Correspondence.

Mr. J. S. Alford called attention to the Author's statement (p. 404) that for the full quantity the Ashop tunnel, which was straight, required only 87 per cent. of the fall given by the Barnes formula, presumably that given on p. 46 of Mr. Barnes's book. The range of experiments on which the Barnes formula was based was stated to have a maximum value of v of 3·02, and a maximum value of i of 0·0003157. The value of v in the Author's experiments appeared to have been as high as 4·5 and the value of i exceeded 0·0005. Therefore, in comparing the ascertained head with that calculated by using the Barnes formula, it was necessary to extrapolate the data on which the latter was based. As Mr Barnes anticipated extrapolation, there was a serious discrepancy which needed explanation. The explanation was probably to be found in the difference in the nature of the surfaces of the conduits classified as "clean smooth-faced concrete conduits." A formula for discharge which required for its accuracy that an indefinite number of curves should be inserted in a straight length, as suggested by the Author, was not of the highest value. He thought that the Author should calculate the value of N in Kutter's formula or in Manning's modification of it. If that value accorded approximately with those obtained by other observers, it would seem that the matter could not be carried any farther. The values of N in Kutter's or Manning's formula, being in approximate linear relationship to the velocity, afforded over a wide range a more convenient means of rating the roughness of surfaces than did a fractional index. Whatever further accuracy, if any, could be obtained in calculating the discharges of conduits by the use of varying fractional indices rather than the older formulas appeared to be more than offset in practice by the defects of indices when used in mental estimating processes. Mr. Alford.

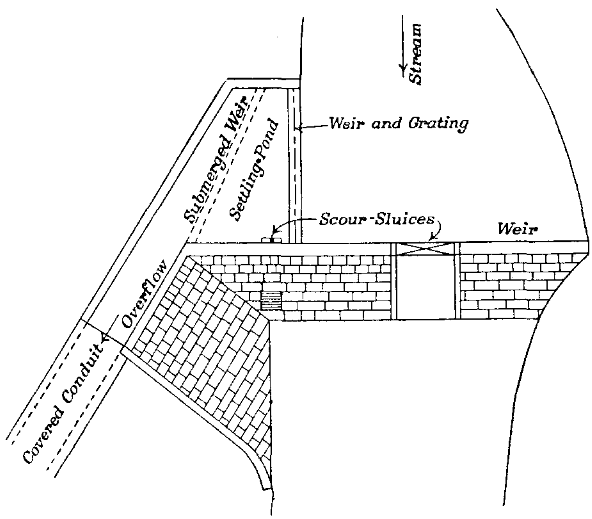
Mr. W. T. Halcrow observed that he was unacquainted with the district and was therefore not conversant with the peculiarities of the site through which the aqueduct passed, but he would ask whether the direct route through the the hill from the Ashop weir to the Derwent reservoir had ever been considered as an alternative to the line adopted. From Fig. 1 the distance would appear to be approximately 5 furlongs less in a direct line, and the work would presumably have been mostly in tunnel. Taking the unit prices of tunnelling given in the Paper, it would seem that, had the alternative route been chosen, a saving in cost might have been effected. He agreed with the Author that rich mixtures of concrete Mr. Halcrow.

Mr. Halcrow. helped to resist the corrosive action of peaty water; the many experiments which he had made showed that aluminous cement gave the best results.

Mr. Temple. Mr. F. C. TEMPLE remarked that the method of making the side weir do its work properly was ingenious, and was very suggestive for dealing with storm-overflows from sewers and open sullage drains. A long side weir in a straight length of an open drain was apt to discharge a steadily decreasing percentage of the total flow as the flow, and therefore the velocity, increased. Expedients such as fixing a cross bar in the channel were effective, but were apt to cause trouble through splashing. Putting a side weir on the outside of a curve might cause it to discharge too much. A corrugated roof over a short length might often be used with advantage in such places.

Mr. Williamson. Mr. JAMES WILLIAMSON observed that the Author was to be congratulated on furnishing a description of an interesting piece of work in which a number of ingenious expedients had been applied. The work was of a class and magnitude probably more often found in connection with water-power than water-supply developments. In the development of which it formed part great care had evidently been taken to make ultimately the fullest possible use of the available water-yield of the area. A special point arose concerning the economical size of the conduit, which had a capacity approximately equal to 5 times the average flow in an average year. Under the conditions existing at that site such a capacity would collect about 95 per cent. of the stream-flow. Taking the average rainfall as 47 inches and the average loss as 11 inches, there remained a stream-flow equivalent to 36 inches of rainfall, of which about 34 inches could be conveyed by the conduit. Of that, the utilizable yield was estimated at about 10 million gallons per diem, equivalent to about 18 cusecs. The capacity of the conduit (217 cusecs) was therefore about twelve times as great as the usable yield, and it was doubtful if such a high ratio was economically justifiable. The level at which the diversion works had been constructed would prevent the heightening of the Derwent dam to increase the storage-capacity of the reservoir, which would be one way of obtaining an increased yield from the water conveyed. It would be interesting if the Author would work out and give the yield that would be obtained if the capacity of the conduit were, say, 120 cusecs instead of 217 cusecs. The intake works were somewhat elaborate and of interesting design. He had inspected a number of power schemes in the Pyrenees where streams of comparable size had been diverted for power purposes. There the intakes tended to a standard type in which the weir was set square across the stream and a lateral intake extended for some distance up on one side. The water entered the conduit over a shallow weir through a long grating, so that water was taken in from the top of the pool and debris and floating material brought down by the stream was not shot against the grating, being carried forward and either evacuated over the weir or discharged when necessary through scour-sluices in the weir. An overflow on the conduit immediately below the dam prevented over-charging of the conduits, which, owing to climatic conditions, were roofed, and did not therefore require any further device of a special nature for limiting the flow. Where the water of the stream carried much matter in suspension there was usually a Mr. Williamson.

Fig. 18.



settling-pool behind the grating, furnished with a scouring-sluice, and from that pool the water passed over a submerged weir into the conduit. In the cases referred to there appeared to be no necessity for a weir at all comparable in length to that of the Ashop diversion. *Fig. 18* showed diagrammatically an intake of the type described. Such an intake avoided certain disadvantages which appertained to the Ashop intake, where debris and floating material brought down by the stream was diverted on one side into the mouth of the Alport conduit, and on the other against the grating of the main conduit. The total fall in the length of $2\frac{3}{4}$ miles (general slope 1 in 1863) appeared to be about 8 feet; and, having regard to the general steepness of the streams, it was not obvious why so flat a gradient

Mr. Williamson. had been chosen. It would appear to have been practicable at small cost to increase the fall by 4 feet, or more, either by raising the intake-weirs or by going a short distance upstream, or by a combination of these devices. Such an increase of slope would have entailed a reduction of the waterway of the conduit by about 20 per cent. and would have effected a large saving (probably not less than £10,000) in its cost. It was improbable that the extra cost of the upper works would have approached the amount of the saving. From theoretical considerations a more effective cross section of the open conduit would have been obtained by decreasing the width and increasing the depth, but the consideration of having a width sufficient for the operation of a mechanical digger would in that case outweigh any slight advantage inherent in a more concentrated cross section. It was inferred that the work had been carried out by administration and not by a contractor. In spite of the length of time occupied in construction, the costs appeared to be fairly reasonable. It would be interesting to have some further particulars of the driving of the tunnel; for example, whether it had been driven full bore or with a bench; the depth and number of shot-holes to each blast; whether shooting had taken place each shift; and the average quantity removed at each blast. The average cost of the tunnel was about £34 4*s*. per yard, or, say, £11 8*s*. per foot. The net section of the tunnel was equivalent to the area of a circle of about 8·5 feet in diameter, so that the cost per foot in pounds was about $1\frac{1}{3}$ times the diameter in feet. For a lined tunnel 10 feet in diameter recently carried out in Wales the ratio of the cost per foot to the diameter was the same, and he believed that in normal circumstances the same ratio would apply approximately to still larger tunnels. The slip-joint method of jointing the steel pipes of the Ashop siphon was hardly to be commended. Wherever steel pipes were laid on a slope, variations of temperature led to slight relative movement at the joints, with a tendency to cumulative creep downhill. That in time might lead to parting of the pipes at a joint, which was believed to have been the cause of more than one serious accident in power pipe-lines. In the Ashop siphon slipping might be prevented by the cement lining of the pipes, and possibly by their being bedded on concrete, but for any large pipe carrying water under pressure on a steep slope it appeared to be of prime importance that the joints (apart from special expansion-joints) should be made rigid by bolting, riveting, or welding.

The Author. The AUTHOR, in reply, remarked, with regard to the losses of head observed on various parts of the watercourse, that the only reason he could suggest for the variations was the amount or

The Author.

absence of curvature on the different portions. The surface of the concrete in the Ashop tunnel was similar to that of other parts of the watercourse and was no smoother. The use of the coefficient $N = 0{\cdot}01285$ in Kutter's formula, or $N = 0{\cdot}268$ in Bazin's (1897) formula would give the correct loss of head for a quantity of 217 cusecs in the case of the Ashop tunnel, but would give very much less accurate results than Barnes's formula for the cut-and-cover section adjoining Ashop weir. As so little information was available as to the loss of head at curves on an open channel, the comparison (given on p. 404) of the observed losses on parts of the watercourse with different degrees of curvature might be of some practical use to anyone designing a similar channel. An all-tunnel watercourse would have had the advantage of not requiring any flow-limiting arrangements, and a simpler weir could have been used. Such a scheme had been considered, but the estimated cost was higher than that of the scheme adopted. The siphon, however, had proved more expensive than was anticipated, and so actually the two schemes would have cost about the same. The capacity of the watercourse had been decided by the necessity of making the utmost possible use of the Ashop drainage-area within reasonable limits of cost, and not because the size chosen gave the cheapest supply. In very dry years, such as 1887 and 1888, the yield of the Ashop and Derwent areas would have been reduced by only about 500,000 gallons per diem by having a watercourse with a capacity of 120 cusecs instead of 217 cusecs. In more normal years the loss would be greater, although less critical, because floods were more frequent. As the towns were able to make use of a rate of supply higher than the minimum, when it was available, the greater yield given by the large-capacity watercourse was useful. Increasing the slope of the watercourse would have resulted in little if any saving in cost, since it would have necessitated higher weirs, or a longer watercourse across bad ground and a longer watercourse to the Alport intake. With regard to the driving of the Ashop tunnel, a benching had been used to facilitate the loading of skips and drilling operations in the upper part of the face. That benching had been kept about 4 feet 6 inches above invert-level, and the upper part of the face had been kept about 10 feet in advance of the excavation to invert-level. Shot-holes had usually been 3 feet deep, and eight had been used in the upper part of the face and two or three in the benching. The time between firing had varied with the amount of timbering to be done. "Abelite" had been used for blasting, and the quantity had averaged $11\frac{1}{2}$ lbs. per linear yard of tunnel.