Discussion.

The PRESIDENT remarked that the Paper described the latest addition to that chain of important engineering works in Egypt of which, he thought, British engineers and British contractors might well be proud. The work, as would be seen from the figures given in the Paper, was a large and important one, and it seemed to have been done in the remarkably short time of 3 years. The President.

Mr. A. G. VAUGHAN-LEE, after showing on behalf of the Author, who was still in Egypt in charge of the barrage during the maintenance period, a number of lantern slides illustrating the progress and construction of the work, remarked that the barrage formed one of the important features of the scheme of irrigation-works being carried out and contemplated in the future. Egypt's present population of about 15,000,000 was increasing at the estimated rate of 750,000 every 5 years, so that considerably more water would be needed during the summer than was available at the present time. For that reason the Assuan dam was being raised and strengthened a second time, and it was also proposed to construct another big dam and impound water at Gebel Aulia on the White Nile, about 25 miles south of Khartoum. The latter work had been projected now for several years, and had been designed several times to suit different requirements. He himself had designed it twice; but politics as between the Egyptian Government and the Sudan Government, as well as other reasons, stood in the way of its commencement. No doubt it would have to be undertaken in the course of a few years, because there was bound to be a shortage of summer water for the supply of the increasing population of Egypt. Those two schemes, the second raising of the Assuan dam and the construction of the Gebel Aulia dam, would, roughly speaking, provide storage for 4,500 million cubic metres of water; and he understood that the additional water obtained by the second heightening of the Assuan dam was practically earmarked for further irrigation needed in the Delta and Lower Egypt, while Gebel Aulia would supply Upper Egypt with water for perennial irrigation. When those two works were completed it would be possible, with the help of certain pumping-stations now in course of construction, to have Egypt under perennial irrigation from Luxor down to the sea. At the present time there was no perennial irrigation above Asyût except in patches where pumping-stations were established, representing no very large acreage. In 1925 the then Minister of Public Works in Egypt, Sir Ismail Sirry, Pasha, a Mr. Vaughan-Lee.

Mr. Vaughan-Lee. very able engineer, who had been the moving spirit in getting the Gebel Aulia dam and the Nag Hammadi barrage into shape, asked for the preparation of designs and contracts for those two works. The idea was that the Gebel Aulia dam should be undertaken first and the Nag Hammadi barrage afterwards, but that order had been reversed. The original designs for the barrage, prepared in Egypt, had had to be modified considerably before his firm considered them suitable. Cast-iron piling had been proposed, copied from the Asyût and Esna barrages. In connection with copying he might tell an amusing story. In 1890 he was engaged on a work in Cumberland in which cast-iron sheet piles were used, and in his enthusiasm he made a working drawing of these piles and showed the methods used in driving them. The piles used on the Asyût barrage were identical in design with those used in Cumberland. They would be found illustrated in the second edition[1] of Sir William Wilcocks's book "Egyptian Irrigation," even to certain mistakes in spelling. Mild-steel sheet piling had been adopted throughout for the Nag Hammadi barrage, in place of cast iron. One of the alterations made was the adoption of 6-metre instead of 5-metre openings, with a view to economy, and that modification had made it possible to shorten the barrage and get it entirely into the existing bed of the river without an embayment on the east bank, which had been tried at Asyût and Esna and had given trouble through silting. The downstream toe of the barrage had had to be modified, because the proposed design, while very strong, would have been costly and rather impracticable. It had consisted of a blockwork wall carried well down into the bed of the river, and the slopes of the excavation had been designed at about $2\frac{1}{2}$ to 1. Those slopes would never have stood at that inclination, and the upstream slope would have undercut the aprons of the barrage and led to much confusion in carrying out the work. The sluice-gates of the barrage were, after all, the most important thing in the undertaking, next to a secure foundation. He had tried to make the rollers of the gates as large as possible, because nearly all moving parts of gates on the Nile became filled with silt, seized, and required constant attention. Large rollers enabled the gates to move with a minimum of friction, and they should be so designed in regard to their attachments that they could be taken off and replaced without trouble. The first thing he had done was to seek the aid of the late Sir Wilfrid Stokes, M. Inst. C.E., of Messrs. Ransomes and Rapier, who had given him a rough sketch of the largest roller that could be got

[1] London, 1899.

into the gate. Its diameter worked out at 22 inches, although he had asked for 24 inches. Having got the rollers settled he had been able to proceed with the general design of the grooves and other matters in connection with the gates and piers. Another important feature of the sluice-gates was the arrangements for raising and lowering them and for getting them out. Two machines were installed on the barrage, each of which could lift a gate clean out of the work, so that it could be put on a trolley and taken away for repairs; which could not be done elsewhere in Egypt. He thought the work was the first in Egypt in which mild-steel sheet piles had been used on a large scale, and they had proved very successful. He believed they had been used in India, on some of the large weirs on the rivers in the Punjab. The lock-gates and swing bridge had been erected by Messrs. Arrol in Great Britain before being sent out. In one of the photographs he had shown on the screen, water could be seen coming out from underneath the concrete foundations; that was an interesting indication of how not to do a thing. It had been found during the first season's work that, owing to the absence of continuous close sheet piling right around the foundations, seepage water rising underneath the foundations came out on the upstream side of the latter and brought sand along with it. Luckily, on the upstream side a solid mass-concrete apron had been substituted for the flexible blockwork apron along that short length of the barrage, for reasons connected with the progress of the work; so that it was possible to obtain a seal and thoroughly grout the small area beneath the foundations thus affected. Having noticed that defect in the first season he had instructed the contractors to drive the two lines of short continuous steel sheet piling along the upstream and downstream extremities of the solid aprons, which had stopped all seepage from underneath the foundations and enabled every part to be grouted up solid. It was very important that foundations of that description on sand should be surrounded with continuous sheet piling when subjected to a slight head of water. Another important feature of the construction was the use made of overhead cableways. They were about the longest ever made and the most useful tools he had ever seen on a job. They had handled all the concrete, rubble, and dressed stone, transporting from the banks to the working-sites. They had generally worked right through the 24 hours. Although the Author was designated Assistant Resident Engineer, he had originally been appointed by the Engineers as Technical Adviser to the Egyptian Resident Engineer. The Egyptian Government had wished to have an Egyptian Resident Engineer, and it was very lucky that the Egyptian Government

Mr. Vaughan-Lee.

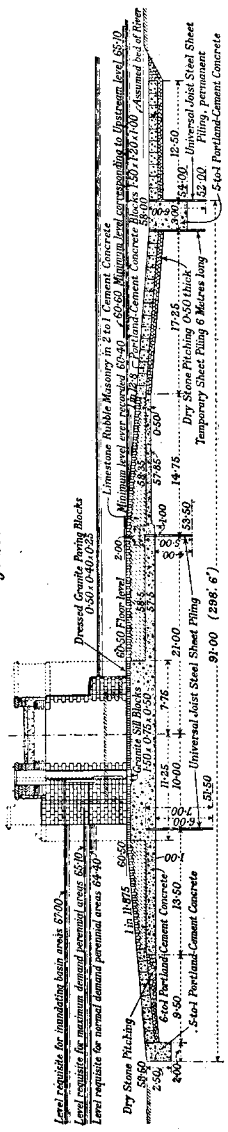
Mr. Vaughan-Lee. selected Neguib Bey Ibrahim for that post, as he was a very able engineer, who had received his technical education at Birmingham University and had been most tactful in his dealings with all concerned. No serious troubles or disputes had occurred during the execution of the works, and it had been what could be termed a "happy" job. They had been fortunate in having as main contractors a firm like Sir John Jackson, Ltd., who had selected their staff with very careful regard to experience, not forgetting the social side of the community at Nag Hammadi; and they were an able and hard-working lot of men.

Mr. Buckley. Mr. A. B. Buckley wished to elaborate a few of the points raised in the Paper. The first concerned the location of the barrage. For certain reasons it had had to be placed somewhere near the spot where it was built, and at that site there had always existed a bad shoal which greatly impeded navigation, the channel passing from the right bank to the left. Examination showed that canals could be taken off conveniently at that place, and it was that combination of circumstances which had fixed the site of the barrage. *Fig. 10*, reproduced from one of the contract drawings, illustrated a section of the barrage which applied for 80 per cent. of its length. The barrages of a similar type on the Nile were all built on sand, and any abnormal velocity eroded the bottom; all the other barrages had given trouble on that account. The Nag Hammadi barrage worked at about twice the head of the other Egyptian barrages. A deep hole had been discovered in the rubble apron downstream of the Esna barrage in the first year of its use. That had been repaired by filling with loose rubble and then finishing off with a layer of concrete blocks. When it came to designing the Nag Hammadi barrage it was thought best to incorporate the same blocks in the design. Difficulty had been found in practice with the horizontal floor existing in the other barrages. At the end of the floor there was always scour, and the best thing to do was obviously to slope the floor. Thus in the Nag Hammadi barrage, under the conditions of head shown in the Figure, which were about the worst possible as regarded erosion, the sectional area of the river at the downstream end of the solid apron was nearly double that adjacent to the barrage, with consequent diminution in the velocity of the water. The top level of the floor had been obtained by trial and error, care being taken to avoid undue obstruction of the flow of the river when in flood. Its thickness was governed by the weight required to exceed any upward water-pressure that might occur. The Author had referred to a hydraulic gradient of 1 in 18 as preventing the flow of water under the barrage. He

Mr. Buckley.

thought the Author meant the prevention of harmful flow of water under the barrage, because there was always some flow. In that connection he had made a filtration experiment with a trough, 90 feet in length and U-shaped in section, with a stand-pipe at one end to provide a head of water. The trough was provided with flanges at the top running for its full length on each side. Sand of the kind encountered in the work was placed in the trough, the top of which was closed by a continuous sheet of rubber running for its whole length and having its two edges bolted down to the flanges by means of continuous strips of steel of the same length as the trough but no wider than its flanges. That provided a flexible covering to the sand to be tested. A strip of $\frac{1}{4}$-inch steel plate, slightly less in width than the space between the steel strips, was then laid on this flexible cover along the whole length of the trough, and was loaded so as to impart an equally-distributed load of 1 kilogram per square centimetre to the top of the sand in the trough. That arrangement permitted the flow of water through the sand under hydrostatic pressure, the sand itself being under pressure from the above-mentioned loading. The experiment was continued for $4\frac{1}{2}$ months, and the result agreed very well with Mr. Allen Hazen's experiments. The actual velocity of flow through the sand was 27 per cent. less than that given by the Hazen formula. Actually for that length of trough the rate of percolation was $6\frac{1}{2}$ feet per 24 hours, 8 feet in 24 hours being quite common in slow sand filtration. Having found that agreement with Mr. Hazen's experiments, and applied the result, he had concluded that it was practically certain that under the Nag

Fig. 10.



Hammadi barrage, when working under its full head at a hydraulic gradient of 1 in 18, there would be a flow of about 2 feet in

Mr. Buckley. 24 hours—that was to say, one-quarter of the rate of filtration of the ordinary water-filters in England. Under those circumstances it was necessary to have everything as permanent as possible, and the Consulting Engineers had very wisely put in a cut-off trench which was absolutely permanent. That trench had cost £70,000, or 3½ per cent. of the cost of the barrage, which was a small insurance premium to pay for a feature which seemed to have prevented much damage when the mishap mentioned by the Author occurred. Coming to the length of the barrage, the original design, as Mr. Vaughan-Lee had said, provided for 5-metre arches. The Author stated that that had been altered to keep the length of the barrage within the width of the river. With 120 arches of 5 metres the barrage would have been only 38 metres longer and would still have been well within the width of the river. The extra cost would have been 5 per cent. The longer span of the gates meant higher relative cost. The whole steelwork equipment of the Esna barrage, where the area of the sluice-gates was only 6 per cent. less than at Nag Hammadi, had cost £98,000, as compared with £245,000 for the latter, though the cost of such steelwork had not increased in that ratio since the Esna barrage was built. There was another aspect of the 6-metre arch which should not be overlooked. The gates were not attached permanently to any winch; they were hung on chains from the decking joists of the barrage by means of slotted plates slipped on to the links. The chains stretched, and therefore the gates usually hung out of level, thereby causing one of the staunching-bars to bear heavily against the cast-iron grooves. When a gate came to be picked up, that want of level had to be adjusted, usually by the "feel" of the gate; and in that respect the greater weight of the 6-metre gates was a disadvantage. When the barrage at Esna was first used chains had been broken through lack of experience on the part of the men working the winch. The older barrages had hand winches, and the men could tell what was happening by the feel of the winch, but with power-driven winches that was not possible, and the chains might be broken. As to the general cost, the Esna barrage contained 164,000 cubic metres of masonry of all kinds, as against 292,000 cubic metres in the Nag Hammadi barrage. The overall rate for the masonry in the latter worked out at 43 per cent. more than for Esna, but the cost of the steelwork at Nag Hammadi was two-and-a-quarter times as much as at Esna. That indicated how little real economy had been achieved by the adoption of the 6-metre arches. Before settling the design which came to London, it had been considered whether it might not be advantageous to

Mr. Buckley. adopt the cylindrical type of weir with very wide openings—much longer than 6 metres. That would have meant greater concentration of loads on the piers, which was undesirable on a sand foundation of that kind. Openings of big span were advantageous where rapidity of operation was essential; but that was not the case in Egypt, where about 15 days' notice was available of the arrival of a flood, giving ample time to open a barrage. In fact he failed to find that any advantage could be expected to accrue from the introduction of the 6-metre arches in the design. At the Asyût barrage the gates were not heightened because there was difficulty in maintaining the minimum summer level, but for the purpose of facilitating the regulation of the water-level during the flood. The Author stated that with a flood normal in height, but 15 days late on the falling river, the value of the crops would be at least 20 per cent. less than if the flood had been up to time. Mr. Buckley did not understand that, because the tendency nowadays was to delay the inundation of the areas which were dependent on the flood. A late flood was helpful in enabling delay in opening the canals leading water to the basins and thus saving the cotton crop which was sometimes grown therein. The basins, which numbered about 270, were large tracts of land. The largest of them, Delgawi, was 45,300 acres in extent, or about two-thirds of the area of the county of London. The average area of a basin was about 3,700 acres. The tendency was to grow cotton in the basins, and that cotton matured just when it was desired to fill the basin. The basins took time to fill, and in 1925 it was found that the period by which the entrance of the water into the basins could be delayed, in order to save the cotton, was about 7 days; a delay of 15 days in the time of the river would have been a great help. Turning to some details of construction, according to the original plans the excavation at the Nag Hammadi barrage would have been 261,000 cubic metres, but it was actually only 212,000 cubic metres, 19 per cent. less. At Asyût it was 1,113,000 cubic metres, and at Esna 1,527,000. The smaller figure at Nag Hammadi was due to the relatively high level of the foundations, which meant economy in excavation, and had greatly facilitated the contractors' work. With regard to pumping-plant, while 65,400 gallons pumped per minute was required at Asyût only 38,500 gallons per minute was required at Nag Hammadi. Perhaps the Author would say how much cement had been used for grouting the foundations, and what was the head of water on the piles when the mishap occurred and the piles were undermined. There was a reference to a small grab for removing stones from the cut-off trench, which was a little mystifying. How had it happened

Mr. Buckley. that the stones in the trench occurred in sufficient quantities to necessitate clearing by grab? The diameter of the sluice-rollers was very important. He thought it would be found that the effort required to close the gates against the maximum head of water was only about 20 per cent. less than their actual weight, and the larger the rollers the less was the effort required. Would the Author state the diameter of the rollers—an important matter in view of the increased head? Finally, he desired to congratulate the consulting engineers on the pleasing design which had been produced. Although he was not an advocate of the 6-metre arch, he admitted that it gave a lighter and improved appearance to the barrage. He wished also to congratulate the contractors, who had had to cope with an entirely new type of design. They had introduced entirely new methods and accomplished their task successfully. The Paper contained much information which could not fail to interest many engineers.

Mr. Reed Mr. H. A. Reed remarked that the point with which he wished to deal was the width of the openings in the barrage, and he approached that question from the point of view of navigation. During the time when the first length of the barrage was under construction, he had passed down the Nile in the course of an inspection for the Egyptian Government regarding inland navigation, and he had found that at both the Esna barrage and the Asyût barrage the navigation was very difficult. It would be gathered from what Mr. Buckley had just said that the barrages were put at a point where the full width of the river was available for discharge, usually at the downstream end of a long, straight reach, with a fairly uniform section, where important training-works would probably be unnecessary. In all cases the barrages had been placed at the end of a straight reach where the river had widened out, and the low-water channel had crossed from one side of the river to the other. The result was that at Asyût, for example, a great deal of dredging had had to be done at the entrance of the lock above, and much difficulty had been encountered. In the Nag Hammadi case the river ran for 8 or 9 kilometres close to the desert on the right bank (Fig. 1, Plate 10), and then the low-water channel crossed over; and the lock had been placed on the left bank. It might be that the channel below the lock would be good, but he was quite sure there would be great deal of difficulty in future in getting the low-water channel to run from the right bank across to the lock at the left bank. With regard to navigation, the levels had been cut very fine. The Author stated that the minimum summer level of the river was R.L. 60·20, and the level of the lock-sills was at 58·50, "thus giving a minimum depth of 2 metres of water." That, however, was really only 1·70 metre, and perhaps the Author would explain the discrepancy. When Mr. Reed was at the barrage the low-water level was 60·50, which would give 2 metres; but even 2 metres was very little for the river traffic. The larger sailing boats drew 2 metres in the ordinary way, and when the water was low they had to load light. Mr. Buckley had spoken as an advocate of 5-metre vents, and the consulting engineers favoured 6 metres. Mr. Reed thought that much larger sluices might be put in—say, at least 20 metres. There were many barrages in India with sluices of that width and more. On one occasion when visiting the Rhine he had found seven such sluices in a barrage in course of construction across the river Neckar, some of them of the cylindrical type; and on another occasion they were making a barrage in the same river at Heidelberg with only three sluice openings, he thought of 50 metres width. With 20-metre openings for the sluices and the same aggregate length of discharge as at present, the Nag Hammadi barrage would be 650 metres long from side to side, including the lock; which would save 23 per cent. in width. The river in the long straight reach above was about 600 metres wide, so that probably with 25-metre openings the barrage would be equal in length to the width of the river. It would then be possible to put the lock on the right bank, where the low-water channel was stable, and then, as far as navigation was concerned, he thought the whole difficulty would disappear. At the same time, a barrage 20 or 25 per cent. shorter would be much cheaper than the barrage as built; he agreed with the Author that the 6-metre vents adopted at Nag Hammadi were more economical than 5-metre openings, for they permitted a considerable saving in masonry. **Mr. Reed.**

Mr. W. T. Halcrow remarked that the increase of the vents from 5 metres to 6 metres appeared to be a very small advance in view of what had been done elsewhere. An outstanding feature of the work was the proof afforded of the utility of rolled steel piling both for temporary and for permanent work. He did not know when that form of piling had been first adopted for general engineering use, but it was probably not more than 25 years ago. Before that time cast-iron piling had been frequently used, and he had been engaged on work nearly 30 years ago in which cast-iron piles 28 feet in length were substituted for timber piles, which could not be driven owing to the fineness of the sand. The great objection to cast-iron piling was that much care had to be taken in driving it. In the case to which he had referred, a solid copper dolly had been used, and, working with a restricted fall of the pile-hammer the **Mr. Halcrow.**

Mr. Halcrow speed of driving had been very slow. There was no doubt about the superiority of mild-steel piling, except perhaps from the point of view of permanence, on which point the estimated life given to it by the late Sir Maurice Fitzmaurice was interesting. A wise precaution had been taken in making the main cut-off in the form of a concrete wall enclosed between two lines of piling. It might be possible to make piles of, say, cast steel which would have a much longer life than mild steel, and by using them for the main cut-off such awkward trench work as had been carried out might be avoided. As to the trouble caused by scouring around the ends of the leading piles in the construction of the sudds, it might have been advantageous to cover the whole of that area in advance with a layer of stone, to prevent erosion during the flood season. He noted that holes had been scoured to a depth of 5 or 6 metres below foundation-level, which must have caused some anxiety to those in charge. Again, would it have been possible to stop the construction of the piers at a height just sufficient to allow work to be carried on during the low-flow season? In that way during the flood season there would have been a larger area to pass the flood-water. He gathered that the piers had been carried right up to springing-level at the same time as the area of the first or second season's work was cut off by the sudds. With regard to difficulties in preventing the sand from getting away from under the foundation during construction, he took it that the references on p. 359 were to the sumps only, and he imagined that a considerable amount of grouting must also have been carried out over the whole floor. That was mentioned on p. 361, and it would be useful if the Author could give some more information about the grouting required to fill cavities under the floor. He had had some experience of foundations on fine sand, and on one occasion he had put down some sumps in the form of cylinders and sealed the bottoms with straw, sand, gravel, and broken stone. But he had found that when the filter was made sufficiently compact to prevent sand from coming to the pump it prevented the water also, and the water started to boil up in various parts of the foundations. In that case the sand was so fine that 75 to 80 per cent. of it passed through a 76 × 76 cement sieve. The Author might give some indication as to the nature of the sand at Nag Hammadi.

Mr. Foy. Mr. E. R. Foy remarked that the Paper afforded some parallel between the works carried out in Egypt and modern works in India, especially in the Punjab. During the last 9 years the Punjab Government had built four barrages across a river, each of the four being comparable in size and in details of design with the one described in the Paper. As he had had the honour of being closely connected with those works, he need not say how interesting the Paper was to him. On p. 341 the maximum head during flood was given as 4 metres, and yet a little lower down on the same page it was stated that the afflux was 40 centimetres. Surely, if the river was in full flood, the gates would be up, and the only head then was the afflux; so that that point seemed to need a little explanation. On p. 342 reference was made to a hydraulic gradient of 1 in 18. In the Punjab the gradient taken was 1 in 15. Mr. Buckley had spoken as if the slope served the purpose of a filter. For his own part he did not think that the medium traversed represented the conditions of a filter; the flow was not infiltration, but a matter of creep between two different materials—the concrete or the piles and the sand below it or around them. However good the construction might be, there was always a little space through which water must pass, and for that infinitesimally fine joint he thought the best gradient was 1 in 15—at least, it was so in the particular cases with which he had had to do. It depended very much on the quality of the sand, but he agreed with Mr. Buckley that it was not possible to stop that flow, though its velocity could be reduced. He was sorry to notice the estimate by Sir Maurice Fitzmaurice that the minimum life of mild-steel piles was only 100 years, because he was afraid the Punjab Government would have some qualms if it were thought that the piles put in on its works would only last for that period. But it would be interesting to know how that estimate had been arrived at. In the Punjab the old practice had been always to build weirs on a line of wells run straight across from one bank of the river to the other and sunk to the necessary depth—25 feet or 30 feet, or whatever it might be. On that slab of masonry the crest of the weir had been built, and, of course, all the piers and abutments had been founded on wells; but in the latest works in the Punjab steel piling had been introduced for the first time. He wished to compliment Mr. Vaughan-Lee on the location of the piles in the work at Nag Hammadi, which he thought was an improvement on the work in the Punjab. There the piles under his direction had been placed, at first, in a single row immediately under the line of gates, and then a thick slab of masonry was placed over that; but he now thought that to separate them and to lay the slab between was better, and he believed that would be done in all future works. The question of gates had been touched on by more than one speaker, and on that point he would only say that in the Punjab the latest gates were 60 feet long and about 16 feet high. Those single gates held up 16 feet of water. Of course, there Mr. Foy.

Mr. Foy. were no arches across; there was a steel-girder roadway, and with the Stoney-gate counterbalance above, it appeared a very light and airy-looking structure. With reference to the question of the gates, there was 708 feet of waterway blocked by the piers of the Nag Hammadi barrage, as against less than 200 feet in the works with which he had been associated. He imagined that the conditions in Egypt had been laid down by the Government. The wider gates were, of course, more expensive, but the extra cost of them was certainly less than the sum saved on masonry in the Punjab. Mr. Buckley had referred to what he considered some dangerous conditions. Mr. Foy's own opinion was that the most dangerous condition was when the river below the barrage was empty or very low, and the water was impounded above. There was always someone foolish enough to lift all the gates and let the water out in a wave, instead of passing a little out through each gate at a time. The result was disaster down below and the formation of those scour holes of which Mr. Buckley had spoken.

Dr. Lowe-Brown. Dr. W. L. Lowe-Brown considered that in no sphere was the doctrine of evolution so true as in Civil Engineering. The Nag Hammadi barrage was the lineal descendant of a long line of weirs and barrages; it came of good stock and should be a worthy representative of the family. Although it had a strong resemblance to some of its ancestors, it differed from them sufficiently to deserve a place in the records of The Institution. It was a pity that the Author had not laid more emphasis upon the substantial differences between the conditions that the Nag Hammadi barrage was intended to meet and those for which its predecessors had been designed. In Figs. 3, Plate 10, he had given a comparison between the foundations at Nag Hammadi, Asyût, and Esna, but that figure did not show the relation between the floor-level and the river-bed. It was only by reference to other sources that Dr. Lowe-Brown had been able to find out that, whereas at Asyût the floor had been placed 1 metre below the average level of the river-bed, at Nag Hammadi it had been placed 2 metres above it for the greater part of its length; that was relatively 3 metres higher. But that difference was not so fundamental as the fact that the barrage had been frankly designed for flood-regulation as well as for regulating the low Nile, whereas Asyût had been built before the idea of flood-regulation had been thought of. Flood-regulation was due to the late Sir Arthur Webb (then Mr. Webb), M. Inst. C.E., who first tried it at Asyût. He had been very bitterly criticized at the time, but in spite of that he had persisted and proved that it could be successfully done. He was glad to have an opportunity of putting on record the facts of the case, because Sir Arthur Webb

Dr. Lowe-Brown.

had never received the credit due to him for that bold innovation. In the early summer of 1902 the reports from up-country made it evident that the flood would not be high enough to reach large areas of land under basin irrigation north of Asyût, with the consequence that the crops from them would be entirely lost. Mr. Webb, who was Director-General of Reservoirs, saw that if he could only raise the level of the water entering the Ibrahimia canal just above the Asyût barrage by about 1 metre, those crops could be saved. It would be a simple matter to shut down the gates of the Asyût barrage against the flood and to raise the level by more than 1 metre; but the idea of obstructing a mighty river like the Nile in flood was considered by most irrigation-engineers to be heading for disaster. Mr. Webb knew that the barrage had not been designed for flood-regulation: the downstream aprons were neither wide enough nor strong enough to resist the scour, and there was considerable risk that the new barrage, of which he was very proud, would be washed away. On the other hand, if it were successful, many thousand feddans of crop would be saved, and that would mean a gain of £600,000 to the country. The barrage itself had cost about £720,000, excluding subsidiary works, so that if it could only hold up for a few weeks, any damage that might be caused would be more than offset by saving the crop. Mr. Webb decided to put down the gates and let the flood flow over them. As a precaution he collected 5,000 cubic metres of rubble, to use in case the scour of the downstream aprons became serious, and boats were kept in readiness to load up should occasion arise. Dr. Lowe-Brown was in charge at Asyût at that time and, on Mr. Webb's instructions, he had arranged for soundings to be taken every day. For a few days there was no change, but when the flood gained in strength erosion commenced. When the soundings showed a hole 4 or 5 metres deep over a considerable area, the boats were ordered to load up and begin to throw in the stone. It was then found that the current was too strong and the water too rough for the boats to get into the proper position, even when assisted by a hawser attached to the top of the barrage. It had not been possible to get into touch with Mr. Webb, who was on a tour of inspection, so Dr. Lowe-Brown changed the plans. The stone was collected on top of the barrage. An improvised overhanging gantry, which would travel along the top of the parapets, was built in two nights and a day, and the stone was thrown in as fast as possible. The scour had by then increased the depth of the hole to 11 metres, but as soon as the stone began to go in, the current was diverted and the hole began to fill. The success of Mr. Webb's plan was complete, Dr. Lowe-Brown. and flood-regulation became a recognized means of dealing with a poor flood. The necessary corollary was to strengthen the downstream apron considerably, to be ready for a similar emergency, and Dr. Lowe-Brown understood that that had been done; so that the Figure in the Paper did not represent the present condition at Asyût, but only that which existed when the barrage was first built. The idea of building two barrages south of Asyût was, he understood, the direct result of Mr. Webb's success with flood-regulation at Asyût. The first design for the Asyût barrage had been a compromise between the Delta barrage and some old Indian weirs. According to that plan the barrage was to have had a floor 2 metres thick, supported on shallow brick cylinders. Sir Benjamin Baker discarded the brick cylinders and substituted a raft 3 metres thick, protected both upstream and downstream by cut-off walls of sheet piling reinforced with impermeable aprons to increase the hydraulic gradient. That was the first big advance in the design of barrages founded on sand. There were two fundamental differences between the design of the Nag Hammadi barrage and that at Asyût: first, the higher floor-level, and second, the fact that Nag Hammadi had been specifically designed for flood-regulation, whereas Asyût had not. The higher floor-level, while rendering construction easier, had the effects of reducing the water cushion downstream, of increasing the velocity considerably, especially in the earlier part of the flood, and of increasing the afflux, which, he believed, had been underestimated by the Author. The provision for flood-regulation had had the effect of making it necessary to strengthen the foundation against increased shock and scour downstream, so that there was ample justification for the considerably heavier and longer apron downstream. The reason for extending the apron upstream was not quite so clear, but the object was presumably to provide against scour from cross currents which might be introduced by the use of low-level vents. The use of granite for paving the floor and for facing the piers was a distinct improvement as compared with the limestone used at Asyût, which he understood had not stood well under the scour.

The Author. The AUTHOR, in reply, stated that, in speaking of a hydraulic gradient of 1 in 18 as preventing the flow of water under the barrage, he had meant "harmful" flow, as Mr. Buckley assumed. Mr. Buckley was also correct with regard to delaying the flooding of the basins to enable the cotton crop to ripen; but, in the basins served by the Nag Hammadi barrage, the area of land planted with cotton was only a small portion of the total area, and at present it was economically unsound to prevent the early sowing of the other crops for the sake of the cotton crop. Early flooding also meant The Author. more fertilization of the ground, due to the rich silt carried by the early part of the flood. He considered that the power-driven machines for lifting and lowering the gates, fitted with gear for equalizing the tension in the lifting-chains, were superior to hand-operated winches. In fact, the Government engineer in charge of the machinery, who had formerly been at the Esna barrage, considered that they were not only preferable but also safer in working. It was an interesting fact that the hand winches at Asyût and Esna had been fitted with engines for lifting and lowering. The Table on p. 380 recorded the grouting of the first season's work. The difference between the number of grouting-pipes built in (169) and the number which took grout (49), was accounted for by the grout fed to one pipe being forced out and eventually blocking adjacent pipes, which consequently withstood the necessary pressure when tested. The quantity of cement used for grouting the second and third seasons' work was considerably less than for the first season's work, owing to the higher level of the foundations. The head of water on the sudd piles when they were undermined had been 4·20 metres. The small grab had been procured for removing stones from the cut-off, not because of the quantity of stones, but because one stone could delay work for a considerable time by becoming jammed in the open end of the suction pipe, and, owing to the struts across the trench, it took some time to lift the pipe to clear the stone. Ancient bricks, broken earthenware, spillings from concrete, odd boulders in the sand, etc., had caused the stoppages, which might have had serious consequences as the main-raft concrete could not be laid until the cut-off concrete at that particular site was completed. The diameter of the gate-rollers was 22 inches. The average low summer level of R.L. 60·50 had been taken when fixing the level of the lock-sills, thus giving a depth of water of 2 metres, which in practice was not too little, because it was greater than the depth of some of the shallows in the river in summer, and boats which were able to navigate those shallows could always easily pass through the lock. The Rais of the river-steamers and feluccas all affirmed that the Nag Hammadi barrage lock was the easiest of all the Nile locks to pass through. He hoped that Mr. Reed's prophecy, that there would be a great deal of difficulty in future in getting the low-water channel to run from the right bank across to the lock on the left bank, might not be fulfilled, because, after its being possible to regulate the barrage freely for the first time during the early and late parts of the last flood, there now appeared to be a tendency for the channel to move

The Author.

Grouting the Foundations of the Lock and Barrage.

Summary of the Work Done.

First Season.

Particulars.	Lock—Including Wing Walls.	Barrage—Including Cut-Off. Vents 1 to 10.
1. Number of vertical pipes (diameter 4 inches) built in and tested	169	79
2. Number of pipes which took grout . .	49	38
3. Total number of sacks of cement used (weight of each sack 204 lbs. net) . .	757 (69 tons)	851 (77 tons)
4. Greatest number of sacks used in one pipe	55	230
5. Greatest number of other pipes affected while grouting one pipe (i.e. water or grout appearing)	8	3
6. Maximum distance of pipe affected, connected with horizontal pipes (i.e. travel of grout) . . . . .metres	53	82
7. Maximum distance of travel of grout without horizontal pipes . . . . .metres	118	12
8. Number of places where grout showed between the concrete and the sheet piles	8	Nil
9. Number of places where grout showed through concrete	Nil	Nil
10. Number of places where bubbles were seen on top of concrete	1	2
11. Number of sumps filled	11	2
12. Maximum pressure under which pipes were grouted (lbs. per square inch) . . .	30	40 Cut-off, 10 U.S.Apron, 30 D.S. Floor and Apron.
13. Date of starting grouting	10/4/1928	4/6/1928
14. Date of completing grouting	26/5/1928	15/7/1928

towards the left bank. Although the erosion of the river-bed in the open channel, between the end of the second season's work and the east bank, had caused anxiety during the early part of the flood, no damage had been done, as sand of good quality had been deposited during the later part of the flood; but serious erosion had taken place during the construction of the rubble bar described on p. 354. In his opinion that scour would not have taken place if the bar had been built up in equal horizontal layers over its entire length, instead of building one length up to water-level before starting the next. With reference to Mr. Halcrow's remarks, a sample of the finest sand at the Nag Hammadi barrage showed, when tested, that 30 per cent. passed through a 76 × 76 sieve. Other samples, taken from the top of the foundations after excavation was completed, gave the following results:— The Author.

	Sample No. 1.	Sample No. 2.
	Per Cent.	Per Cent.
Retained on 20 × 20 sieve	13·6	Nil
,, ,, 30 × 30 ,,	14·0	0·2
,, ,, 76 × 76 ,,	62·2	98·4
Passed through 76 × 76 sieve	10·2	1·4

The steps taken to deal with the trouble caused by the infiltration water from underneath the concrete foundations carrying sand with it were described on p. 360. If the piers had not been built up to such a height as to allow the construction of the roadway arches, flying arches, etc., to be carried on during the flood seasons, when the cableways, concrete-mixers and other plant were not employed on work inside the sudds, the barrage would not have been completed for at least another year. The information given by Dr. Lowe-Brown as to the regulation of the Asyût barrage for the first time during the flood was extremely interesting, but the Author did not think Dr. Lowe-Brown's belief that the afflux at the Nag Hammadi barrage had been underestimated would prove to be correct, as during the last flood (28th August to 9th September), when the upstream level had risen from R.L. 66·43 to R.L. 66·92, the afflux had remained steady at about 50 centimetres. Vents Nos. 21 to 100 had been fully open, and the passages under the bottom gates of vents 1 to 10 had been increased from 5·80 metres to 6·50 metres during that period.