Correspondence.

Mr. Inglis. Mr. C. C. INGLIS observed that the first large automatic siphons constructed in India had been designed and built by Mr. E. S. Crump, Executive Engineer, Lower Bari Doab Canal, Punjab, in 1922. A hydro-electric station had been built on a by-pass channel round a needle regulator at Renala. That type of regulator—though very cheap and suitable where the variation of water-supply was small—could only be opened very slowly; it was therefore entirely unsuitable at that place, where a sudden diversion of water from the by-pass channel to the main canal would be necessary in the event of a breakdown of any main part of the hydro-electric plant. The discharge was about 5,000 cusecs. Those siphon spillways had been built under great difficulties, in that the work had had to be begun at short notice and completed within 10 days. The siphons were built of reinforced brickwork, and the work had had to be done so quickly that the mortar had tended to ooze out of the joints between the bricks under hydraulic pressure. The design had been worked out by Mr. Crump with the assistance of Mr. Stickney's Paper [1] and proceeding on his own conviction that the flow must be a free vortex. The work had been completed within time, and the siphons had worked satisfactorily ever since, giving an efficiency (based on $V = \sqrt{2gH}$) of about 75 per cent. Investigations based on Mr. Crump's ideas, carried out under Mr. Inglis's supervision in Poona, showed that the free-vortex distribution of flow, though never quite attained, was a sound working basis to adopt. A full-scale working model had been built at Khadakvasla, near Poona, the siphon being of rectangular section, and having a uniform diameter of 5 feet and a width normal to the axis of flow of 4 feet, with a vertical downstream leg. That model, working under a head of 23 feet, showed negative pressures equivalent to 26 feet head of water, or a positive pressure of only 6 feet (Khadakvasla being 2,000 feet above mean sea-level). The internal radius of curvature was 3 feet, and the external 8 feet; and the efficiency obtained at maximum flow was 67 per cent. Velocities across various cross sections had been measured by a pitometer, in addition to pressures on the outer and inner shell; and these showed—as pointed out by the Author—that the outer shell needed no great strength, whereas

[1] *Loc. cit.*

the inner shell must be designed to withstand negative pressures up to 26 feet. The invert at the crown must, in fact, be by far the strongest part of the structure, and for this reason the "baby siphon" was not a very desirable method of priming. The other objection to the baby siphon was that it reduced the efficiency. He did not mean by this that a larger discharge would be obtained if the baby siphon were closed, but that the stream-line design was interfered with. This loss of efficiency could be reduced to a certain extent by starting the outer shell of the baby siphon, which was also the inner shell of the main siphon, before the convergence towards the throat reduced the section—in other words, the water for the baby siphon could be drawn off at a point where the velocity of approach was low; but even then the contraction in the downstream leg would remain. The necessity for air-tightness at the crown (invert) had been demonstrated at Khadakvasla (when a pressure pipe was being fixed at this point and water had to be passed through the siphon to unwater the canal during a canal closure.) The opening was only about 10 square inches, as compared with a cross section of 20 square feet; yet the siphon, which had been previously discharging 500 cusecs, would only pass a discharge estimated at 130 cusecs. The Author stated (p. 41) that the use of siphons made it possible to reduce the height of the dam by an amount equivalent to the depth of flood over an ordinary flood spillway. That was true; but the same result could be given by automatic gates, such as those at Khadakvasla (Lake Fife), Darna (Lake Beale), and other lakes in the Bombay Deccan. The main advantages of siphon spillways were that they were cheaper, did not leak, passed a very high discharge per linear foot of weir, and were certain in their automatic action (provided de-priming air-inlets were of such a type that they were "fool-proof"). The Author stated (p. 41) that "Notable improvements effected in the design of siphons in recent years have been, firstly, the contraction of the throat of the siphon and the flaring of the downstream leg . . . ., by which means substantially increased efficiences can be obtained, calculated on the contracted throat section." Later he qualified this statement, as regarded its being a notable improvement; and his second statement was much more correct. A throat obviously would not increase the discharge per linear foot of spillway, and unless it could be shown that it reduced the cost per unit of discharge or improved the priming qualities, it was a very doubtful improvement, in view of the fact that it increased the danger of blocking by trees, and, where the head was considerable, increased the negative pressure. The latter was undesirable where the siphon worked

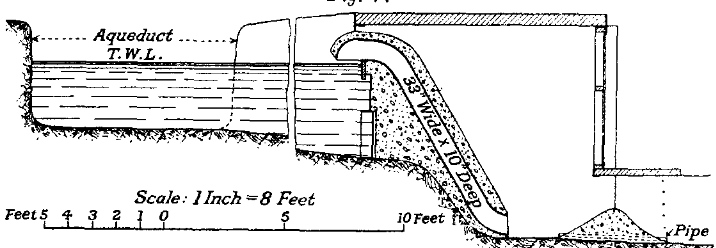
Mr. Inglis.

Mr. Inglis. under a considerable head, when the negative pressure would approach limiting conditions—probably about 5 feet positive pressure. If, for instance, a throat were put on the full-scale model at Khadakvasla, where limiting conditions had almost been reached, the discharge would certainly be reduced appreciably, though the so-called throat efficiency would increase. Another improvement mentioned by the Author was "the omission of the sealing-cistern for small siphons, by which means a higher efficiency is attainable owing to the avoidance of the obstruction which the cistern offers to the flow when the siphon is in full operation." If by "small siphons" the Author meant those working under a small head—of say a few feet—this statement was correct; but where the head, and hence the velocity of the water issuing from the downstream leg of the siphon, was considerable, the momentum was so great that the water in the sealing-cistern (if the latter was properly designed) would be swept away downstream. The available head could thus be appreciably increased, and the effective head would in some cases be slightly increased, so that the downstream cistern was by no means always a disadvantage; it was, on the other hand, generally desirable, since it made the starting of siphonic action more certain. The experiments at Poona, on models of one-quarter full size and full scale, showed similar results to those given in the Paper, including the positive pressure in the downstream leg. The design of siphons was tricky, and it was unwise to adopt new ideas without testing them—at least on a model scale. One of the one-quarter scale models at Poona, which differed but slightly in design from the standard type, gave efficiencies of 83 per cent. and 37 per cent. alternately—the latter apparently due to the formation of an air-pocket at the outer radius of the downstream leg, near the crown. He congratulated the Author on the value of the information given in the second half of his Paper, dealing with the losses in the various parts of the siphons and with the results of his experiments on models.

Mr. MacAlister. Mr. JAMES MACALISTER observed that the Paper was of exceptional interest to him on account of the fact that during the past year he had been responsible for the construction of three siphon spillways for the discharge of flood waters from an open aqueduct, which formed part of the Greenock Corporation water undertaking. The aqueduct, which was about $5\frac{1}{2}$ miles in length, was used chiefly for the conveyance of a stipulated quantity of water from a storage-reservoir—Loch Thom—to the Burgh of Greenock, where it was used for power purposes at numerous millsteads. An area of moorland, amounting to 617 acres, drained directly into the aqueduct, Mr. MacAlister.

and the overflow waters from several small reservoirs, which had a total catchment-area of 578 acres, also discharged into the aqueduct. The maintenance of the power supplies, the use, whenever possible, of flood waters, and the prevention of overflows from the aqueduct, called for close attention and supervision. The late Mr. Robert Thom, M. Inst. C. E., the engineer of the scheme in 1825, designed and constructed on the embankment of the aqueduct several ingenious self-regulating sluices. When the water in the aqueduct rose above a predetermined level, the sluices opened and discharged the flood waters into watercourses intercepted by the aqueduct, and when the water-level again became normal they closed automatically. These self-regulating sluices had been abandoned at some later date, and hand-operated sluices alone had now been in use for many years. It was evident that some form of spillway or storm overflow was necessary, and the adoption of a siphon spillway was first suggested by a perusal of Dr. Adolf

Fig. 7.



LONGITUDINAL SECTION

Ludin's contribution[1] to the correspondence on the Loch Leven water-power works. As stated by the Author, the published data regarding the design of spillway siphons were meagre, and it was only after the construction and testing of models that this type of overflow had finally been adopted in Greenock. The three siphons installed were, of course, small in comparison with the Maramsilli siphons, but they would appear fully to serve their purpose, having already been in operation on several occasions. *Fig. 7* showed a typical section of the aqueduct and spillway. The small pipe through the concrete dam was inserted in order to empty the pond at the outlet, and thus to prevent the formation of an ice-block. He congratulated the Author on the successful completion of the Maramsilli scheme, and was convinced that the Paper, besides forming a valuable contribution to the subject, would enable engineers in this country to explore further the

[1] Minutes of Proceedings Inst. C.E., vol. clxxxvii (1912), p. 123.

Mr. MacAlister. possibilities of siphon spillways, and eventually lead to their adoption, with confidence, in situations wherever they were likely to prove advantageous.

Mr. Thrupp. Mr. E. C. THRUPP remarked that in 1913 he made preliminary studies for a project involving a flood spillway of large capacity. No account of siphon spillways had then been published, so far as he was aware, and his experience had been limited to sewer flush-tanks; but it had occurred to him that large siphons constructed of reinforced concrete might prove satisfactory in regulating the water-surface, and economical in passing heavy discharges per linear foot of dam, which was an important consideration. Several designs were studied for dams 50 feet and 80 feet high, with passages up to 12 feet by 15 feet in section, and with ejectors for exhausting the air. It became evident that the sharp right-angled bends were a serious obstruction, and diverging outlets designed to regain "velocity head" added seriously to the expense. A siphon with the long leg shaped something like a saxophone seemed to be most practical, but the result of the study tended to show that a mean velocity of 25 to 30 feet per second was about the limit to be expected, and that, as the dimensions were enlarged, a limit was reached where some form of sluice-gate showed greater economy. An ideal arrangement seemed to be a combination of siphons and sluices, which would maintain the water-level correctly in the intervals between operation of the sluices. Reports of results obtained with siphon spillways (including one at Anyox B.C. and that at Maramsilli) were in harmony with the conclusions of these studies. He did not concur with the Author's statement of account of the loss of head. It was usual, in sewerage and open-channel work, to calculate the head necessary to produce the mean velocity and call that the "loss at entry," providing the necessary drop to produce it. With the velocity of 20 feet per second the loss at entry must exceed 6·20 feet, but the Author only debited 0·29 foot to that. The observations of suction, however, disclosed the right figures, although they were somewhat erratic, owing to eddies. The Author made up the account by charging 5·92 feet as loss in kinetic energy at the outlet. That was not the place where the loss occurred, and was merely a "failure to refund" which would not appear in a accountant's statement if the debits were in cash.

Mr. Wadley. Mr. A. J. WADLEY, late Chief Engineer, Irrigation Branch, Central Provinces, observed that the applicability of siphon spillways to reservoirs in the Central Provinces had first occurred to him in connection with the Kharung scheme, a smaller project in the adjoining District, where the problem was to convey safely about

25,000 cusecs over a rounded shaly hillside, with a fairly abrupt drop of about 40 to 50 feet. A siphon spillway seemed the only alternative to overlaying the whole surface of the shaly rock with cement-faced concrete, and interposing several flights of small falls. Accordingly, the Superintending Engineer had been referred to certain literature on the subject, and instructed to get out a design for a reinforced-concrete siphon spillway. It was a pleasure to see that the idea had not been lost, but had taken root in another scheme. The Author had, in fact, much improved upon the idea, and, by his examination of siphon spillway works in operation in Europe and his experiments at Maramsilli, had added considerably to professional experience on the subject. Mr. Wadley hoped that further Papers, dealing with constructional methods, and with the method of controlling the high velocity below the siphons, might be forthcoming. Did the 20-foot fall built there suffice to moderate the exit-velocity to desired limits? The low discharging-efficiency of about 50 per cent. was a conundrum at which the Author was still working. Mr. Wadley suggested that it might be due to air, which, after being absorbed by the water during the turmoil in the lower leg, was given off again as the siphon primed, and remained entrapped in or near the crown. The Paper did not allude to the existence of an automatic air-vent in the soffit, which could release such imprisoned air. He congratulated the Author on bringing to notice the valuable fact that a siphon spillway could be trusted to take charge of a surface level, presumably even of the maximum-flood level in a reservoir. Therefore overflows which normally occurred between full-tank level and maximum-flood level need no longer occur, to the loss of irrigation. The siphon spillway could be "set" a few inches below maximum-flood level (sufficient to allow for priming) and would infallibly control that level, thus saving for irrigation almost the whole of the volume contained in the "flood lift" region of the reservoir. About twenty years back open waste weirs used to be constructed of a length capable of dealing with the whole discharge which was in excess of full-tank level, quite regardless of the fact that the reservoir itself controlled a large part of this surplus in the zone between the full-tank and maximum-flood-level limits. It was owing to the late Colonel A. Ff. Garrett's valueable formulas that this wasteful method was corrected, and waste weirs came to be designed of such length, only, as in conjunction with a free fall and the flood-lift-depth on crest would give the required volume of overflow. Now the spillway siphon, with its double property of being able both to control a surface level and to discharge at once with a velocity due to the full head between maximum-flood level and Mr. Wadley.

Mr. Wadley the level of the water in the escape channel, had introduced further economies, not only by reducing the length of the waste weir, but also by conserving the overflows between full-tank and maximum-flood levels which had hitherto run to waste. With regard to the materials of future construction, he suggested that the prices of alloy steels should be watched. Unfortunately rustless steel was still ten to twelve times dearer than ordinary steel. But there were other alloys. No falsework would be required for steel tubes, and their erection was rapidly affected. Where the total drop to be negotiated by a spillway siphon exceeded the vacuum head of water, it would of course be necessary to build a cistern at the point below which siphonage was no longer possible, and to accomplish the remainder of the drop by means of a flume or a fall of special design.

The Author. The AUTHOR, in reply to the Discussion and Correspondence, expressed his appreciation of the kind reception accorded to the Paper. Comment had been made on the absence of a diagram showing the positions of the piezometer-pipes. He had contemplated the inclusion of such a diagram, but he felt that a study of the actual measured losses of head in the various parts of the siphons could only properly be made from a large-scale drawing, too large for inclusion in the Paper, and that it was preferable to indicate in tabular form the positions of the pipes, so that a large-scale diagram could easily be prepared, from the data given, by anyone interested. It was clear, however, that a small-scale index diagram would have been useful, and Mr. Crewdson had very kindly had one prepared. But, unfortunately, the positions of the pipes as shown therein differed markedly in many cases from the true positions. For example, in the case of the B type siphon, pipe No. 23 was shown about the centre of the throat of the priming siphon, whereas Table III showed that its true position was at R.L. 1,235·39 (practically coincident with the crest of the main siphon), an error of nearly 1 foot; and the whole series of pipes in the same vertical section appeared to be similarly in error. It was obvious, too, that the positions of pipe No. 16 and others in the adjoining series were incorrect; no pipes were placed in the priming-siphon walls, as shown in the diagram. When this was borne in mind and the diagrams were treated as rough general indexes only, they served a useful purpose. The Author would be glad to furnish a large-scale drawing showing the positions of the pipes, to anyone wanting one. In the case of an individual siphon of the B type, the main siphon started to prime immediately the main air-vent was sealed by the rising water. In the case of the A type siphon, the discharge through the priming siphon had proved insufficient to prime the main siphon

The Author.

until the water-level topped the crest of the latter, although the main air-vent was sealed at a level several inches lower. He had referred to this on p. 46. The air-vents of both the main and priming siphons extended over the whole width of the siphon, namely 8 feet, and were arranged at slightly different levels so as to avoid vibration effects, which might occur if neighbouring units came into action or went out of action at the same moment.

The point raised by Mr. Williamson regarding the undulatory motion of the water at the air-vents had been taken into account in the Maramsilli siphons by the provision of a diaphragm wall upstream of the air-vents, an idea suggested by Colonel Rivett-Carnac, R.E., then Chief Engineer of the Central Provinces; by this means it was possible to secure comparatively still water at the air-vent. A fall in water-level of about 6 inches below the top of the air-vents had been necessary before the siphon units went out of action, and, as this was excessive, some of the air-vents had been re-modelled so as to provide for the actual admission of air into the siphon at a higher level, whilst retaining the existing sealing level, and this arrangement had resulted in reducing the necessary drop from about 6 inches to $2\frac{1}{2}$ inches; it seemed clear that the higher the level at which the air actually entered the siphon, the smaller would be the fall in water-level required to cause siphonic action to cease.

With regard to the questions of vibration and surface erosion, raised by Professor Dixon and Mr. Gourley, no attempt had been made to ascertain by instrumental means the presence or otherwise of vibration, but as far as could be detected by the human senses, the action of the B type siphon was perfectly smooth and silent. He was unable to speak with the same certainty about the A type siphons, as he had not had the advantage of seeing them in normal operation, but in the cases of very similar siphons built in Italy, to which reference had been made in the Paper and by Professor Dixon, he had been unable to detect any sign of vibration. The latter installation, designed to operate under the same head as the Maramsilli siphons, but substantially lighter from the point of view of structural strength, had been in constant operation at the forebay of a hydro-electric station for some years; and the Author had been assured that no ill effects had been observed, due to either vibration or erosion. In the matter of possible erosion downstream of the fall, referred to by Mr. Gourley and Mr. Wadley, the working of the spillway had not been satisfactory. Below the lower fall, where the water spilled into the river-bed, no ill effects had been observed, but below the upper fall the floor had been damaged on both flanks of the spillway, owing to erosion under the toe of the floor. Detailed

The Author. examination of the damage had shown that it was due to the existence of a natural bank of earth immediately downstream of the floor and 10 or 15 feet above floor-level. The remedial measures consisted of clearing away the obstruction and reconstructing the toe-wall of the fall floor; but further damage to the floor on one of the flanks had since occurred, the extent of which was not yet accurately known. The preliminary reports received, however, indicated that the foundations of the cut-off wall, which, during its re-construction were carried down to hard rock almost throughout, had not been disturbed, and that the damage was confined to the upper layers of the wall and floor.

The correctness of the Author's propositions on p. 47 had been questioned by Mr. Crewdson, but he felt sure that study of the piezometer results on an accurately plotted large-scale diagram would clear up his difficulties. The best section for the purpose of examining the nature of the flow round the bends was perhaps that immediately above the main crest in the B type siphon. There were six piezometers on this section, Nos. 19 to 23 in Table III, and No. 5 in Table IV. In order to arrive at the velocity heads at each pipe, the figures for suction in columns 4 and 3 of Tables III and IV respectively must first be converted to suction in terms of feet of water. The amount of the suction lift should then be eliminated for each pipe, according to their reduced levels given in column 2 of the statements. The next step was to deduct from the value thus arrived at for each pipe the total upstream losses of head occurring from all causes other than creation of velocity, so that the net result arrived at was the velocity head, which could very simply be converted into the corresponding figures for velocity. The calculations were given in Table V.

TABLE V.

Pipe.	Suction.	Suction.	Suction Lift.	Net Loss.	Velocity Head after Deducting other Losses,[1] amounting to 1·24 Foot.
	Inches of Mercury.	Feet of Water.	Feet.	Feet.	Feet.
5	11·35	12·84	8·98	3·86	2·62
19	9·95	11·25	7·05	4·20	2·96
20	9·05	10·24	4·89	5·35	4·11
21	8·65	9·8	2·93	6·87	5·63
22	9·35	10·55	1·86	8·69	7·45
23	9·95	11·25	0·89	10·36	9·12

[1] The deduction of 1·24 foot made in the last column represents the sum of the losses under (1) to (4)—see p. 52—the loss under head (4) as calculated by the Author being 0·44 foot for the portion of the bend up to the crest only.

The Author.

Now it was clear that the passage of the water round the bend would be mainly influenced by the radius of the crest wall, which was 8 feet, so that if the Author's first proposition on p. 47 was true, a constant of 199 could be expected in a hyperbolic curve of the form $xy = C$, assuming that his calculations for the discharge through the main siphon and the losses in the inlet leg were correct. The actual constants obtained were given in Table VI.

TABLE VI.

Pipe.	Velocity Head.	Velocity V.	Radius R.	VR.
	Feet.	Feet per Second.	Feet.	
5	2·62	13	16·06	209
19	2·96	13·8	14·13	195
20	4·11	16·3	11·97	195
21	5·63	19	10·01	190
22	7·45	21·9	8·94	196
23	9·12	24·2	7·97	193

The velocities at pipes Nos. 19 to 23 lay on a hyperbolic curve for which C was equal to about 194, and the divergence from the curve of the velocity at the crown of the siphon was explainable by the fact that the upper layers of water came under the influence of the flatter curve, of radius 25·5 feet.

Mr. Crewdson had also found difficulty in following the Author's second proposition relative to the law which appeared to govern the change from suction to pressure in the outlet leg of a siphon, and considered that if the proposition were true, the loss in the lower bend in the B type siphon should be at least 15 or 16 feet, the height above the discharge level at which the change in the character of the pressure took place. This, however, could not be the case, and a more careful analysis of the proposition and the losses in the B type siphon would show that it was equally true of that siphon also. According to the proposition, the sum of the downstream losses, not the loss in the lower bend only, equalled the height from the change of pressure to the discharge level. In the case of that siphon the change took place about a third of the way up the middle bend, and the sum of the losses would be:—

(7)	Loss in the middle bend	0·36
(9)	Loss by impact of the streams	1·07
(10)	Loss by impact on the ledge	0·56
(11)	Loss in the bend beneath the junction of the streams	0·27
(12)	Loss by friction	0·11
(14)	Loss in the lower bend.	11·44
		13·81

The Author. To this total must be added the loss incurred in the production of the increased velocity downstream of the junction of the two streams, which was about $1\frac{1}{2}$ foot, bringing the total to about 15 feet, at which height above the discharge-level, as far as could be seen, the change of pressure did occur. The Author agreed with Mr. Crewdson that the apparent loss of head in the outlet leg was explainable by the fact that the velocity was unsteady in that part of the tube. The commotion resulting from the impact of the streams would be likely to have a marked effect on the piezometer readings downstream of the junction. He would suggest a reference to Mr. Barnes's treatise[1] for the loss of head by friction in pipes and conduits of various materials. He was also obliged to Mr. Crewdson for drawing attention to the anomaly between the readings of pipes No. 32 in Table I and No. 6 in Table II. He was unfortunately unable to examine the latter point, as the original records were in India, whilst at the time of writing he was in England.

Mr. Inglis's account of his experiments with model siphons at Poona was of great interest, and the Author hoped that he would see his way to publish a complete account of them. The Author agreed with him that the stream-line design was interfered with by the inclusion of the priming siphon, and an allowance for loss by impact was made in the analysis of losses in the Paper. Experiments with models had shown that the discharge of the siphon was actually increased with a priming siphon, despite the loss of head due to impact of the streams, so the interference with the stream-line effect did not appear to be important.

He considered the contraction of the siphon tube at the throat and the provision of an expanding leg a notable improvement, because the arrangement did appreciably reduce the quantity of material necessary, and consequently the cost per unit of discharge, where the conditions were suitable. He agreed in part only with what Mr. Inglis had said on the subject of cisterns. The sole function of a cistern was to make the priming of a siphon more sensitive, and thereby to enable it to come into action with smaller variations in the upstream water-level than was possible with an open outlet, a desirable and perhaps necessary condition in some cases. A cistern affected the priming only in the earlier stages, and in the final stages it not only served no useful purpose, but had a tendency to delay and, under certain conditions, to prevent full priming, owing apparently to the passage of the air-charged water back into the siphon. Once the earlier stages of priming with a cistern had passed, the conditions essential for priming were the same as those required

[1] *Loc. cit.*

for an open outlet, as described in the Paper, and failure to appreciate this point had resulted in the preparation of some designs, and even the construction of some siphons in which, in the Author's opinion, priming could not advance beyond the early stages. The Author.

The correctness of his method of analysing the losses had been questioned by Mr. Thrupp, in that he had recorded no value for the loss of head due to the creation of the necessary velocity at the entry to the siphon. That a definite loss of head due to this cause occurred at the mouth of the siphon was obvious, and were the siphon tubes of uniform section throughout, it would appear reasonable so to consider it; but in the case under consideration, where the velocity head continually varied from section to section, it was more convenient to take into account the net loss at the point where the stream left the siphon, which loss included that occurring at the entry to the siphon.

References had been made to the matter of the efficiency of siphons, and Professor Dixon had commented on the undoubted fact that the efficiency of the Maramsilli siphons was poor. The Author had already remarked (p. 54) that the abrupt lower bend was responsible for most of the avoidable loss, and some very instructive information had since been obtained from a series of experiments carried out by Mr. Abdul Wahid, Executive Engineer, under the Author's directions, to throw further light on this point. The experiments were carried out with a model having a waterway 12 inches wide by 18 inches high, designed throughout to secure the minimum possible loss, and a movable floor was provided so as to test the loss due to this cause only in an otherwise highly efficient siphon. The results, which spoke for themselves, were shown in Table VII.

TABLE VII.

Height from Outlet to Floor.	Working Head.	Discharge.	Efficiency.	Height above Outlet of Point of Change of Pressure.
Feet.	Feet.	Cusecs.	Per Cent.	Feet.
1·57	5	15·6	58	2·7
2·01	5·08	18·2	67	1·8
2·54	4·81	18·5	70	1·3
3·49	4·47	19·5	77	0·3
4·22	5·07	22·1	81	Zero

The ratio between the height from outlet to floor and the height of the siphon was $\frac{1\cdot 57}{1\cdot 5}$, or 1·05, for an efficiency of 58 per cent.; whereas, with a ratio of 2·81, the efficiency was 81 per cent. In the Maramsilli siphons the ratio was $\frac{9}{8}$, or 1·13.

The Author. These experiments had shown that the Author's statement that positive pressure was apparently necessary at the outlet to maintain uninterrupted flow did not apply to a siphon of that form and size, because in that case the siphon continued to work after the point of change of pressure had fallen below the outlet-level. There was little doubt that efficiencies of 80 per cent. and more could be attained by careful design. Designs could also be greatly cheapened in the light of present knowledge of the forces obtaining in such structures. One useful method of cheapening the cost was to construct the siphon tubes on the natural surface of the ground, where the levels permitted that course.

The great mass of concrete under the B type siphon was provided because the natural ground, which, at the site of some of the siphons, had previously existed to a high level, had been excavated to permit of the erection of the A type of siphon. Had it been possible to foresee the design of the B type, the natural ground would merely have been excavated to fit the siphon-barrels, and the mass concrete provided would not have been necessary.