been given full consideration, but the cost of purchasing electric current from the Cairo Electric Company would have rendered that method far too expensive, apart from the fact that there were difficulties in regard to the concession held by the Company. The Author.

Correspondence.

Mr. L. M. BELL remarked that although the opportunity of designing substantial modern works for a large town where there were no older works to be considered and co-ordinated did not now often arise at home, in the East there were still many large towns where drainage was practically non-existent. These towns must be dealt with before long, and the Author's plan of dealing with the drainage of Cairo could hardly fail to be adopted by younger engineers as a model, even if it were not followed entirely. In this connection additional particulars as to the gradients of the smaller reticulation sewers would be of advantage. The only information given under this head was that the sewers had been designed to give a velocity of 3½ feet per second when running half-full. Authorities differed to some extent as to exactly what gradient would give this velocity, but assuming that it was 1 in 135 for a 9-inch diameter circular sewer and 1 in 100 for a 7-inch, these were fairly steep gradients for sewerage works and meant either very short sewers or deep cuttings, with corresponding increase in the cost of the works. It would be interesting to learn why the Author had decided on 3½ feet per second as the proper velocity. Gradients of 1 in 200 for 9-inch sewers were not uncommon in England and appeared to give satisfaction. The Author had had wide experience in the matter, and some expansion of the Paper in this direction would be advantageous. The number of people using the mosque latrines was put at 150,000, giving, at an average of 4·4 gallons per head, 660,000 gallons per day; yet apparently it was only intended to deal with 25,000 × 4·4 gallons = 110,000 gallons per day. Surely the scheme must be very imperfect unless it was proposed to deal with all the latrines, whether supplied with well water or piped water. Except in the better-class houses there seemed to be no provision for domestic latrines. If the present percolation-pits inside the houses were still to receive the drainage of the closet and slop-sinks, the scheme Mr. Bell.

Mr. Bell. must be very far from perfect. In most Mohammedan countries women did not use mosque or public latrines to any extent, and unless the conditions were different in Cairo, these internal soakaways were likely to continue to be used by about half of the population, thus largely perpetuating the present insanitary conditions. A difficulty which Mr. Bell had found in latrines for natives was the practice of using stones or pieces of wood, etc., instead of paper. In accordance with the injunctions of Mahomet, stones were used in the urinals to prevent the clothes from becoming polluted by contact with urine. Road-metal was often used for these purposes. It would be interesting if the Author would say how these practical difficulties had been surmounted in Cairo, if they had arisen there. Possibly the adoption of a velocity of $3\frac{1}{2}$ feet per second might be partly due to such considerations. With regard to the reticulation sewers, Mr. Bell's experience was in favour of nothing less than 9 inches, as less likely to clog even with small flows of sewage. An improvement on the usual practice was the use of 5-inch house-connections in place of the ordinary 4-inch. The necessity for locking the street-gutters to prevent them from being used as dust-bins had a true touch of the Orient. The Author did not say how the gully-traps were to be kept sealed with water in a dry climate like that of Cairo, where evaporation was rapid, and it was probable that traps would be fixed in streets which were only partially paved and not regularly washed down. If this was not attended to, complaints of smell were likely to follow; and even in the paved streets washed down every day evaporation might unseal the trap in less than 24 hours. The disposal of the sewage by irrigation in the desert was undoubtedly the correct method, but it would seem that even less in the way of purification-tanks, etc., was necessary in an isolated position such as Gebel el Asfar. Mr. Bell saw some years ago the sewage-farm at Melbourne, where practically crude sewage was used for irrigation. This was probably the most successful sewage-farm in existence. The crop grown was mainly grass, which was of great value in such a dry climate as that of South Australia. Sheep, bought in a poor condition up-country, were fattened on this grass and re-sold, care being taken, of course, not to foul the grass or to sour the land. The result was very satisfactory financially, and no nuisance occurred. Egypt was no doubt an ideal country for irrigation, but with a native population there were certain risks in sewage irrigation for market-gardens, while grass might be very profitable with less risk. It was satisfactory that the sewage-farm would yield a net return of £10 to £15 per acre annually. It was to be feared that engineers did not always pay sufficient attention to the financial side of these matters. The engineer's duty did not merely consist in constructing fine works; it was equally his duty to see that they were of real assistance to the people they were intended to benefit; and a successful sewage-farm might well make all the difference between success and failure of a whole scheme of sewage-disposal. Mr. Bell.

Mr. C. L. Cox observed that it would be interesting to know whether any preliminary experimental work had been undertaken in connection with the question of disposing of the sewage. As both the final effluent and the sludge were to be applied to the land, the necessity for such complete tank treatment (involving separation of the suspended matter) and for partial filtration was not quite apparent. The soil at the farm would appear to be particularly suitable for dealing with sewage, and he suggested that under tropical conditions, and with such a soil, physical disintegration of the grosser suspended solids would prove to be all that was required. With the high temperatures that must rule in Cairo, and with any considerable length of main sewer, this process, which was essential if nuisance and danger from flies at the farm was to be avoided, would probably be effected in the sewers, and could in any case be effected by suitable tank treatment on quite a small scale. Mr. Cox.

Mr. Harrison P. Eddy, of Boston, Mass., considered that the Author was to be congratulated upon having had the opportunity of providing *de novo* a comprehensive system of sewerage for so large a city. This was very seldom possible in the older countries, and even in a relatively new country it was quite exceptional. The two cities in the United States where this good fortune had fallen to the lot of engineers in recent years were New Orleans, Louisiana, and Baltimore, Maryland, with populations (in 1910) of 339,075 and 558,485 respectively. Probably the fundamental consideration in the case of Cairo which was most interesting—almost startling—to an American engineer was the small quantity of sewage produced, namely, 8·9 gallons per head per day, as contrasted with upwards of 80 gallons[1] produced in the United States by most cities of comparable size. The density of population in Cairo appeared to be about 85 persons per acre—a state of congestion which existed only in small portions or districts of cities in the United States. In 1910 the city of densest population there was Hoboken, New Jersey (population 70,324 in 1910), the density being 85 per acre, Mr. Eddy.

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[1] Imperial gallons (1 Imperial gallon = 1·2 U.S. gallon).

Mr. Eddy. substantially the same as in Cairo. No other city in the United States, however, approached Hoboken in density of population. Baltimore had 29, Boston 27, New York 26, Pittsburg 20, Cleveland 19, Philadelphia 19, Chicago 19, and San Francisco 14. All these cities were nearly as large as, or larger than, Cairo. The high density of population in Cairo offset, in a measure, the small quantity of sewage produced per head, the average quantity being about 756 gallons per acre per day. In the upper-class districts it would be 2,805 gallons per acre per day, assuming that the average density of population applied to those districts. Probably, however, the density there was less than the average density, while in other districts it was more. These conditions would tend to reduce the yield per acre in upper-class districts, and increase it in others. It would be interesting if the Author would state what maximum rates of flow per acre and per head had been provided for, because these quantities governed the sizes of the sewers. Practice in the United States had varied in respect to maximum rates of flow for which provision had been made. Some of the older intercepting sewers had been designed to carry a maximum flow of 188 gallons per head per day. This allowance was now considered too small, and such sewers were rarely designed for less than 250, and often for 292 to 333 gallons per head per day. Trunk sewers were designed upon about the same basis, while sub-mains were designed often upon a somewhat more liberal basis, and lateral sewers upon one still more so. The allowances per acre, of course, depended in part upon the density of population. It was necessary in the United States, however, in most cases, to make allowances for ground-water infiltration and leakage of storm-water through perforated manhole-covers and other openings; for, unfortunately, few, if any, sewers built there were perfectly watertight, and there were many opportunities for leakage of storm-water into them. It was also necessary to provide for a marked increase in the maximum rate of flow per acre in commercial areas (those devoted to office-buildings, retail shops and wholesale houses), and in industrial districts where large quantities of water were used for working lifts, washing goods, and many other purposes. The following Table summarized the allowances which formed the basis of sewer-design recently adopted by the city of Dayton, Ohio, upon Mr. Eddy's advice. The allowances in the Table included 623 gallons per acre daily for the maximum rate of ground-water infiltration. It would be helpful to know the controlling reasons for adopting a minimum velocity of 3½ feet per second, especially in the separate sewers. For combined sewers, which were certain to

Mr. Eddy.

BASIS OF DESIGN OF SEWERS AT DAYTON, OHIO, U.S.A.

(Population in 1910, 116,577.)

Separate System.

	Cubic Feet per Second per Acre.	Imperial Gallons per 24 Hours per Acre.
Maximum rate of flow in lateral and trunk sewers :—		
For residential areas—		
Small lateral sewers	0·0182	9,800
Sub-mains and trunk sewers	0·0071	3,800
For industrial areas	0·0257	13,800
For commercial areas—		
[1] Districts No. 1 and No. 2	0·1000	53,800
Other districts	0·0302	16,300
For parks, etc.	0·0015	800
Maximum rate of flow in intercepting sewers :—		
For residential areas	0·0048	2,600
For industrial areas	0·0234	12,600
For commercial areas—		
[1] Districts No. 1 and No. 2	0·0977	52,600
Other districts	0·0280	15,100
For parks, etc.	0·0015	800

[1] Districts destined to become the commercial centre of Dayton.

NOTE.—These allowances are assumed to be adequate for conditions in 1950, when it is estimated the population may reach 300,000, and the density of population 13·2 persons per acre. The assumed population of Cairo in 1932 is stated by the Author to be 960,000, equal to 127 persons per acre on an area of 7,530 acres.—H. P. E.

receive more or less mineral detritus, such a velocity might be desirable to ensure freedom from deposits. Separate sewers, however, were built quite extensively at gradients which would not afford a velocity of more than 2½ feet per second, and Mr. Eddy had laid and maintained many in which the half-full velocity had been less than 2 feet per second. In a city which was as flat as Cairo appeared to be, this difference in required velocity might much reduce the difficulties of bringing the sewage to the point of final pumping, and perhaps somewhat reduce the expenses of construction and operation. Such an extensive use of the

Mr. Eddy. compressed-air ejector for lifting sewage was unique and of special interest. He was not aware of any installation in the United States approaching this one in extent. While in charge of the sewerage-works at Worcester, Mass. (population 145,980 in 1910), he had been responsible for the working of several ejector-stations, and had found this means of lifting sewage rather troublesome and expensive. The ejectors had been standard Shone machines, but while ostensibly automatic, they had required much attention—in fact, rather more than automatically started and stopped electrically-driven centrifugal pumps. The conditions at Worcester were probably quite different from those at Cairo. In early spring much trouble had been caused by the freezing of the slide-valves and exhaust-pipes, due, in part to the low temperature of the sewage, because some water from melting snow had leaked into the sewers around manhole-covers; in part to low temperatures in the ejector-chambers; and in part to the release of the exhaust air to atmospheric pressure. This latter cause had probably been aggravated by the high pressure required, the lift at several stations being 50 to 70 feet. Another cause of difficulty had been the stranding of pieces of wood, or other material, in the discharge flap-valve in such a manner as to prevent its closing. When this happened the sewage from the discharge-main would surge in and out of the ejectors with much loss of air: this would usually continue until discovered and remedied by the attendant, and in the meantime the compressors were running at high speed, sometimes continuously. In 1906 he made a test of the work performed by the ejectors compared with the power consumed, and found, under the best conditions, an efficiency of only about 17 per cent. He was convinced that under average conditions the efficiency was much lower than this. No doubt improvements had been made in machines of this type in recent years, and conditions in Cairo might be much more favourable to their use than in Worcester; some undoubtedly were. It would be very interesting if the Author would give an account of the experience of working at Cairo, where the conditions apparently were favourable and the installation large enough to warrant the use of more efficient air-compressing equipment than at Worcester. The conditions at Gebel el Asfar, as described by the Author, were certainly ideal for sewage-works, and particularly for broad irrigation. It was gratifying to observe that even under such advantageous natural conditions the Author had taken good account of previous experience, and had provided means for removing much of the suspended matter, which had been a source of trouble in other places. The provision made for the intensified treatment of the effluent from liquefying-chambers was logical. It was a good illustration of the desirability of treating sewage by successive steps, which was becoming more and more common as more accurate knowledge was acquired of the principles involved in sewage-treatment. It was illuminating to consider the duty placed upon the filter—195 gallons per cubic metre per day. Expressing it in another way, 1 cubic metre (1·3 cubic yard) must deal with the sewage of about twenty-two persons per day, assuming 8·9 gallons of sewage per head. At that rate the sewage of 178,090 persons would be dealt with by a filter 6·56 feet deep and 1 acre in area, assuming that the effluent from the liquefying-chamber was no stronger and not more difficult to treat than the average effluent from both sedimentation- and liquefying-chambers would be. Probably the effluent from the liquefying-chamber would be considerably stronger than that from the sedimentation compartments, although the single analysis given indicated that there was little difference in the composition of the two effluents. In the United States 12,000 to 20,000 persons per acre of filter 6·56 feet deep were as many as could be allowed ordinarily with good results, including substantial nitrification such as the Author predicted for the Cairo filter. This difference emphasized the disparity in conditions, chief among which was probably the volume of sewage—8·9 gallons per head per day in Cairo and 83 gallons in the United States. Further, the analysis given indicated a sewage of no greater strength than was common in the United States, where the quantity was very much greater. In conclusion, he wished to express his appreciation of the service rendered by the Author in placing at the disposal of the engineering profession so clear a description of a notable achievement in the field of sanitary engineering. Mr. Eddy.

Mr. C. H. Godfrey considered that the Paper would be of the greatest value to engineers and others who were concerned with the disposal of sewage in Eastern countries; in the West the drainage system of a town generally followed the development of the town itself. The town of Shanghai was at the present moment faced with the same difficulty "of changing at a stroke the long-standing habits of the people," and some particulars of the situation which had arisen might be of interest. The Foreign Settlements were situated about 12 miles above the junction of the Hwangpu river with the most southern arm of the Yangtze-kiang. The Hwangpu had a rise of 8 feet at ordinary spring-tides. The country for many miles around was an alluvial plain and was dead flat, generally at a level of not more than 3 feet above high water of ordinary spring-tides. Mr. Godfrey.

Mr. Godfrey. The foreign population in 1915 was 18,519, as against 13,536 in 1910, an increase of 36·8 per cent. The Chinese population in 1915 was 620,401, as against 488,005 in 1910, an increase of 27·1 per cent. In addition, there was a population of about 400,000 in the Chinese City, which adjoined the Foreign Settlements, giving a total of more than a million inhabitants living 2 miles above the point where the water-supply was drawn from the river. The system adopted hitherto had been daily collection of night-soil from houses, whence it was carried in sealed buckets to certain stations on navigable waterways, loaded into boats, and taken up country for use as manure. The work was done under contract, the contractor providing all labour, buckets, and boats for removing the ordure from every house in the settlement once a day. In 1916 ninety-four tenders were received, ranging from $126,000 to $177,600 per annum, the latter being accepted. At the present rate of exchange, therefore, the Council's revenue benefited to the extent of about £18,000 per annum. Dr. Arthur Stanley, the Municipal Health Officer, had pointed out in 1899 that the Chinese solved the question of economic sanitation long ago by using sewage for manure, wasting nothing, and that to adopt the water-carriage system, and turn sewage into the river, whence the water-supply was derived, would be "an act of sanitary suicide"; but that the flaw in the present system of disposal was that infection of typhoid fever and cholera was not completely prevented. The typhoid bacillus could live and multiply in polluted soil, and both cholera and typhoid fever could infect vegetables when the infective material was applied directly to them. Dr. Stanley's view was that there was no necessity for a costly and elaborate system of drainage, and that the most should be made of the great natural advantage Shanghai possessed in tidal flushing. The following Tables showed the death-rate from 1902 to 1915, and analyses of the water-supply in 1915:—

Year.	Death-rate of Resident Foreign Population.	Death-rate of Chinese Population.	Year.	Death-rate of Resident Foreign Population.	Death-rate of Chinese Population.
1902	18·1	30·9	1909	18·1	17·3
1903	15·9	21·2	1910	20·2	17·5
1904	12·9	19·2	1911	15·9	13·8
1905	11·2	14·2	1912	18·9	19·3
1906	12·3	12·3	1913	18·6	15·8
1907	19·9	21·9	1914	18·0	16·2
1908	18·2	17·2	1915	15·4	13·2

Mr. Godfrey.

SHANGHAI WATER SUPPLY, 1915.

	Solids.		Hardness.	Chlorine.	Nitrates.	Saline Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 1 Hour at 37° C.	*Bacteria per c.c.*	Organisms of the Coli group present per c.c.
	Total.	Volatile.								
January .	15·3	5·4	9·0	2·6	0·0678	0·0013	0·0120	0·0311	60	1·5
February .	17·0	5·8	9·3	3·1	0·0560	0·0016	0·0114	0·0300	120	0·2
March . .	17·2	5·9	9·4	3·05	0·0572	0·0115	0·0118	0·0288	68	1·5
April . .	16·2	5·2	9·0	2·8	0·0560	0·0014	0·0116	0·0300	120	1·5
May . . .	16·0	5·1	9·3	2·6	0·0570	0·0014	0·0117	0·0310	104	1·5
June . .	17·4	5·9	9·1	3·1	0·0560	0·0015	0·0118	0·0280	120	0·1
July. . .	18·4	6·4	9·3	3·4	0·0590	0·0018	0·0119	0·0301	200	0·5
August . .	16·2	6·1	9·4	2·8	0·0562	0·0016	0·0115	0·0300	200	0·5
September .	16·0	5·9	9·3	2·7	0·0553	0·0017	0·0116	0·0320	70	1·5
October . .	18·0	6·2	9·4	3·5	0·0556	0·0018	0·0118	0·0300	88	1·5
November .	..	..	..	..	..	..	..	..	..	..
December .	18·2	6·2	9·3	2·9	0·0580	0·0016	0·0119	0·0320	38	1·5

With a view to safeguard the water-supply, the Municipal Council had passed a by-law prohibiting connection from being made with any drain, public or private, whereby ordure would be discharged into the same, and enacting that no water-closet, cesspool, cistern, or permanent receptacle for sewage should be constructed or used. In 1915 an application from the owners of a large seven-story building for permission to install a system of water-closets was refused; but the Court of Consuls, having jurisdiction over the Council, decided that the by-law was *ultra vires*, though the Council were entitled to refuse to receive into the boats used by their contractor the contents of the tank or cesspool connected with the proposed water-closet system, the periodical removal of which must be provided for by the owners of the premises. As a result of this judgment, a Commission was appointed to draw up rules, which provided for the reception of ordure in private cesspools, the emptying of which was to be undertaken by the Council. In his Annual Report for 1915 the Health Officer pointed out that the main object in prohibiting water-closets had been to safeguard the water-supply on account of the difficulty of disposing safely of the drainage; that if 2,000 water-closets were provided the drainage from them would be equal in volume to the total quantity of night-soil from the rest of the Settlement; and that this dilute sewage being of little use for agricultural purposes, its removal, instead of being a source of profit, Mr. Godfrey. would be an expense falling upon the whole community. Further, that beyond a certain limit it would be impracticable to deal with water-closet drainage by emptying by tank carts and boats, and then it would be imperative to have a water-closet sewage system, which would render it advisable either to remove the waterworks intake to the Yangtze or to adopt a sewage-purification scheme. Such works would be very costly and would present unusual difficulties. As, at the best, only a small portion of the population would have water-closets, whatever sanitary advantage could be claimed for them would not apply to the Settlement as a whole. Dr. Stanley also expressed the opinion that the only real sanitary benefit resulting from the adoption of water-closets and a water-carriage sewage system—namely, the disuse of night-soil as a fertilizer for market produce, with resulting diminution in infectious intestinal disorders, such as typhoid fever, dysentery, cholera, etc.—was practically unobtainable in Shanghai. Applications for permits to install water-closet systems were now coming in rapidly, so that the emptying of cesspools by vacuum carts was not likely to remain feasible for very long. The removal of the waterworks intake to the Yangtze would be a serious matter; even at pre-war prices the cost of laying a duplicate line of 30-inch diameter iron pipes alone would exceed £200,000, and in addition to this there would be the intake, pumping-plant, etc. A great objection to such a scheme would be the danger of the pipes being cut during revolutions such as had occurred in the last few years—in which event the Settlement would be left without water, unless pumping from the polluted river were resorted to. It would thus be seen that "changing at a stroke the long-standing habits of the people" was likely to prove very expensive to Shanghai.

Mr. Hill. Mr. JOHN W. HILL, of Cincinnati, observed that to one who had held to high ideas of sanitation since he had come to know what modern sanitation meant, some features of the former drainage of Cairo, as set forth in the Paper, were astounding. The rainfall was probably seldom sufficient to produce flow in the Khalig, and except during the 3 months of flushing with Nile water this ditch must have been at best an intolerable nuisance in hot weather. Whilst there were still many such sewage-laden ditches in modern cities, it was doubtful if any of them were also sources of water-supply for any purpose. In Cincinnati there was a creek with a drainage-area of 170 square miles, which had a constant though widely varying flow. For more than 9 miles from its mouth this creek was within the city limits and received the sewage from a population exceeding 160,000, together with the drainage and some other wastes from many large manufacturing industries. During the period of dry-weather flow the stream was an elongated cesspool reeking with organic matter in decomposition and giving off during the hot weather large volumes of sewage-gas, which sometimes was very offensive and had given rise to long-continued serious complaint. Steps were being taken to intercept all sewage and factory-drainage into the stream. The public "dumps" would be eliminated, and before many years had passed the creek would be restored to its primitive condition. The low rainfall of Cairo was another interesting fact. That one-half of the rainfall for a maximum year could happen in one day seemed odd to people in the United States, where a rainfall during four consecutive days of one-fourth the average for the year had caused appalling floods, with large loss of life and the destruction of property worth millions of dollars. Indeed, frequent occurrences of this kind, during the past 10 or 15 years, had created such an interest in flood-prevention in the United States that it was now the paramount problem for hydraulic engineers in the district between the Appallachian Mountains and the Pacific Coast. Many populous and prosperous cities lying in the flood-zones must be protected from floods or they would be threatened any year with destruction. A rainfall of 2 inches in 24 hours (equal to the maximum yearly rainfall for Cairo) was not unusual in the vicinity of Cincinnati, and storm-water sewer problems were now being developed on that basis. It was not quite clear to Mr. Hill why the drainage pumped from the sewer-trenches in Cairo should have been a menace to the Nile water. The flow of the Nile was large, the water pumped from the trenches was a naturally filtered sewage, and the dilution by the water percolating into the trenches must have been great; it would seem, therefore, that no harm could result from pumping into the Nile the water from the sewer-trenches. Perhaps this matter was not fully explained in the Paper. If the Nile water was used unfiltered by consumers below Cairo, and also by Cairo this should have been stated; any possible addition to the sewage pollution of the river by the water pumped from the sewer-trenches could have been corrected by modern methods of filtration. Concerning water-filtration to eliminate turbidity and throw down or intercept the suspended matters—and incidentally to reduce or practically remove the bacteria, pathogenic and other—it must be remembered that the germ of the so-called American or rapid method of filtration had its origin in the use by the ancient Egyptians of clay to clarify the muddy waters of the Nile, and render it acceptable for potable purposes. The Author laid some Mr. Hill.

Mr. Hill. stress on the use of a single line of 36-inch cast-iron pipe, $1\frac{1}{4}$ inch thick, for the rising main to the disposal-works. Considering the low working-head (a maximum of 109 feet, equal to 47·2 lbs. per square inch) and the excellent quality of the iron, there should be no anxiety about this pipe. Cast-iron pipes were often used for inverted sewage-siphons under streams and in other places, and Mr. Hill had never known a case of failure, due to either internal pressure or erosion. The complex nature of domestic sewage was such that acids, alkalis, and undecomposed greases largely neutralized the effects of each other, and the deleterious effects of any ingredient were seldom shown in sewers which had been long in service. Indeed, the greases from domestic sewage seemed to be most in evidence in old sewers which he had examined, and where erosion had been noted it had been due to the heavy solids brought into combined sewers by storms—a condition which it would seem could not arise in the 36-inch cast-iron rising main.

Lieut.-Col. Jones. Lieut.-Col. Alfred S. Jones, V.C., remarked that both Mr. Baldwin Latham and the Author had recognized the necessity of dividing the area into several distinct sections, to the centre of each of which the sewage produced therein could be led in properly-graded pipes without sinking that central point to an unreasonable depth; and the Author had wisely chosen compressed air in preference to hydraulic pressure for lifting and sending the sewage forward from those centres to the common sewage-outfall. But a great "tank-sewer" (one of the faults of old systems of sewerage) 14,900 yards in length on the flat gradient of 1 in 2,500, appeared to be laid along the lowest part of the drainage-area as the destination of the sewage, under the name of a "main collector," leading to a main pumping-station at Kafr el Gamus, whence the sewage had to be pumped a distance of $7\frac{1}{4}$ miles through a rising main, to an outfall well or badly chosen as the case might be. The question arose whether one or other of the lifts already given in the sections might not have been utilized by adopting a higher level for the collector, instead of pumping the same sewage twice or more times in its course to the outfall. As an old advocate of the separate system for European sewerage districts, Colonel Jones could not see how separation need be of any account at Cairo with hardly any rainfall at all: indeed, he would rather admit Nile water to dilute Cairo sewage and flush the collector; and he was surprised to find no mention of such an expedient in the Paper. He had but little personal knowledge of Cairo and its neighbourhood, but he believed that some point on one of the irrigation-canals which abounded in the valley of the Nile might have been found at a less distance than 7 miles from Cairo and at a lower elevation than 109·88, which appeared to be the distance and level of the outfall selected at Gebel el Asfar. In a country like Egypt, where countless generations of fellaheen had been utilizing Nile water in the growth of vegetation of all kinds, it seemed superfluous work for an English engineer to attempt purification of sewage by any artificial means, which had been proved inferior to natural means by 17 years' examination and reports of the late Royal Commission on Sewage Disposal. It was manifest that the cultivators who now used Nile water from such canal would soon find advantage from an addition thereto of sewage, thus to be disposed of without cost to the Cairo ratepayer. And if no such convenient canal-outfall could be found, and if pumping to the Gebel el Asfar sewage-farm must be resorted to, the crude sewage, with any dilution desired by the cultivator of that farm, might be applied to the land at his discretion. Therefore he desired to enter a protest against any idea that the Paper represented useful work beyond that very good and necessary part which related to the removal of sewage from the populated area of Cairo. It appeared to him that the engineer in this case had yielded to the clamour of a fastidious cosmopolitan population anxious to have the sanitary arrangements of their foreign residences provided exactly according to the latest fashions they had read of as being employed in England and America. The terms "colloider," "liquefying-chamber," "hydrolyzing-chamber," and "sedimentation-chamber" used in the Paper seem to imply some such desire to be "up-to-date," because those technical terms appeared in a Paper[1] in the Proceedings in which highly artificial treatment for sewage was contemplated in cases where land could not be had so easily as in Egypt. Lieut.-Col. Jones.

Mr. G. B. KERSHAW considered that it would have been of interest had the Cairo "pre-drainage" mortality statistics been given, for subsequent comparison with future figures after all connections had been made. The soil and subsoil appeared to contain an appreciable quantity of salt: had any special precautions been taken to prevent corrosion—due to electrolysis—from taking place through the formation of carbon-iron couples? He would be glad to know the calculated average time taken by the sewage to reach the purification-works when the full flow of sewage was Mr. Kershaw.

[1] Lt.-Col. A. S. Jones and Dr. W. O. Travis: "On the Elimination of Suspended Solids and Colloidal Matters from Sewage." Minutes of Proceedings Inst. C.E., vol. clxiv, p. 68.

Mr. Kershaw. being dealt with, and whether the bulk of the sewage would not be in a septic condition on its arrival at the works. In connection with the system of tank treatment adopted, he noted that the total combined tank-capacity admitted of a stay in the tanks of 6·2 hours. Was it proposed to shorten this stay in hot weather? Concerning the figures of analysis given for the crude sewage, tank-liquors, and straining-filter effluent, were these based upon "average" samples—drawn according to the rate of flow—or upon "chance" samples? Mechanical analyses of the soil and subsoil of the farm would have been useful as indicating the amount of suspended matter which the soil was capable of receiving without clogging. Soils of a barren sandy character were almost invariably deficient in humus, and benefited accordingly by the application of very large quantities of sewage and of sludge. Seeing that the farm and works were far away from any inhabited place, and that the prevalent wind was from the north, it would be of interest to know whether the application of crude sewage to the land was considered feasible—at all events for the first few years the farm was in operation—thereby applying the sludge evenly to the land during ordinary sewaging operations, and obviating the necessity of tank treatment and of handling the sludge twice? In this connection he would like to know whether the direct treatment of crude sewage on the land, carried out in April, 1914, had proved in any way unsatisfactory. He assumed that the effluent from the farm would all disappear by evaporation, transpiration, and absorption, and that underdrains were not provided. Was it anticipated that these might eventually become advisable in order to assist nitrification? Records of the temperatures at various depths of the soil and subsoil, taken after the farm was in full working order, should be of considerable interest in connection with nitrification.

Mr. Roechling. Mr. H. Alfred Roechling observed that foremost among the novel points contained in this very interesting Paper was the astonishing figure of the estimated dry-weather flow of 10,613,000 gallons of sewage in 24 hours from a prospective population of 960,000 in 1932. Such a flow was equal to about 11 gallons per head per day, and he could not remember at the moment any large town in which the daily flow was so small. In England the figure usually adopted was about 30 gallons per head per day, and in America the flow was considerably larger. Hence it was not possible to draw any comparisons between Cairo and other towns, especially as to the cost involved, without making ample allowance for this great difference. Treating Cairo as a separate and independent unit, and dealing first with the conception of the scheme as a whole, it appeared to him to be somewhat lacking in unity of design. There had been, in fact, not one scheme but a number of schemes on different principles. He could have understood this if the main drainage of Cairo had been the growth of years, extended and added to at different times by different authorities in succession; but as the Author stated that he had designed the scheme *de novo*, that explanation did not apply. More than thirty schemes had been submitted before the Author was appointed, and it might be that this absence of uniformity was due to the fact that the Author had incorporated in his scheme the best features brought out in the previous ones. Dividing the drainage of Cairo into two main sections at Pont Ghamra, there was below that point a combined pumping and treatment scheme, but above that point there were several schemes, embracing all known methods of collecting rain-water and sewage. To separate the rain-water from the sewage first and then to mix the two again did not appear on the face of it a rational proceeding. A velocity of $3\frac{1}{2}$ feet per second in all sewers when flowing half-full was in excess of what was generally held to be necessary, and might have led to extra pumping; and the advantage gained was doubtful at the time of the average flow, when owing to the small depth of the sewage heavy suspended matters would be left behind on the invert. To pump both the rain-water and the sewage several times over might not be economical. Any sewerage scheme must be in keeping with the requirements of the locality and was governed by them, but he did not think that the physical conditions of the surface of the ground in the Nile valley at Cairo were so diverse, and the slopes so cut up, as to call for so many varieties. A complicated apparatus was as a rule more expensive than a simple one and was also more liable to get out of order. In connection with this point it must be borne in mind that the International Commission, about the year 1892, came to the conclusion "that the only system suitable for Cairo was a combined system, by gravitation, with one main pumping-station," and that notwithstanding the fact that one of the Commissioners, Mr. James Hobrecht, was then carrying out a large scheme of radial or sectional drainage for the City of Berlin. Coming now to individual characteristic features of the scheme, and starting at the low end, there was first the sewage-farm at Gebel el Asfar with a total area of 3,114 acres, a preliminary-treatment plant consisting of six hydrolytic or Travis tanks for 11 million gallons in 24 hours, and four percolation-filters for about 2 million gallons, and in addition a storage-tank for 1,166,000

Mr. Roechling

Mr. Roechling. gallons for the night flow. Everyone would agree that the only rational treatment of the Cairo sewage was land treatment, and as there would be practically no effluent from the land, all that had to be done was to concentrate attention on the crops, so as to produce a handsome revenue. It was all the more surprising, therefore, to find that preliminary artificial treatment had been considered necessary, involving considerable expense, and that the authorities had only taken over what must in the circumstances be considered a very small area, when they might have had an unlimited area for the mere asking. He estimated that after making all necessary deductions for houses, roads, tree-belts, and sewage-carriers, the rate of treatment would be about 5,000 gallons per acre, which with a large quantity of rain-water at times might lead to undesirable conditions. The 36-inch rising main, taking a usual maximum velocity of 3 feet per second, could discharge about 7,900 gallons per minute, and as the estimated future maximum dry-weather flow was 11,458 gallons per minute, it would be necessary, in order to cope with this flow, to increase the velocity in the rising main to 4·32 feet per second, which was for ordinary working conditions—as a daily contingency—a somewhat excessive velocity. With a velocity of 3 feet per second, the rising main could discharge 11,432,448 gallons in 24 hours, but as the main intercepting sewer or main collector could bring forward 27,894,902 gallons per day, it was clear that in addition to the estimated daily dry-weather flow of 10,615,000 gallons the rising main could only take a very small volume of rain-water, the remainder of which, unless other provision—not mentioned in the Paper—had been specially made for it, would have to back up in the main collector and thus transform it into a reservoir. And what would happen if repairs had to be carried out on the rising main, necessitating the total stoppage of the flow of sewage? In such a case, too, the main collector would have to act as a reservoir, with the danger of silting up. The system was working apparently without any factor of safety, if he might use that term, and in his opinion it would have been better to lay a duplicate main, which would have given, at all events, some factor of safety in case of accident. The total capacity of the main pumping-station at Kafr el Gamus was not given in the Paper, so that he could form no opinion whether it was sufficient for its purpose. Taking the main collector, he did not think a velocity of 3 feet per second would be obtained after it had been at work for some years. From considerable experience in the matter of the velocity in large sewers, he was of opinion that Kutter's formula gave very fair results, and, using it, he found that the velocity, when flowing full, was only about 2·39 feet per second, which gave a discharge of 19,371 gallons per minute, or 27,894,902 gallons in 24 hours. Deducting from 19,371 gallons per minute the estimated maximum future dry-weather flow of 11,458 gallons per minute, the collector could only accommodate 7,913 gallons of rain-water, not 14,643 gallons per minute, as stated in the Paper; but even this quantity might probably be sufficient for some time. With regard to the cross section of the main collector, he could not help thinking that to lay an unreinforced-concrete sewer 5 feet 3 inches in diameter in such treacherous ground was a very bold proceeding, and he concluded from the Paper that great difficulties had been experienced. He had seen a large unreinforced-concrete sewer in ground of this nature that had first shifted about and finally collapsed completely. Unless specially provided for in the contract, such a method of construction would, in his judgment, inevitably lead to large extras. The storage-capacity of the collector was about 6 million gallons, which was equal to about 9 hours' maximum flow without rain, and in that case the pressure at the outlet end would be about 8 lbs. per square inch. What would be the result of that pressure on the sewer? In case of accident, the drainage of Cairo would be seriously interfered with, and in his opinion a duplicate sewer would have given some relief in that event. With regard to house-drainage, he noticed that the Author proposed to do away with the disconnecting trap, so as to be able to ventilate the street-sewers through the house-drains. There was a good deal to be said against such a proceeding. The opposition to the disconnecting trap originated probably in Germany, where sanitarians ridiculed the views expressed in this country that sewer-gas could produce zymotic disease, especially typhoid fever and diphtheria—views which had necessitated the introduction of the trap. But even in Germany it had never been contended that sewer-gas was perfectly harmless. The German view was based upon the contention that it had never yet been possible to prove the presence of specific pathogenic germs in sewer-air. In connection with this, however, it must be remembered that it was not yet possible to assign to every specific effect its true specific cause; and further, that the methods of investigation and the apparatus used therein, though greatly improved, were anything but exact. Smells could be detected by the nose which could not be established by analysis, Mr. Roechling.

Mr. Roechling. and it had been stated that the sense of smell in man was at least a million times more delicate than the most refined of physical tests, such as the spectroscope, and probably a thousand million times more delicate than the most refined tests of bacteriology. That sewer-gas or sewer-air was harmful when it escaped into houses admitted of no doubt, and he thought it was against common sense to do away with the means of preventing its entry into houses. It had been contended that a disconnecting trap must always be a nuisance. That, however, was proved to be wrong by experience gained in millions of cases; when the trap did prove a nuisance this was due to local faults. It had also been stated that there was more sewer-gas in house-drains than in street-sewers; but when that was the case it was due to faulty design or careless maintenance, which should not be tolerated. He was reminded of an incident that occurred in a town abroad, where the disconnecting trap had been abolished. An influential company had been invited to witness the opening of a large new storm outfall system, and near the outlet into the river, far below the town, a repast had been provided in a large junction-chamber decorated for the occasion; but just as the company were about to partake of the good things an abominable smell travelled down from the town, which quickly and effectively emptied the chamber. There would always be smells in public sewers, and they could not be avoided. In the case of Cairo the sewage in the main collector would probably be in a putrefying condition, and as the connections with branch sewers were made at a level of 2·62 feet above the invert, there would probably be a good deal of splashing at times. This would disengage the noxious gases and distribute any germs that were in the sewage, and if air laden with these matters travelled up the smaller sewers, it might, in the absence of disconnecting traps, find its way into the houses. Matters of health called for the greatest care, and in his opinion it was far better to be over-cautious than to run risks which could easily be avoided. In conclusion, he had already pointed out that the cost of the Cairo main drainage, owing to the extraordinarily small flow of sewage, could not be compared with that in other large towns without making ample allowance for this difference. Remembering that the Cairo works were not yet quite complete, that probably no money had been paid for the land for the sewage-farm, and that the rising main was hardly sufficient, etc., and dividing the total ultimate cost not by a population of 960,000 but by about one-third of that number, he thought it would be found that the cost of main drainage in European towns compared very favourably with the cost in Cairo, Mr. ISAAC SHONE observed that the Paper revived his recollections of a visit to Egypt in 1884—a year following a severe visitation of cholera—when he had opportunities of discussing with Sir Colin Scott-Moncrieff, the Under-Secretary of State for Public Works in Cairo, the question of the application of the Shone system to Cairo. He was asked to show how it could be applied to some of the houses abutting upon the Khalig, and he had a vivid recollection of a visit to that noisome ditch, which in parts resembled a big open railway-cutting with a sewage-sodden bottom. He submitted a scheme for diverting the sewage of the Khalig houses from the bed of the Khalig and discharging it into a sewer, and he also prepared drawings and estimates of small experimental test works in connection with the drainage of Alexandria and Port Said. Owing, however, to the fact that the Egyptian Government could not then see its way to make it compulsory on the part of all the inhabitants of the towns named to contribute towards the cost of new drainage-works, nothing was done. In perusing the Paper he had been struck by the disparity between the volume of sewage discharged by the population occupying the houses of Class A and those occupying the houses of Classes B and C; the former were estimated to discharge 33 gallons and the latter only 2·2 gallons per head per day—thus the daily total volume proceeding from the population of the houses under Class A amounted to 71·6 per cent. and that from the population of Classes B and C, although comprising 84·5 per cent. of the total population, amounted to only 25·9 per cent. Of course, where the volume was 33 gallons per head per day, that volume discharged into properly sized and graded house-drains would preserve them in a self-cleansing and sanitary condition; but the smaller volume of 2·2 gallons would not possibly render any ordinary house-drain self-cleansing and sanitary in its everyday working. An apparatus had been specially designed to deal with such driblets of sewage as evidently must be dealt with in the houses of classes B and C, and would be described in the forthcoming second part of Mr. Shone's work on "Sewage-Drainage Systems." Mr. Shone.

Mr. H. O. B. SHOUBRIDGE remarked that the point to which attention was at once drawn, in connection with the main drainage of Cairo, was the consumption of water assumed in 1932, namely, 11 gallons per head per day. This was an extremely low figure for an underground sewerage system, and in the Bombay Presidency it was now considered unadvisable to introduce an underground system with less than 15 gallons per head per day. Where the gradients were flat and extensive flushing had to be resorted to, Mr. Shoubridge.

Mr. Shoubridge. 20 gallons per head was considered the absolute minimum. In large towns the consumption of water might amount to between 30 and 40 gallons per head. The population of Cairo had been assumed at 960,000 in 1932, and no doubt it had been considered whether, in a city of that size, the consumption might not eventually greatly exceed the 11 gallons per head assumed. The reason for the small consumption was stated to be the high rate charged for water; but it was difficult to believe that that cause even would restrict the growing use of water in a city of the size of Cairo. It had been found in some Indian cities that the water-closet system grew in popularity with time, and this alone led to a large consumption of water. The figure assumed hardly appeared to be liberal enough. It was stated that the subsoil of the city consisted of highly plastic clay and sands of considerable thickness. It would be interesting to know whether any special measures had been taken to prevent settlement or movement in the smaller gravitation sewers, e.g., laying them on a bed of concrete, or completely encasing them in concrete. It would be useful if the Author would give the ruling gradients adopted for the glazed-earthenware pipe sewers. Cairo was particularly lucky in having a very low rainfall, which rendered the discharge of surface-water through the sewers a comparatively easy matter. It would also be of interest to know whether any difficulty had been experienced with the engines on account of grit. In Indian systems it was now found necessary to exclude as much surface-water as possible on this account, and settlement of the sewage before pumping was being introduced. In connection with the main pumping-station, had the bucket dredgers proved entirely successful in removing the heavy solids from the detritus-pits? The detritus in Indian sewages was sometimes found to be too stiff a material to flow towards the dredges, with the result that a vertical channel was dredged out, and hand clearance had to be resorted to periodically. It was advisable in such cases to provide a means of clearing the whole area of the detritus-pit, and a grab-bucket might prove more advantageous.

Mr. Thomson. Mr. Gilbert Thomson thought that all engineers who had to do with sewage would envy the Author the opportunity of designing a scheme which covered the whole field from house-drainage to sewage-disposal. This allowed the whole problem to be treated as one, and avoided the complications often caused by divided jurisdiction. It was specially interesting to observe that the ventilation of sewers was to be carried out through the house-drainage, and that no intercepting traps were to be provided. This decision was opposed to the usual home practice, enforced by the regulations of most local authorities; but on the other hand it embodied the conclusion which had been reached after a long and minute investigation by a Departmental Committee of the Local Government Board. That investigation had not borne out the opinion on which the usual practice was based, that the air (or gas) in sewers was more dangerous than that of individual drains. Everyone agreed that in any case the house-drainage system should be airtight, and if this condition could be fulfilled there was no reason for the intercepting trap. His own experience was that this condition could be fulfilled, and that it was best permanently ensured (1) by making the whole system, drains as well as vertical pipes, of cast iron; and (2) by proving its air-tightness by means of air-pressure and a pressure-gauge. No test was sufficiently reliable which depended on the detection of a testing agent, such as smoke, in the act of escaping. If the abolition of the intercepting trap in Cairo were accompanied by a high standard of construction and testing, it would be a valuable object-lesson. Much of the work described was adapted to conditions not usually met, but much of it was readily applicable to other conditions. Mr. Thomson.

Mr. J. W. Tomlinson remarked that as the omission of intercepting traps was altogether different from the practice commonly adopted in England, it would be interesting to know what considerations had induced the Author to fly from slight, known evils to evils that were unknown. The reasons must have been very cogent, especially as Cairo had a hot, dry climate, the quantity of water supplied was, for most of the town, exceedingly small, and the domestic gully would be far more likely to be dry than to contain its proper seal of water. The question of the proper ventilation of a sewerage system was extremely important. The object of the installation of such a system was essentially to safeguard the health of the community, and the engineer had to exercise great care to ensure that in removing sewage from domestic premises he was not at the same time supplying sewage-gas to them. In England this danger was obviated by the use of the intercepting trap, introduced between the sewer and the private house-drain to cut off the air in the latter from the air in the former, and Mr. Tomlinson did not think there was much question that it did its work efficiently. The problem was thus divided into two, the proper ventilation of the smaller and more stereotyped house-drainage and the ventilation (if desirable) of the larger and more varying network of main sewers. Under pressure from the Local Government Board the house-drainage was ventilated (or supposed to be) on a certain uniform plan throughout England; at any rate certain ventilating-shafts and fresh-air inlets were uniformly supplied. The Mr. Tomlinson.

Mr. Tomlinson. main sewers, however, were for the most part left unventilated, and, strangely enough, no one seemed to be much the worse! A ventilating-column erected here and there on the outskirts of the district as a sacrifice to public opinion was common enough: the cross-sectional area of the column was invariably inadequate for any really effectual ventilation; but the engineer rested content that he would have no complaint unless someone objected to a ventilating-shaft. Any possible trouble arising from air-lock in case of storm was readily provided for by means of trapped outlets of ample size. In short, the common practice of municipal engineers (though they would not always admit it) was to do without ventilation, and the results obtained were not likely to induce them to vary from that practice. Was it possible that this plan was wise, and that it was undesirable for the objectionable sewer-gas to be distributed among the community when it was quite simple and perfectly healthy to keep it bottled up? At all events, it would be helpful to many to learn the Author's views of the question, and to know what had prompted the authorities in Cairo to diffuse sewer-gas over the dwellings of the people when that could easily have been avoided by following the practice invariably adopted in English towns.

Dr. Travis. Dr. W. Owen Travis thought the Author would admit that the Paper by Colonel Jones and Dr. Travis, presented to The Institution some years ago,[1] which had had some influence in modifying the views held in regard to the principles of sewage-purification, had been responsible in no small measure for the method of sewage-treatment applied in Cairo. Having spent 3 months of every winter in Cairo between 1907 and 1914, and having had special opportunities for studying the drainage problem as a whole, Dr. Travis could speak with some knowledge in regard to the necessity for the scheme, its importance, and the efficiency of the sanitary procedures adopted. The difficulties encountered in constructing the main collector and sump had appeared for some time to be almost insuperable, but a very anxious and onerous period for both the Main Drainage Department and the contractors had been safely negotiated. The question of dealing more effectively with the sewage-gas in the main collector and larger gravitating sewers would in all probability arise in the immediate future, owing to the large volume and putrescent character of the sewage. The problem of disposing of the sewage of Cairo became simple when it was

[1] "On the Elimination of Suspended Solids and Colloidal Matters from Sewage." Minutes of Proceedings Inst. C.E., vol. clxiv, p. 68.

decided to take it into the desert, where an ample sandy area was available. A natural filtering area of practically unlimited extent for filtering sewage as well as for draining and drying sludge having been provided, the installation of plant for artificial sewage-treatment could be limited to the separation of the suspended solids, and to the treatment by artificial media of a small portion—the stronger part—of the sewage, in order that the effluent carriers should be clean, and the admixed liquids made as inodorous as possible. For carrying these objects into effect the hydrolytic tank had been considered by the Author to be the most suitable apparatus. In this form of tank the separation of the suspended solids contained in the sewage flowing through sedimentation-chambers was expedited and more completely effected by the downward projection of the lower 20 per cent. of the liquid. This volume carried the suspended solids out of the sedimentation-chambers into a liquefying-chamber, where time was given for their settlement, and out of which the liquid passed, through a further chamber for resettlement, before flowing on to the filters. The submitted analyses of the sewage and tank effluents, when compared as a whole, showed a removal of 87·2 per cent. of suspended solids and 70·5 per cent. of albuminoid ammonia. Dr. Travis.

Sir Arthur Webb.

Sir ARTHUR WEBB, K.C.M.G., congratulated the Author on his very interesting Paper, and the Egyptian Government on obtaining, after 30 years of discussion of different proposals, a definite and, in all the main points, complete system of drainage for Cairo City. Although occupied at the time with the construction and administration of many irrigation-works in Egypt, he had been quite aware of the numerous difficulties presented to his predecessor, Sir William Garstin, and the Author in deciding on the final scheme. One scheme had been to pass the main under the Nile and deliver the sewage on the cultivated land in Gizeh near the Pyramid Road; another to take the main over the Delta Barrages to the Wardan estate, which was then being reclaimed from the desert: other schemes had also been proposed, but he was quite convinced that the site chosen for the final disposal of the sewage was undoubtedly the best. Much of the land around Kafr el Gamus was cultivated, not only by native but also by European subjects, and anyone conversant with land-tenure in Egypt knew that it was not possible even to scratch desert land within several miles of Cairo without coming into collision with an owner, who would very quickly claim compensation in the courts for any disturbance. Not being an expert on sewage-disposal he hesitated to criticize the Author's scheme, but having been called in as arbitrator between the Egyptian Government and the contractors

Sir Arthur Webb. on the construction of the main collector, he had taken the opportunity of inspecting the works very carefully during their execution. The difficulties encountered in the construction of the main collector in the last sections of its length had been very great. The quantity of water dealt with had been much in excess of any anticipated, and at the pumping-station of Kafr el Gamus the foundations had been executed under the same unfavourable conditions. That the works had been soundly completed was very creditable to both the engineers and contractors engaged. At the same time, it had occurred to him that it might have been preferable and more economical to place the site of the pumping-station much nearer Cairo, and thus avoid the great depths in the foundations of the main collector and pumping-station which had been the cause of the trouble with the subsoil-water. The Author had probably a good reply to give to this suggestion, but it would be interesting to know that it had been considered and why it had been rejected. Again, it would be useful if the Author would state why he had decided to adopt the compressed-air system instead of electricity; Sir Arthur Webb understood that at Alexandria the opposite course had been taken. As his staff had inspected the construction and erection of the machinery in the shops, he was pleased to learn that the final trials in Egypt had been so satisfactory. From a personal visit to the shops during the erection of a portion of the engines he had been satisfied that the quality of the material and the workmanship was of the excellent British standard for which the makers were known. The Author had rightly drawn attention to the fact that, after his scheme was approved in 1909, he had, a year later, to modify his arrangements for the disposal of storm-water, for the reasons set forth on p. 68. It certainly seemed to be opposed to all modern principles that the responsible engineers of the Egyptian Government should have allowed the Water Company to draw water from the Nile below the surface-water outfalls. It would be much too long a story to explain why the Government had arranged a few years previously with the Water Company to abandon their intake from the Nile for the drinking supply of the city and erect a large new pumping installation down-stream of the town, dependent on wells. The wells failed to give the anticipated supply; the distribution-pipes in the town became filled with a fungus which threatened to completely block them; the inhabitants disliked the water; and a Committee, of which Sir Arthur Webb was President, was formed to examine the whole question. It was decided to go back to the Nile, but it was with the greatest reluctance that the Committee were forced to recommend the use of the new pumping-station on the site of the wells. Undoubtedly the final solution must be a new installation, up-stream of Cairo and its suburbs; in the meantime, for financial reasons alone, the supply had to be taken down-stream of the town, as there was no other pumping installation. A good deal of the financial success of the scheme must depend on the ultimate annual revenue derived from the sewage-farm at Gebel el Asfar, which the Author estimated at £E30,000 at least. Even if the 167 miles of sewer reticulation were completed within the next 4 to 5 years, and the development of this sewage-farm proceeded *pari passu* with the extension of the sewers, it would be somewhat premature to rely too much on such a large revenue for some years. His experience was that the full development of desert land required much experiment, patience, time, and money; and there was for some considerable period a constant battle against the drift sand caused by violent storms. However, the results up to the present had certainly been promising, and a considerable revenue might reasonably be expected. In order to obtain the true financial aspect of the scheme, it would be necessary to take into account the accumulated interest on the capital expenditure; unfortunately, owing to financial stress due to the war, the completed scheme would be delayed, and consequently further accumulation of interest would continue; it was thus too early to express any opinion on the financial results likely to be obtained. He had been told lately by Sir Murdoch Macdonald, Under Secretary for Public Works in Egypt, that in the area where the sewers had been completed and the scheme was in operation there had already been a very marked improvement in the sanitary conditions. He had every reason to suppose that this improvement would continue, and that when the whole scheme was completed it would obtain the success which was due to the years of labour and life the Author had expended upon its preparation and execution. In connection with the statement that the whole cost of the scheme has been paid out of the Government surplus revenue Sir Arthur Webb would mention that funds had accumulated for some years in the coffers of the *Caisse de la Dette Publique*, which could not be used for works in Egypt without the consent of the Powers. It was due to the far-sighted statesmanship and policy of Lord Cromer, a very distinguished Honorary Member of The Institution, in arranging the *entente cordiale* with France in Egyptian affairs that these funds had been released and placed to the account of the general revenue of the Government, and had thus been made available for the execution of this scheme and many other engineering works which had been of immense benefit to the inhabitants of Egypt.

Sir Arthur Webb.

Mr. Willcocks. Mr. G. W. WILLCOCKS asked, with regard to the statement that all sewers were laid at gradients giving a velocity of $3\frac{1}{2}$ feet per second when running half-full, whether the Author expected the volume of sewage would be sufficient to maintain this depth for any considerable period daily in each sewer, or meant that the sewers were laid at such gradients and of such sizes as to be capable of producing the effects mentioned without taking into account the volume of liquid likely to pass through the sewers. It was essential to adjust the sizes and gradients of sewers and drains to suit the actual flow, not some assumed discharge which might never occur. The quantity of sewage per second was therefore an important factor when dealing with the question of the sizes and gradients of sewers and drains.

Mr. Williams. Mr. G. B. WILLIAMS observed that the rainfall of Cairo was remarkably scanty and in great contrast with that of the large Indian cities with which he was acquainted. In Calcutta the maximum rate of rainfall recorded during the past 7 years was 3 inches in 20 minutes. More than three times as much rain fell on that occasion in Calcutta in 20 minutes as fell in Cairo in an average year. This fact would alone show how different were the conditions to which the sewerage system in Calcutta had to conform, and it would readily be understood that the Calcutta sewers had been designed of vastly greater capacity than those in Cairo. In the consumption of water there was also a great difference. At Cairo the water-supply per head was very small. The consumption per head of filtered water in Calcutta was about two and a half times that in Cairo, and of unfiltered water twice that in the latter city. What the unfiltered water was used for at Cairo did not appear. It did not seem to be used for flushing latrines or drains, although if there was an unfiltered supply at all it would be supposed that, in some cases at all events, it would be real economy to use it in place of filtered water for these purposes. The small consumption of water in Cairo was apparently largely due to the supply being in the hands of a company, who presumably saw that there was no serious waste that was not paid for. The fact that waste of water was, in the case of a municipal waterworks, waste of the ratepayers' money had so far been very imperfectly appreciated by the municipal authorities in India. On the other hand, the supply at Cairo seemed to be too scanty: an average of only 2·2 gallons per head to the persons supplied from the street standpipes was much too little for a capital city in a hot, dry climate. It was very unfortunate that some of the most important features of the drainage scheme had had to be changed in the midst of the work of construction. Whatever the circumstances

Mr. Williams.

which had led to the discharge of surface water into the Nile being forbidden, the result of making this radical alteration so late in the day was a very complicated arrangement of surface-water drains, gravitation sewers, and ejectors, which he must confess to not being able to follow altogether from the Paper. Without local knowledge it would be presumptuous to criticize the general design of the scheme, but there were a few points which struck him as requiring further elucidation. The scheme had been designed for the prospective population at the end of 25 years from the time when it was commenced—that was 16 years hence. He presumed that by that time the areas actually served by the main sewers would have been fully developed, so that no further increase in the population on those areas was likely to take place subsequently. In a scheme of this magnitude, which had taken about 10 years to carry out, it could not be contemplated that any part of the system of sewers would require duplicating 16 years after completion of the scheme. Perhaps the Author would state rather more clearly than he had done the provision made for subsequent further expansion of the scheme. The whole scheme seemed to be based on the supposition that the present sanitary system of Cairo was to be perpetuated. That system apparently was that one-sixth of the inhabitants were to live under European conditions with an ample water-supply, and all modern conveniences in the way of baths, water-closets, etc., whilst the remainder of the inhabitants were to have no private connections to houses for water or drains, and the men were to continue to resort to the public latrines, whilst the women and children were apparently to use dry closets connected with internal percolation-pits. The latter one would expect to be filthy and insanitary. The Author did not need to be informed that the policy now adopted by some of the larger Indian cities was different. The European system of water-carriage drainage required considerable modification to adapt it to Oriental conditions; but when once a properly designed sewerage-system had been introduced, the policy, in Bengal at all events, was to make as much use of it as possible. The Calcutta Corporation had possibly pursued this policy rather too rapidly, and in general substitution of connected water-closets for insanitary hand-service privies, it had been found that in some cases the water-closets would cost more than the total value of the houses they were required to serve. On the other hand, a policy which acquiesced in the continuance of a very large number of insanitary internal closets and percolation-pits seemed to require some explanation. Supposing that within the next few

Mr. Williams. years the water-supply of Cairo were to be increased, the cost of water reduced, the private closets transformed, and the number of private water-supply connections doubled or trebled, it looked as if the whole of the new sewerage system might be found inadequate. This must have been considered in drawing up the scheme; and it would be interesting to know what had led to the decision to work on the lines chosen. The advantages of the sectional pumping system at Cairo were presumably sufficiently obvious, when the scheme was drawn up, to warrant its adoption. One reason appeared to have been to prevent the sewers from being laid at more than a certain arbitrary depth below the surface of the ground. The necessity for making the sewers so shallow, comparatively speaking, was not apparent. The subsoil did not seem to be worse than that of many other cities situated on alluvial deposits. Another reason for sectional pumping had no doubt been to get the velocity of 3½ feet per second when the sewers were flowing half-full. This was no doubt an ideal state of things in an Oriental town, but Mr. Williams found its attainment generally impossible, except at prohibitive cost. A daily dry-weather velocity of 3 feet per second was therefore the standard he generally worked upon for cities in the plains, and occasionally even this had to be relaxed somewhat. The examples given by the Author showed that in the main sewers the 3½-feet-per-second standard had not in fact been worked to. A sewer 33 inches in diameter at a gradient of 1 in 1,500 had nothing like this velocity. Without wishing to suggest that the Shone ejector system was not suitable to or necessary for Cairo, he could not help mentioning that elaborate systems of sectional pumping were occasionally proposed where they were not required. He had an example in the Bengal Presidency, in a sewerage scheme for Dacca which had been worked out for the late Government of Eastern Bengal and Assam, and which came under his jurisdiction after the repartition of the Bengal Province in 1912. Under that scheme, which, though on a smaller scale, was in some respects not unlike the Cairo scheme, the city of Dacca was to have been divided into a number of comparatively small sections, from which sewage was to have been pumped by either electricity or compressed air. On going into the question *de novo*, he had found that sectional pumping was unnecessary for any part of the town, except two small outlying areas which would probably not require sewering for a number of years; and the scheme as it now stood was a straightforward one for main sewers gravitating to one pumping-station. The velocities in the sewers were actually better than those that had been proposed in the sectional pumping scheme, whilst the depths of the sewers had not been appreciably increased. The total estimated capital costs of the two schemes did not differ much, but the working-costs were much smaller in the present scheme than in the project first put forward. Mr. Williams.

The AUTHOR, in reply, observed that the prospective population at the end of 25 years had been adopted as the basis of the scheme because the extension of Cairo within the drainage-area could only take place over a limited area. The Nile bounded the city on the west, hills and large cemeteries on the south, and the Ismailia Canal on the north. The present extensions were largely in the neighbourhood of Giza and Ghezira, and could never come into the present scheme, leaving the suburbs of Zeitun, the Heliopolis and Shubra for future extension within the drainage-area. The Author.

As to the adoption of a velocity of 3½ feet per second in pipe sewers, his experience was that Oriental sewage was heavily laden with solid matter, because Eastern races invariably cleansed their cooking-utensils with road-detritus, earth, or sand; and these ingredients, often mixed with grease, went straight to the sewers and formed an exceedingly difficult substance to remove, unless the velocity of flow was specially good. Cairo did not differ from other Eastern cities in this respect. In the native districts water was used so sparsely that it was of paramount importance to increase the gradient of pipe sewers so as to get as self-cleansing a velocity as possible at all times. Again, water for flushing purposes was very expensive in Cairo. It was proposed to remodel all mosque latrines, and also to provide numbers of public conveniences. All these would have catch-pits and gratings to retain road-metal and other heavy substances. The Drainage By-laws provided for the filling-in of the existing percolation-pits when a house was connected with the sewer. In asphalted or paved streets the traps of the surface-water gullies were renewed by the washing-down of the streets. In unpaved streets the gullies were filled with sand in the dry season. As to preventing the settlement of pipe sewers, the soil of Cairo was generally close alluvial ground, but wherever the ground necessitated it the sewers were laid on a bed of concrete, and at certain depths they were encased in it. The Crimp-Bruges formula had been used in all calculations for sewers. So far no trouble had been experienced with grit in the valves of the pumps, neither had there been any difficulties in removing detritus from the screening-chambers by the bucket elevators. No special pre-

The Author. cautions had been taken to prevent the corrosion of cast-iron pipes. Such pipes, which had been in the soil of Cairo for 50 to 60 years, showed little deterioration.

He regretted that he had not at hand the necessary information to answer some of the questions raised by Mr. Eddy. He had not found that compressed-air ejectors gave much trouble. Occasionally an ejector was stopped owing to the inlet-valve being blocked by wood or sticks, but in that case the alternating gear caused the sister ejector to do the work, and further, all pipe sewers were connected at their heads with adjoining districts to provide against the worst happening. The efficiency of the system had often been disappointingly low in the past; but the report of the "overall efficiency" of the Cairo scheme so far was good, it being given as 40·2 per cent., or 5·2 per cent. in excess of specification.

The reason why the subsoil-water from the trenches had not been pumped into the Nile was that the subsoil and subsoil-water of Cairo were strongly impregnated with the sewage of many generations, and were often very objectionable. The Government forbade any discharge into the Nile because the intake of the Water Company was near to and below the city. This matter was explained in the remarks of Sir Arthur Webb (p. 132). No unfiltered water from the Nile was used for potable purposes, though the Water Company supplied it for road-watering and gardening.

An alteration in the position of the main collector, as suggested by Colonel Jones, would have meant the extension of the sectional system to the whole of the suburbs, and would have seriously added to the expense of the scheme, both in capital and maintenance, besides being bad engineering. Arrangements had been made to flush the main collector at its head with Nile water from the Ismailia Canal. The canals in Egypt often contained the only drinking-water available for the villages and towns, all else being brackish; and a suggestion to use any of these canals for the discharge of sewage, even if highly purified, would rightly meet with strenuous opposition.

With regard to Sir Arthur Webb's suggestion that the main pumping-station might have been constructed nearer Cairo, thereby saving a considerable length of expensive main collector, several schemes had been prepared for the consideration of Government. In one a pumping-station had been proposed at Ein el Shams station, 2 miles nearer Cairo than the existing site; and in another a site at old Heliopolis, still nearer; but both sites had been emphatically objected to, because of the proximity of dwellings and the fact that the city was extending in that direction. The question of electric pumping had been fully considered and rejected, first, on account of the cost, and secondly, because of the undesirability of having a number of pumping-stations all over a large area of the city, to which screening-chambers would necessarily be attached, and from which the screenings would have to be removed by hand, leading almost assuredly to nuisance. The Author.

The average time that sewage took to travel to Gebel el Asfar was 6 to 7 hours. It was not proposed to shorten the period of tank treatment. The analyses given were based on average samples. No underdrains had been necessary so far at the sewage-farm, nor was it anticipated that they would be.