a population of about 33,000 souls and is situated on the slopes of the first of a series of foot hills which lead on to the Himalayas. Below it flows the Tawi river, which is the source whence the town draws its supply. The water is pumped into service reservoirs on the top of the hill, and thence distributed by gravitation to the whole town through a network of pipes.

The pumping station is to the north of the town, on the right bank of the river, where the hill drops suddenly, and space is restricted by the river. The pumps, which were steam driven till 1909, and, subsequently, electrically driven, used to pump directly from the wells on the river bank into the service reservoirs, with no filtration, except what occurred from the river water percolating through the shingle bed on its way to the wells, but this arrangement, though not entirely satisfactory, seems to have worked fairly well till 1910. Since then, however, the river, which used to flow in a channel in the centre of what is, at this point, a wide bed, changed its course, and the main current passing over to the right bank, near the pumping station, threatened not only the works on the bank, but scoured the bed till the yield of the wells was considerably reduced owing to less head, while the quality of the water also suffered.

The remedy tried was to build domed wells in the bed of the river and to bring their yield through a pipe to a well on the bank, to feed the pumps, but this did not prove satisfactory, and in 1912-13 matters became so critical that it was decided to make a radical change. Having electrical power from the Jammu hydro-electrical installation at hand, with the Tawi so close to the town, it was thought best to instal electrically driven pumping plant, and, after passing the water through suitable mechanical filters, to pump it into the existing service reservoirs. This led to the preparation of a project for the work which was completed towards the close of 1917, and, so far as the author is aware, the installation of mechanical filters at Jammu is one of the first of its kind in the Punjab, if not the very first excepting Delhi ; and the installation has several interesting and instructive features about it which it is proposed to describe in the following pages.

Outline of the Scheme.

In order to allow for future developments, and for the fact that, Jammu being on a hill, there is no other source of supply, it was decided to instal a plant capable of giving a million gallons of filtered water a day into the reservoirs, while to allow for washing operations etc., it was decided to pump and filter this quantity in twenty-three hours daily. Plate No. 1 shows the general lay out of the works. All the pumps are electrically operated, of the Rees Roturbo type, while the rest of the electrical plant is of Westinghouse manufacture. The gravity type of Patterson patent rapid filter has been used.

The existing infiltration well, into which river water is directly led, was used as the raw water well, and in this pumps were installed. These discharge into the settling tanks, through a measuring tank and a mixing trough where a suitable quantity of sulphate of alumina is added. From the settling tanks the water is passed on to the filters, and the filtered water is then led through inspection boxes to the clear water tank, above which are installed the clear water high lift pumps, which lift the water into the several service reservoirs on the top of the hill.

Having thus briefly indicated the origin and the outline of the scheme, the several component parts may now be dealt with in detail.

Raw Water.

The Tawi river is more or less a hill torrent, with its source about sixty miles up in the hills. For several miles up

stream from the pumping station there are no villages on the river, and the country being open and sparsely populated the water is not subject to contamination, and consequently, from a bacteriological point of view, would not be likely to put the filters to a severe test, but, though it is beautifully clear and transparent during most of the year, in the rainy season it is highly charged with muddy silt of reddish colour, when it puts the plant to a severe test as the water is very turbid on account of suspended impurities.

Raw Water Pumps.

The untreated or raw river water is led through two cast iron pipes into the raw water well which is partially covered up, and the raw water low lift pumping station is located over it so as to have a direct and short suction. The highest flood level of the river is R. L. 1185, or 8½ feet above the floor of the pumping station at R. L. 1176·5. To prevent damage to the pumping plant due to a high flood causing an excessive rise in the water level in the raw water well, sluice valves were provided on the in-take pipes, and the staff has orders to limit the level of the raw water to R. L. 1173 as a maximum, or 3½ feet below the floor, by operating the sluice valves when the river is in high flood.

Two sets of low lift pumps have been installed.—one being a stand by. Each set consists of a Rees-Roturbo patent, self-regulating, pressure chamber pump, with phosphor bronze impellers, capable of delivering 43,500 gallons an hour, against a total head of forty-two feet, at a speed of 960 R. P. M., and a direct coupled, three phase, 50 cycle, 220 volts, squirrel cage, Westinghouse motor, capable of delivering 17 B. H. P. Each pump has an independent suction pipe, foot valve, and strainer, and discharges through a common ten inch delivery pipe into the measuring tank, located above the wash pump room in the filter house. Each motor is operated by a low tension, oil immersed auto-starter, complete and is fitted with fuses and an ammeter.

Inlet Controller.

An automatic inlet control valve was installed on the raw water pump delivery. This valve is operated by a float, controlled by the level of the water in the settling tanks, from which a two inch pipe was led into the float chamber of the inlet control valve, so that when the level of the water in the settling tanks rises, this valve automatically throttles the discharge from the raw water pumps till the normal level of the water in the settling tanks is attained, and *vice versa*.

Measuring and Chemical Mixing Gear.

A special feature of the Patterson rapid filter is the accurate measurement of the incoming crude water, and the addition of the chemical in a precise ratio. This is effected automatically by the Patterson automatic measuring and chemical supply gear, of which some details are shown with the chemical storage tanks on Plate No. 3. It will be seen that water enters the iron tank by a ten inch cast iron pipe at *A*, and passes into the chamber *B* through openings towards the bottom of the partition between *A* and *B*. In the side wall of chamber *B* are two V notches, through which the water is measured before it falls into the trough leading to the distribution box at the settling tank. Chamber *C* of the tank is also connected by bottom openings to chamber *B* and is really a float chamber. The float carries a ratchet, which operates a pinion quadrant, and the spindle of the pinion operates two tapering valves in the adjoining slate tanks, into which the chemical solution is delivered from the large chemical storage tanks. One of the slate tanks is working at a time, the other being spare. The chemical passes through a lead tube into the trough, through the annular orifices round the tapering valves of which the positions are controlled by the float in the measuring box, while the orifices are regulated automatically so as to supply the chemical in a precise ratio to the quantity of raw water delivered into the trough. The chemical solution in the slate tanks is maintained at a constant level above the valve openings by ball cocks in the pipe line connecting the tanks with the two main chemical storage tanks. The latter are of brick, cement plastered ; 6 feet by 6 feet by 4 feet in height ; and are located on the first floor, to the right of the filters in the filter house (Plate No. 3).

Below is the store room for the sulphate of alumina, which can be hoisted up as required through a trap door, weighed, and then put straight into the chemical storage tanks. Compressed air and filtered water pipe lines are led into each storage tank ; the compressed air being used for agitation in preparing the solution. The density of the latter depends upon the nature of the turbidity in the water, and is varied accordingly.

Mixing Trough.

The raw water is led from the measuring tank to the distribution box on the settling tanks by means of a mixing trough, constructed of quarter inch mild steel plates fitted with a salmon

ladder baffling arrangement, to ensure thorough mixing of the chemical solution with the raw water. The distribution box, which is also of quarter inch mild steel plates, has a cast iron pipe leading to each of the three settling tanks, with the necessary valves to completely control the supply of raw water to any of the tanks.

Settling Tanks.

As the name implies, the function of the settling tanks is to allow the settlement or precipitation of all suspended impurities in the raw water ; and to expedite this, sulphate of alumina, commonly known as alum, is added in doses of suitable strength, depending upon the turbidity of the water, but in order that the requisite chemical action may take place, it is necessary that the raw water should have, in solution, a certain amount of chalk. Most natural waters contain this, and the Tawi is in no way deficient, as its bed is full of limestone boulders.

The chemical action which takes place on the addition of alum to raw water is represented by the following equation :—

(Sulphate of Alumina) + (Chalk) + (Water)

$$Al_2(SO_4)_3 + 3CaCO_3 + 3H_2O =$$

(Hydrate of Alumina) + (Sulphate of Lime) + (Carbonic Acid)

$$Al_2(OH)_6 + 3CaSO_4 + 3CO_2$$

Expressed in words, the sulphate of alumina combines with the chalk in the raw water and produces hydrate of alumina which is insoluble and glutinous, and sulphate of lime and carbonic acid which are soluble in water, and it is this hydrate of alumina on which the sedimentation and filtration depend. Being glutinous, it rapidly collects and entangles any suspended particles, whether silt or germs, and being insoluble, it precipitates with the suspended matter caught by it. The hydrate of alumina further fixes any colouring matter in the water, rendering it insoluble, and thus also causes its precipitation, rendering the water colourless.

This process of clarifying turbid water takes some time for its completion, the period varying with different waters, but the design of settling tanks essentially depends upon this period of sedimentation. When preparing the project, the author referred this question of a suitable period for sedimentation to several persons, including some well-known firms dealing in mechanical filters, and found that there was a great divergence

of view in this matter. It was eventually considered best to leave the design of the tanks to the firm contracting for the supply and erection of the filter plant, and to hold them responsible for the daily output of one million gallons of water, purified to a specification guaranteed by the firm.

The question of the time required for sedimentation is, however, well worth discussion in this Congress, and it would be interesting to know the experience of members who have had occasion to deal with this class of work. It is, no doubt, true, that the time will vary for different waters, but it ought to be possible to base a rule on experience, connecting the time of sedimentation, the percentage of suspended impurities in the water, and the most economical chemical dose.

Plate No. 2 shows the settling tanks, with particulars of the brickwork, and Plate No. 3 shows the pipe arrangement, valves, etc. It will be seen that there are two large tanks, one on each side, with a small one in the middle, while adjoining the latter is the draw-off chamber, into which the surface water from all three tanks is led by cast iron bell-mouthed pipes, each controlled by a sluice valve operated from the top. A small portion of each tank is partitioned off to receive the incoming water mixed with the chemical, and this is connected with the rest of the tank by small openings at the bottom of the partition wall. The result is that water becomes dead on entering, and has to gradually rise from the bottom at one end to the top at the other in order to pass through the bell-mouth pipe into the draw-off chamber. During this slow journey the suspended impurities sink to the bottom. The depth of the tank is seventeen feet, with sixteen feet of water, while there is a slope of a foot in the floor of the larger tanks towards the river. Sludge pipes are laid in all tanks, with necessary valves, and these are connected with a main sludge pipe discharging into the river, so that any of the tanks can be readily washed out when necessary. An overflow pipe is also provided, and is connected to the main sludge pipe to prevent the tanks from being flooded at any time. The treated water is led away from the draw-off chamber on to filters by a cast iron pipe.

The tanks are of first class brickwork; the mortar used consisted of white lime, surkhi and local kankar lime in the proportion of 2 : 3 : 5. The tanks are cement plastered inside. The concrete in the foundations and bed is of stone ballast in lime mortar, of the same composition as that used in the brickwork.

Filters.

Plate No. 2 shows the elevation and plan of the filter house, and Plate No. 3 gives various working details, and shows the connecting pipe work, etc. There are three filters side by side, each eighteen feet by ten. In front of these pass the wash water, compressed air, waste water, and clear water mains, while each filter has an inlet control valve at the other end to regulate the flow from the settling tanks, as well as the air, wash, and waste water valves, operated from the front gallery.

Plate No. 4 shows the details of one filter. This is built of brick in cement mortar and cement plastered, with a cast iron duct sunk lengthwise down the middle of the floor. The draw-off pipe takes off through the floor from the centre of the duct. Over the cast iron duct, strainer pipes are fitted crosswise. These are of wrought iron, $1\frac{1}{2}$ inches in diameter, extending across the full width of the filter bed, and perforated by a line of holes, an eighth of an inch in diameter. The strainer tubes are closed at both ends, so that the only outlet for the water in the filter is through these small holes into the cast iron duct, to which the strainer tubes are connected at the centre. Above the strainer pipes were laid small stones, and over these layers of $\frac{1}{2}''$, $\frac{3}{8}''$ and $\frac{1}{4}''$ pebbles, each layer being four inches thick, while on top is a layer of clear, sharp, sand, of 30/40 grade, for a depth of thirty inches. Above the sand a mild steel trough, running centrally along each filter and crosswise at one end, serves as an inlet-distributor during normal working, and as a waste draw-off during washing periods. At the inlet end it is connected with the draw-off pipe from the settling tanks, and at the waste end, with the sludge pipe leading to the river, both pipes being controlled by suitable sluice valves. The filtered water is collected by the strainer tubes at the bottom of the filter and discharged into the central cast iron duct. It then passes through the draw-off pipe and a Patterson outlet controller into an inspection box, before falling through a V notch into the clear water main, which delivers into the clear water tank.

For the efficient working of a filter it is essential that the sand used should be the best, that is to say, it should be sharp, clean, and of the required fineness. Further, the grains should be hard, and not likely to deteriorate under water action, and hence most of the filter makers recommend and use quartz sand. In the case of the filter plant at Jammu, sand obtained locally

from the bed of the Tawi was used, after necessary screening and washing ; as the contracting firm, on careful examination, considered this sand suitable for their filters.

For a filtrate to be satisfactory, it is essential that a filtering film should be formed on the surface of the sand. In the case of the Patterson filters, this film is composed of the hydrate of alumina which is present in the water entering the filter from the settling tank. This glutinous substance coats the sand grains and completely seals up any interstices, thereby forming a film, which, though allowing water to pass freely, prevents the passage of any bacteria or of any colouring or suspended matter, so that while most of the impurities in the raw water have been precipitated in the settling tanks, what remains is held up by the film on the filter. From this it is clear that the filtrate cannot be satisfactory until a film is formed over the filter, and satisfactory filtration will only go on so long as this film remains in proper order. It is therefore necessary that the film should not be disturbed during filtration, nor should it be overloaded by taking too great a discharge from the filter, and, for this reason, filter makers lay down certain limits as to the density of filters. Thus, in the case of the Patterson filters installed at Jammu, the filter density is kept at eighty gallons per square foot of filter area per hour.

Outlet Controller and Inspection Box.

The Patterson outlet controller is one of the special features of the installation. Its function is to start the filtration process *gradually*, after washing the sand, so as to allow the all-essential filtering film to form on the surface of the filter and to prevent the rate of flow through the filters from exceeding a given limit. Briefly described the outlet controller (Plate No. 4) is a valve controlled by two floats ; one on the surface of the water in the filter ; the other on the surface of the water in the inspection box. When the washing of the sand in the filter is finished, and the water above the filter bed has been lowered to the level of the waste trough, the controller valve is held in the closed position by the float above the filter. When, however, water is let on to the filter, and the water level rises for re-starting filtration, the float also rises and the valve is *gradually* opened until the water in the filter rises to its normal level, and when this is done, the valve is released from the control of this float, and the rate of discharge from the outlet valve is then controlled only by the regulating float in the ferro-concrete inspection box. This has three compartments. In

one there is the controller valve and the regulating float, while an over-flow weir allows the water to pass into the second compartment. When the water, flowing through the weir, rises to a height determined by the maximum allowable rate of discharge from the filter, the regulating float partially closes the outlet valve, and thus the rate of filtration is kept under control. In the bottom of this second compartment is a valve connected to the waste pipe, and this by-pass enables the water from the filter to run to waste till the colour of the water is found, on inspection, by means of a sight test gauge, to be satisfactory. When the valve in this second compartment is closed, the water rises and falls into the third compartment through a V notch in the partition wall, and from this compartment the water is led into the clear water main through a sluice valve.

Washing the Filters.

In all filters, the filtering medium get choked by the impurities in the water passing through it, and hence the removal of these impurities is essential. As the rate of filtration of mechanical filters is far more rapid than that of slow sand-filters, the choking of the filtering medium is much more rapid, and, therefore, the effective and rapid rectifying of this choking is a most important item in all mechanical filters. This is generally done by raking or agitating the sand, which is the filtering medium, and washing it with clear water. Various methods are adopted for washing the sand in mechanical filters, each maker claiming that his particular system gives the best result. Thus, while the Jewell Filter Company use electrically operated rakes to agitate their sand, and Messrs. Mather and Platt have a rotating propeller and high pressure jets, each necessitating, as a consequence, a circular shaped filter, the Patterson Filter Company adopt the method of first forcing compressed air up through the sand for loosening it, and then clear water in the reverse direction for washing it. This does not necessitate any particular shape of filters.

Compressed Air and Wash Water Pump Plant.

At Jammu, the plant for compressed air and wash water is installed in duplicate to ensure perfect reliability. Normally, one set is supposed to work while the other remains as a stand-bye. A reference to Plate No. 3 will show that, in the right hand corner, on the ground floor of the filter house, are installed two air compressor sets and two wash water pumps, each coupled to an electric motor. Each air compressor

set consists of an air compressor machine of the pattern (6" × 7") made by Messrs. Broom and Wade, Ltd., High Wycombe England, and capable of delivering fifty cubic feet of free air per minute. This is driven by a direct-coupled British Westinghouse squirrel cage motor of 9 B. H. P. at 220 volts, three phase, fifty cycles, and running on full load at approximately 640 R. P. M. Each wash water pump set consists of an eight inch Tangye Type B, centrifugal pump capable of delivering a thousand gallons per minute against a total head of forty feet, coupled direct to a British Westinghouse protected type of squirrel cage induction motor of 20 B. H. P. when running approximately at 875 R. P. M. at 220 volts, three phase, fifty cycles. The motors of the pumps, as also the compressors, are controlled by suitable starters and switchgear. There are four compressed air receivers, each 3'-9" diameter, and 11'-9" high, of three-eighths inch mild steel plate suitable for a pressure of 80 lbs to the square inch, and these are connected by suitable piping with the compressor and filters.

The air compressor is supposed to run daily for about three hours, and the wash pump for about twenty minutes. When the discharge from the filter is observed at the V notch in the inspection box to be going down, compared with the normal discharge, it is an indication that the filter in question needs washing, but as to how often a filter will require washing, must obviously depend upon the condition of the raw water. Thus, in wet weather, when the river is in flood, the filter may require washing almost daily, whereas in clear weather washing may have to be done only twice or thrice a week.

Method of washing a Filter.

Briefly described, the procedure when washing a filter is as follows :—The inlet valve is closed, as well as the valve on the clear water delivery pipe into the inspection box, and the waste valve opened. Compressed air is then let into the filter in the reverse direction by opening the air valve. When the sand has been sufficiently broken up, which is generally done in a few minutes, the air valve is closed, the wash pump started, and clear water is forced into the filter in the reverse direction, that is to say, upwards, from the strainer pipes, through the sand, by opening the wash water valve. The water washes out all the impurities choking the sand, etc, into the waste water trough, and from there into the river by the main sludge pipe. This goes on till the colour of the water on the top of the filter is sufficiently clear, when the waste and wash valves are closed, and

the treated water is let on to the filter by opening the inlet valve. For a little while the filtrate is allowed to run to waste through the small valve in the bottom of the second chamber in the inspection box, and when the colour of the water in the inspection box is sufficiently clear, this little waste valve is closed and the filtered water is let into the clear water main by opening the delivery valve.

The guarantee for wash water is, that it will not exceed 2½% of the total purified daily, irrespective of the condition of the river at any time of the year or season. This includes water required for actually scrubbing the sand, and also any water run to waste through the by-pass, after cleaning, until such time as the filter regains its normal efficiency.

Clear Water Tanks.

The clear water tanks, into which the filters discharge by a common main, are close in front of the filter house (Plate No. 1). They are under ground and covered, and are also screened from the sun's rays as much as possible to prevent any kind of growth. Over part of the clear water tank is erected the clear water pump room, the floor being supported by brick arches on columns and on the side walls of the clear water tank. This arrangement gives a direct and short suction to the clear water pumps and economizes space and piping. The capacity of the clear water tanks is approximately 69,000 gallons.

Clear Water Pumps.

There are three clear water pumps. Two to run normally in parallel and one spare. These pumps are Rees Roturbo centrifugal pumps, each capable of delivering 23,000 gallons per hour against a total head of 335 feet, when running at an approximate speed of 1450 R. P. M. Each pump is directly coupled to a slip ring type induction motor of 65 B. H. P. at 3,000 volts, three phase, fifty cycles. The duty of the pumps is guaranteed by the suppliers to be according to their characteristic curves, supplied with the tender. As the service reservoirs into which these pumps have to discharge are at different levels, the variation of discharge according to variation of head ensures efficient working. Each pump has an independent suction, and all pumps deliver into a common rising main. The motor of each pumping set is controlled by a liquid starter and suitable automatic switchgear.

Construction and Cost.

The estimated costs of all these works amounted to approximately Rs. 1,69,000. Of this, Rs. 51,000 and

Rs. 49,000, in round figures, covered the cost of filtering and pumping plant respectively, each including erection, etc., and complete. The remaining Rs. 69,000 covered the cost of the filter house, the settling tanks, one new service reservoir of 360,000 gallons capacity, a clear water pump room, etc., etc. It may be mentioned that owing to the utilization of some of the existing works, such as the raw water well, the clear water tanks, the rising main, and the three service reservoirs, the total cost remained low. The contract for the supply, delivery and erection of the filter plant as well as the pumping plant, complete in all respects, was given to Messrs. Jessop and Company of Calcutta, whereas all the brickwork, etc., was rried out by the Public Works Department of the Jammu and Kashmir State. The work was commenced towards the end of 1915, and it was expected to be finished within a year, but the plant was delayed by the war, so that the installation was only completed towards the end of 1917.

Test and Operation.

The author regrets not being able to supply details of the tests and of the operation of the plant, as, just after the works were completed, he was transferred, and his connection with them ceased. He is informed, however, that the plant is still under test, and that the results are being jointly looked into by the State and the contracting firm.

Guarantee.

It may be of interest to know that the filter plant has been guaranteed by the contracting firm to give the following results:—

(*i*) *Output.*—The output shall not be less than 43,480 gallons per hour, exclusive of wash water, for twenty-three hours a day, when operating the filters at not more than eighty gallons per square foot per hour.

(*ii*) *Clarification.*—The filtered water will be so clear that when a platinum wire of 1/25″ diam. is placed at a depth of six feet in it at midday, it shall be discernible to a person of normal vision.

(*iii*) *Bacteriological purification.*—The number of bacteria, per cubic centimetre of the filtrate, capable of growing on gelatine, and counted after fourty-eight hours incubation, according to the usual laboratory practice, at 18 to 20° C, shall not exceed a hundred irrespective of the number present in the raw water

at any time or season. The filtrate shall be so purified bacteriologically that no typical bacteria of sewage, and in particular no B. coli, no B. typhosus, no B. enteritidis, nor germs of cholera nor dysentry, can be detected in forty cubic centimetres of the filtrate, when incubated on the usual culture media for two days at 37° C.

(*iv*) *Taste and odour.*—The filtrate shall be free from taste and odour when heated to 37° C.

(*v*) *Freedom from co-agulant.*—The filtrate shall not contain a residue of any co-agulant added to the raw water that can be detected by ordinary chemical analysis, unless a competent authority is satisfied that such residue is innocuous to the consumers.

(*vi*) *Acid reaction.*—The filtrate shall not have an acid reaction under any circumstances.

(*vii*) *General.*—The filtered water shall be suitable for all dietetic and household purposes.

(*viii*) *Wash water.*—The percentage of wash water shall not exceed $2\frac{1}{2}$ % of the total water filtered in twenty-three hours, irrespective of the condition of the raw water.

DISCUSSION.

MR. A. R. ASTBURY introduced the paper in the absence of the author. Through the courtesy of the State officials he had been permitted to visit the installation and see it under working conditions. The site chosen appeared to have been determined more by the accident that the original wells happened to be there, than by its suitability for the operations of mechanical filtration. It seemed to him very confined, and not to provide sufficient space for sedimentation ; also it was subject to flooding and erosion.

A serious mistake had been made in placing electric motors down a well at a level where they could be submerged. In the pump room the pumps had been placed in a row vertically beneath the rising-main which was supported by the pumps ; this made it very difficult to isolate any one of the pumps for repairs. An interesting feature of the supply was that it had been constructed and was maintained as a charitable institution. The water was supplied free to all, whether drawn from the public standposts, or from private house connections, all of which were unmetered.

The paper dwelt too much on working details of the measuring gear and the filter plant ; which information could be had from the pamphlets issued by the makers of the filtering plant, illustrated by blocks which made the description easy to follow, and it omitted much that would have been of practical interest regarding the working of the installation.

RAI BAHADUR GANGA RAM remarked that the water supply schemes at Jammu ought to have been described in more detail, as he thought a much better scheme could have been devised. The first installation had been a failure, and the second promised to be another. He would like to know whether any gravitation schemes had been thought out, as the Tawi had a large slope ; about one in a hundred. Hydraulic rams should have been considered, as they were more permanent and less expensive in their maintenance, while the quantity of water to be lifted was not large.

MR. G. H. THISELTON-DYER, Honorary Secretary, Bombay Engineering Congress, said that he would like first of all to thank the Punjab Congress for having invited him. The Bombay Engineering Congress realized what they owed to the Punjab Engineering Congress for having given them a lead.

The paper had interested him a good deal. It was very descriptive, but he was sorry that the author was not able to give them some details of the results. The time for coagulation was the real crux of a mechanical filter, as alum was now very expensive and great economy was necessary in its use.

Sedimentation was one of the difficult questions yet to be solved. The author says "it is no doubt true that the time will vary for different waters, but it ought to be possible to base a rule on experience, connecting the time of sedimentation, the percentage of suspended securities in the water, and the most economical chemical dose." There was a similar case in Poona, where the quantity of the sediment altered from time to time. The effect of temperature was also one which had been responsible for some of the anomalous results. One of the great difficulties in keeping filters in good order was lack of expert attention. Filters should, as far as possible, be fool-proof, and if an inexperienced man was allowed to turn on the compressed air, or even to reduce the air, the results would be vitiated. He had a case regarding a new design of filter, and he would much rather have a tank with a roof on, as only by this means could a filter be kept in good order. In conclusion he said that the guarantee was pretty stiff, but it should have contained a statement of the maximum amount of alum to be used.

MR. C. QUINN-YOUNG thought that if the discoloured water were tested the colouring matter would be found to be almost pure clay. This was generally so fine that it did not deposit. A practical method of gauging the amount of alum necessary for clarification might be found by taking volumes of water of various degrees of discolouration, and registering the tints. Then by testing a gallon, or more, of each of these classes to clearness by adding alum, the quantity of alum corresponding each class of discolouration would be known, and this could be recorded. When a flood or freshet occurred, by comparing the colour of the water with that recorded in the register, the quantity of alum necessary to attain clearness in he settling tanks would be immediately known.

RAI SAHIB MAKHAN LAL explained, with reference to Rai Bahadar Ganga Ram's remarks, that a gravitation scheme had been considered, but it was found that its cost would be prohibitive, amounting to about twelve or thirteen lakhs of rupees. Moreover, the place where water was available was about 42 miles from Jammu, or in a straight line about 27 miles,

and there was danger of the pipe line being frequently washed away owing to its having to pass through very hilly country.

MR. J. ASHFORD said that Mr. Astbury had drawn attention to mistakes when designing the plant. The pumps used were placed in the wells and driven by electric motors at a level where they could actually become swamped, and it was clear that electric motors could not be expected to work under such conditions. An electric pump would always work well when the suction-head was small, and consequently it was desirable to place it near or below the water surface, but electric motors were liable to damage by floods. He advocated the use of a vertical spindle pump, with which he had done a very large amount of work. It was made in Amritsar, had a high efficiency, and could work twenty-four hours a day continuously without trouble. They had been obtaining an efficiency as high as 75 %, and if such pumps were installed at Jammu, there would be less trouble, and the efficiency would be very much higher than it was at present.

MR. A. S. MONTGOMERY called attention to Mr. Dani's statement that the general practice was to add two grains of alum to a gallon of water, and that if any precipitate was found taking place with that quantity, it was considered enough and if it was not sufficient, more alum was added. He thought Mr. Dani was not correct in thinking that this was the usual procedure, and he maintained that the amount of alum to be added should not be a matter of guess work, but should be ascertained from an analysis. The maker of any mechanical filter would furnish a guarantee that a filter of a certain size would purify water, and when he was putting in the hydro-electric scheme at Simla he found no difficulty at all in getting a contractor to give filters of certain sizes. Mr. Thiselton-Dyer had mentioned that in Poona they introduced chlorine into the water, after filtration, for the purpose of sterilizing, but he thought that it must have been a very small quantity.

MR. DANI in reply wrote that as regards Mr. Astbury's criticism that the site of the filters was very confined, and exposed to floods, it had to be admitted that the site was by no means ideal. When the scheme was under consideration the disadvantages of the site had been taken into account, but the choice was limited and any change would have been meant very heavy expenditure. It was therefore decided to instal the

filters on the existing site of the pumping station, and build and maintain such protection works as might be found necessary from time to time.

As regards there being insufficient space for sedimentation, he wished to draw attention to the top of page 30, where he had stated that owing to the difficulty in deciding upon the right period of sedimentation, the design of a suitable settling tank was entirely left to the contracting firm, and holding them responsible for the specification guaranteed. There was sufficient space to put in larger settling tanks, if such had been considered necessary.

Also, as regards placing the electric motors down a well at a level where they could be submerged, attention was invited to page 27 where it was clearly stated that "to prevent damage to the pumping plant, due to a high flood causing an excessive rise in the water level in the raw water well, sluice valves were provided on the in-take pipes, and the staff had orders to limit the level of the raw water to R. L. 1,173 as a maximum, or 3½ feet below the floor, by operating the sluice valves when the river is high in flood." The operating staff was present at the pumping station day and night, and when the river rose in flood there was sufficient warning for the men to operate the valves to protect the plant from flooding. If the staff was reasonably careful and operated the valves, when necessary, there was no reason why the raw water pump motors should get flooded. The main reason why the pumping plant had been thus located was to secure a short and direct suction, and this, as Mr. Ashford had rightly pointed out, was a great advantage for pumps, reducing the cost, and meeting the installation more compact.

A gravity scheme had been investigated in 1914, when it was found that the nearest source of water was about thirty miles from Jammu, so that the cost would not have been less than seven lakhs of rupees, while such a long length of pipe line in a hilly country would have been liable to frequent damage and difficult to repair. He did not quite follow Rai Bahadur Ganga Ram's remark that the first installation had been a failure. If he had in mind the old steam pumps, these had been replaced, not because they were a failure, but because larger and more efficient pumping had become necessary, and was possible when electricity appeared on the scene with the Jammu hydro-electric installation. As for hydraulic rams, he would like to know where, in India, such plant had been

ound to give a satisfactory solution for the water supply of a arge town.

He quite agreed with Mr. Thiselton-Dyer in his remark that the time for co-agulation was the real crux of a mechanical filter. He had put forward this question for discussion at the Congress, where he had looked for some useful information, but was disappointed to find that none of their experts had even touched this most important question. The discussion had not forwarded the solution of this quəstion and further information would be most welcome.

As for the method of gauging the amount of alum, suggested by Mr. Quinn-Young, it was no doubt useful, but the stocked samples of water of different degrees of discolouration would gradually lose their right tints, as the suspended matter settled, and this would cause an error in the dose of alum. He thought the method of gauging the turbidity by noting the depth at which a platinum wire, of given thickness, was perceptible under given conditions of light, would prove more reliable. A rod having a platinum needle attached horizontally at the end, might be used to measure the turbidity by the depth at which the needle was discernible. This could be suitably calibrated to indicate the degree of turbidity, and a table prepared from actual tests showing the dose of alum necessary for clarification for the different degrees of turbidity as indicated by the different depths at which the platinum needle was discernible.

Mr. Montgomery was under a misapprehension in attributing to him a statement that the general practice was to add two grains of alum to a gallon of water, and that if this was not sufficient more was added. He had made no such statement in his paper, and it was certainly right that the addition of alum should not be guess work, but should be determined by some such system as that indicated by Mr. Quinn-Young, or as suggested by himself. It should, however, be borne in mind that there must always remain a slight residue of alum in the water, after clarification, as this was essential for forming a thin film on the sand in the filters, on which the filtering principally depended.