

by extending the aqueduct for several miles, to dispense with Mr. Turner's pumping. But, taking into consideration the cost of carrying the main-pipe higher up the river, the severe character of the floods, the large variation of water-level in the narrowing cañon, and the increased difficulties of access to works situated at any point higher up than Mii Mura, it was found to be desirable and economical to establish small pumping-works at the intake, to raise the water at all times into the conduit, whence it flowed 27 miles by gravitation to the Nogeyama reservoir. It might be correct to characterize Japanese earthquakes generally as large waves of earth. But of course the period and rate of propagation of the waves depended upon the proximity of the point of observation to the seat of disturbance. At Yokohama, he had seen walls split, and solidly built brick chimney-stacks projected through the roofs of the houses by the violence of the earth-waves. From his own observation of such effects, and from personal sensations during one particularly destructive earthquake, he considered that it would be imprudent to rely upon obtaining water-tight structures of brick, masonry or concrete, without puddle, at least in that immediate locality. As to the drainage of Yokohama, Mr. Hart must surely be misinformed. During the progress of the laying of some 50 miles of pipes in the streets, he became well acquainted with the drainage system as it existed in 1885. Excreta and urine were removed in pails from the houses and were carted away for manure. But the ordinary street drains, in five-sixths of the town, consisted of wooden shoots about 6 inches square in cross section. The main drains had flat wooden floors and covers and stone sides, with open joints. Many of the drains were choked with slime, and all that were opened were surrounded by earth saturated with sewage. In the remaining sixth of the town there were brick drains, which lacked adequate ventilation and flushing arrangements. He therefore considered himself justified in alluding to the absence of a good drainage system at Yokohama.

### Correspondence.

Major-General H. S. PALMER, as the Engineer of the Yokohama Water-Works, wished to say a few words by way of supplement to Mr. Turner's Paper. First, as to the works at the intake. To any one unacquainted with the local features and conditions, the questions might very well occur:—Why was pumping resorted to at all at the head of a gravitation supply; and why, in the second

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place, was it found necessary to pump into a settling-tank placed as high as 34 feet above flood-level? The answer to the first of those questions would be, that, owing to the great fluctuations of the level of the stream, ranging over fully 20 feet, and to the rocky and precipitous nature of the river margin, the construction of a pipe-aqueduct that would be effective at all times without the introduction of pumping was practically prohibited, on the grounds of difficulty and expense. It had to be borne in mind that the intake was in the heart of a formidable river cañon, walled in by rugged cliffs and slopes. Assuming a gradient of 6 feet per mile for the pipe, and (which was about correct), a fall of 22 feet per mile for the stream, and that the first pipe was placed 3 feet below low-water level, it would have been necessary to lay the first  $1\frac{1}{2}$  mile of the aqueduct in the zone between high-water and low-water, in bare rock, or rock with a shallow, loose covering of shingle; and the work would have been liable to all the inroads and interruptions of a river subject to freshets of sudden and dangerous violence. It was unquestionable that this consideration alone, not to speak of others less obvious, left him practically no alternative but to introduce pumping, that should, at least, lift the water clear of flood-level. As to the second question, namely, the raising of the water some 34 feet higher, he had been guided to this also by a careful study of the best and cheapest way of dealing with the problem. Those 34 feet, he had found, gave, in addition to the extra head affecting the first 18 miles of aqueduct, a much better and easier pipe-line out of the river gorge, and much advantage in surmounting the elevations on the hither side of Kami-Kawai, which was the lowest point of escape from the basin of the Sagami River. Further, the main part of the cost of the pumping-station lay in the preparation of the site itself, and in the buildings, foundations, suction-well, quarters, and other accessory works. The additional prime outlay involved in machinery adapted for the 34-foot lift, coupled with the sum representing the extra annual cost of pumping, had been carefully compared with the probable extra expenditure if no such lift were resorted to, and had been found largely in favour of the higher level. It might be asked, however, even after this explanation—Could not the same result have been got by continuing the higher pipe-line up stream, at its grade of 6 feet per mile, until the high-water level was struck? Of course, this could have been done, if the cost had not forbidden it. But, as a matter of fact, the natural difficulties increased so greatly above the point of intake, that a continuation of the pipe-line for some

2 miles upwards would have been ruinously expensive, not to speak of the highly unfavourable nature of the river-margin thereabouts for forming an intake station. For all these reasons, he had come to the conclusion that the problem was to be best solved by placing the intake at Mii-Mura, and introducing a total lift of 54 feet from low-water level. And he might add that he had extended his investigation to points below as well as above Mii-Mura, with the result above stated. There was one more point, referred to by Mr. Turner, on which he wished to dwell with some emphasis. That was, the precautions taken against earthquakes, as in the adoption of lead joints for the pipes, and the encasing of the service-reservoir, filter-beds, and other water receptacles in puddle, freely used and prepared, and laid with the greatest care. If any critics should be disposed to think such precautions needless, or overdone, he would urge them to bear in mind that the personal experiences of earthquakes in the Yokohama district, which had been gained by foreigners during their thirty years of intercourse with Japan, were not necessarily any real measure of the risks or even the probabilities of the case. No engineer would dare to argue solely from the records of such an insignificant period. Rather, he would take a wider survey, looking back to the stories which the remoter past had to tell, considering the seismic conditions of the region in which he had to construct his works—and in Yokohama those conditions were distinctly precarious; and would remember that, while no human foresight could fend off the havoc which attended the graver class of convulsions, it was at least his duty to exercise all possible care as against preventable injury from the shocks, not uncommon in Japan, which, while far short of being cataclysmal, were yet severe enough to work very serious injury upon solid structures built in Western style. As regarded Yokohama especially, its situation was on one of the chief lines of volcanic weakness in Japan. It so happened, moreover, that even the last half-century had afforded ample warnings. In proof of this, he might mention the great earthquake at Tôkiô (only 18 miles from Yokohama), in 1855, which destroyed some sixteen thousand houses, and brought death to tens of thousands of the people. Or, again, the latest serious warning, namely, the earthquake of no longer ago than the 15th of January, 1887, which, originating some 30 miles south-west of Yokohama, spread its effects over 27,000 square miles of country, and wrought very considerable damage in the town itself, as well as in the capital. In the full account of this earthquake, which appeared in *The Times* some three months later,

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it was shown that in the region of chief activity, namely, at a distance of only between 20 and 30 miles from Yokohama, "Professor Sekiya counted no fewer than seventy-two cracks in the ground, in a distance of 7 miles, one of them being a foot wide and 500 feet long;" that people walking abroad were thrown to the ground; that a large river became "so strongly agitated that the ferry-boat could not be taken across it for some time after the shock," and so on; and, further, that, "had the maximum intensity reached Yokohama, it is more than likely that not a chimney would have been left standing; and that, in the foreign quarter, at least, there would have been heavy ruin and loss of life." Plainly, then, it was not necessary to go far for evidence amply sufficient to refute any attempt to belittle earthquake risks in Japan. To ignore such practical admonitions as the foregoing would be to live in a fool's paradise. And, in his opinion, the engineer would be culpably negligent who failed to take past evidence and future risks into account in his designs, and to carry his anti-seismic precautions as far as was reasonably practicable.

Mr. Perrett.

Mr. E. PERRETT observed that water-works, of the kind described, were generally provided to give the inhabitants of a district an abundant supply of fairly pure water; but neither of the Papers contained an analysis of the water as it entered the works, and as it was supplied to the consumer, and there was a question as to its condition. But there seemed to be no doubt that the water in all three cases was liable to be heavily charged with matters in suspension. The method adopted for cleaning the water was filtration, such as had been used for several years with fairly good results. In this arrangement, when dirty, the surface of the sand was scraped off, washed, and put back; but nothing was known of the cost of this process. The ordinary rate of filtration through sand was 2 to 3 gallons per square foot of surface per hour, the upper surface of the filter only being in action, the lower and large bodies supporting the fine sand. The cost of the filtering material was small; the chief expense (omitting land) was the construction of the filters and the cost of cleansing them. In an arrangement with which he was connected, a more expensive, but a more efficient filtering material had been adopted, namely, a mineral carbonaceous matter, by which the rate of filtration was increased at least twenty times, owing to the porous nature of the material, which was unlike sand in that respect. To effect the cleansing of such material, perforated pipes were placed under the media, and slightly compressed air was supplied, which, violently agitated, cleansed, and aerated the filtering material; a small reverse current

of water carried the dirt away, and in a few minutes the cleansing Mr. Perrett. was effected. A great advantage of effecting the cleansing by mechanical means was that it could be done every day, and the passage of the water through the accumulated dirt, which in the case of an infrequently cleansed filter was very objectionable, was avoided. The size of the filters was reduced by this plan to at least one-twentieth, the cost of cleansing was practically nothing, and the cost of the filtering arrangement itself was very small.

Mr. G. J. SYMONS remarked that there were two points in the Papers Mr. Symons. upon which some further meteorological details would perhaps be acceptable. In the Paper on the Hong-Kong Water-Works reference was made to a slip of 25,000 cubic yards of earth, and to other damages, as resulting from "a deluge of rain in May 1889." But no details were given as to the amount of rain. The fall, however, was so great as to be worthy of setting out *in extenso*. There were two rain-gauges in operation; in so enormous a rain precise agreement was not to be expected, but they agreed very fairly. One gauge was measured four times, and opposite its record was entered the total by the Observatory gauge.

1889.	Interval.	Gauge measured four times.	Observatory Record.
	Hours.	Inches.	Inches.
May 29th. 3 a.m. to 7 a.m. .	4	0·90	0·90
„ 7 a.m. to 0.30 p.m.	5½	11·56	10·13
„ 0.30 p.m. to 7 a.m. }	18½	11·54	17·95
30th . . . . . }	3¼	1·66	0·62
May 30th. 7 a.m. to 10.15 a.m.			
Total . . .	31¼	25·66	29·60

The Table in the following page gave the fall at the Observatory in each hour.

From this it would be seen that in the twenty-four hours, ending 6 A.M. on the 30th of May, the fall reached the enormous total of 28·44 inches, being considerably more in that one day than fell in London in an average year. It might, however, be noticed that there was no hour in which the fall exceeded 3·40 inches; therefore the rate of fall was not greater than had been recorded in England, and the special characteristic was the long duration of an intense fall. The general feature of the fall had been already illustrated.<sup>1</sup> In the Paper on the Yokohama Water-

<sup>1</sup> Symons's Monthly Meteorological Magazine, vol. xxiv. p. 104.

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## HOURLY RAINFALL AT HONG-KONG OBSERVATORY.

	May 29th.		May 30th.	
	In Hour.	Total.	In Hour.	Total.
	Inches.	Inches.	Inches.	Inches.
1 a.m.	..	..	1·80	15·41
2 "	..	..	2·30	17·71
3 "	0·08	0·08	3·20	20·91
4 "	0·20	0·28	3·40	24·31
5 "	0·08	0·36	3·00	27·31
6 "	0·14	0·50	1·63	28·94
7 "	0·40	0·90	0·04	28·98
8 "	1·44	2·34	0·58	29·56
9 "	0·46	2·80	0·02	29·58
10 "	3·07	5·87	0·07	29·65
11 "	3·35	9·22	1·03	30·68
Noon	1·27	10·49	0·55	31·23
1 p.m.	1·08 <sup>1</sup>	11·57	0·55	31·78
2 "	..	11·57	1·20	32·98
3 "	..	11·57	1·12	34·10
4 "	0·37	11·94	0·01	34·11
5 "	0·40	12·34	..	34·11
6 "	0·03	12·37	..	34·11
7 "	0·02	12·39	..	34·11
8 "	0·07	12·46	..	34·11
9 "	0·20	12·66	..	34·11
10 "	..	12·66	..	34·11
11 "	0·11	12·77	..	34·11
Midnight	0·84	13·61	..	34·11
Total	13·61	13·61	20·50	34·11

Works, it was stated that "It was difficult, and often impossible, to obtain information about such matters as rainfall, evaporation, etc." It would hardly be gathered from that statement that there was, and had been for several years, a well-worked Meteorological Office in Japan, and that observations at Yokohama dated back to 1863. Ample materials for a very creditable monograph on the rainfall of Japan existed in 1885, when these works were commenced; for not only were there eighteen stations, scattered over the country, at which regular observations were made; but, for the Imperial Observatory at Tôkiô, both for rainfall and for evaporation, the observations had been made with a completeness rare in this country, and the values had been published.

Mr. Walker. Mr. THOMAS WALKER stated that, in 1887-88, he constructed a covered service-reservoir to hold 5,000,000 gallons of water on

<sup>1</sup> In another report this value is given as 0·08; if that is true, the totals in the Table for each subsequent hour should be 1 inch less, and the gross total 33·11 instead of 34·11.—G. J. S.

Addington Hills, near Croydon. It was made entirely of concrete, Mr. Walker. no puddle having been used; and, as the reservoir was perfectly water-tight, a few particulars might be of interest to the Institution. The hills were composed of the water-worn pebbles and fine sands of the Oldhaven beds, and these materials were chosen for the concrete, a portion of the sand being removed by screening. The contour of the ground necessitated the reservoir being oblong; the inside dimensions were 420 feet by 124 feet by  $16\frac{3}{4}$  feet deep. The floor, outer walls, and roof were of Portland cement concrete, 6 to 1 by measure; and for the piers and arches of the longitudinal and cross walls, up to the springing level of the covering arches, the proportions were 5 to 1, a little Thames sand being used. The concrete was hand-made, turned over twice dry, wetted from a rose on india-rubber tubing, and thoroughly mixed on wooden platforms. It was not dropped from a height into its final position, but placed there with a shovel in layers, not too thick, so that the coarse and fine parts of the concrete were laid or mixed together equally and well worked, ensuring solidity throughout. Water was rather freely employed, but not so as to stand on the surface of the concrete when in position. For joining up all old work when it was set, grout made of 1 part of cement to 2 parts of Oxted sand was used, and, when necessary, the old work was cleansed, roughed over with a pick, and brushed before the grout was applied. The floor was 18 inches thick, put down in two layers with overlapping joints. The inside of the outer walls (which required to be roughed) and the floor were carefully rendered, the first coat  $\frac{1}{2}$  inch thick with cement and washed Thames sand in the proportion of 1 to 1 of each, and the finishing coat  $\frac{1}{4}$  inch thick was of neat cement put on before the first coat was quite set, and thoroughly well trowelled to a smooth hard face. A double thickness of rendering was laid under the piers and on the springing of the arches against the outer walls. The rendering might be said to line the floor and sides of the reservoir in every part up to 6 inches above overflow level. Fifteen slight vertical cracks, that appeared in the outer walls before they were rendered, were cut out in a V shape, with a cross-sectional area of about 1 square foot, and filled in with good concrete. Careful examination after the reservoir had been in use failed to detect the slightest fracture in the rendering in any part of the work. The outside of the concrete arches forming the roof was covered with asphalt  $\frac{3}{4}$  inch thick, in two coats, and was found to be water-tight. The spandrels of the arches were inclined from the centre to the ends of the reservoir, and had 3-inch land drains laid along them to carry off

Mr. Walker. surface water. A party-wall, 12 feet high across the reservoir, allowed the water on either side of it to be run off independently of the other. The main from the pumping-station entered each division at the springing level of the roof arches, which was also the overflow level, and a water-cushion was formed on the floor under each inlet by walls 2 feet high enclosing a space 10 feet by 6 feet. The surface of the hills over the reservoir had been restored and planted with heather as before.

Mr. Turner. Mr. J. H. T. TURNER, in reply to Mr. Symons, pointed out that the very complete meteorological establishments at Tôkiô, Yokohama, and the sixteen other stations in Japan, though doubtless most serviceable in their respective localities, could afford but little aid in ascertaining the meteorological conditions which prevailed in the water-shed of the Sagami. Meteorological stations at important places were of great use in a country, such as Japan, subject to violent atmospheric phenomena, as a means of recording and predicting the same. But, for the purposes of an inquiry into a supply of water to be derived from the distant water-shed of the Sagami, it would not be advisable to apply statistics gathered at Yokohama or Tôkiô, as these places were subject to their own special meteorological influences. Meteorology had not yet become so wide-spread in Japan as to afford engineers information with respect to the less thickly populated, and therefore for water-works purposes, more important districts, as was the case in Great Britain.

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25 February, 1890.

SIR JOHN COODE, K.C.M.G., President,  
in the Chair.

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The discussion upon the Papers by Mr. J. W. Hart, Mr. J. Orange, and Mr. J. H. T. Turner, on Water-Works in China and Japan, occupied the whole evening.