been about 490 feet, a serious though not impracticable pressure for such large mains. The lightening of the load by 127 feet was, however, without doubt a thing to be desired. Mr. Deacon.

The rainfall on the Vyrnwy area had been determined by no less than thirty gauges. The rainfall towards the western boundary of the area was approximately 50 per cent. higher than that near the eastern boundary, and over the whole drainage area of 23,200 acres, which the Corporation had power to intercept, the mean fall during the decade ending 1891 had been about 68 inches.

Objection had been made to the use of Latin for certain inscriptions on the Vyrnwy works, but he could not concur in that objection, still less could he concur in the view that, if there were to be one uniform language, Latin would be the best. There would not long be much of the Latin left; and the objection that Latin was not the language of any living generation seemed a good reason for using it where a record for all time was to be maintained. In simple dignity moreover a correct Latin inscription was unsurpassed and unsurpassable. The day might yet be far distant when that traveller from New Zealand—whom Macaulay had made immortal—should "in the midst of a vast solitude take his stand on a broken arch of London Bridge to sketch the ruins of St. Paul's." But when it came would he be satisfied with sketching ancient London? Would he not also visit the great aqueducts of the north? And if he did, could there be any doubt that inscriptions in the language of Augustus would be more intelligible to him than any records in the long-forgotten tongue spoken by Englishmen of the Victorian era?

Correspondence.

Mr. Percy Griffith observed that the capacity of the Manchester Waterworks, previous to the carrying out of the Thirlmere scheme, was given as 25,000,000 gallons per day, and that of the new works as 50,000,000 gallons per day, or a total of 75,000,000 gallons. Allowing 25 gallons per head per day, the old works could thus supply a population of 1,000,000, the new works 2,000,000, a total of 3,000,000. The cost of the former was given as £3,150,000, including service-reservoirs and distributing-mains; and that of the latter as £4,400,000, or a total of £7,550,000. The rates per head of population provided for were thus— Mr. Griffith.

	£	s.	d.
Old works	3	3	0
Thirlmere scheme	2	0	5
Average	2	10	4

Mr. Griffith. From statistics relating to small waterworks, which he had recently collected, it appeared that the average cost of complete works rarely exceeded £2 per head of population provided for, and excluding service-reservoirs and distributing-mains, the average cost was about £1 per head. As the question of cost was often a vital one in the comparison of impounding with pumping systems or underground supplies, he thought some explanation of the high cost of the Thirlmere scheme, namely, £2 0*s.* 5*d.* per head, would be valuable. It would also be interesting to know whether this rate might be taken as an average for impounding schemes. The total cost of the Vyrnwy scheme had not been given, but the available supply of 40,000,000 gallons per day was (at 25 gallons per head) sufficient for a population of 1,600,000. An approximation to the total cost, so that the rate per head could be calculated, would be of interest.

Major Scott-Moncrieff. Major G. K. SCOTT-MONCRIEFF was at a loss whether to admire more the moral courage with which the construction of colossal works, described in Mr. Deacon's Paper, had been undertaken on principles hitherto untried, in this country at least, or the care with which each detail has been organised so as to ensure the practical translation into actual work of the principles in question. He desired to record his admiration of the way in which not only the works had been designed, but of the way in which each subsequent step had been made thoroughly secure by testing, by care in the selection and in the use of the materials, utilizing them in the manner indicated by theory and experiment, though not, it might be, in accordance with trade customs. In his present capacity as an Instructor at the School of Military Engineering, he was fortunate enough to have the opportunity of visiting large works under construction in various parts of the country. To one who had carried out works in India there was perhaps nothing in English engineering practice that was more striking than the difference that usually obtained in the two countries in the treatment of concrete. In England the concrete was usually mixed with so much water that ramming, or consolidation other than that afforded by the working of a spade, or the trampling of working navvies, was impossible. Generally the explanation given was that any ramming was injurious to the setting of the concrete. Sometimes it was said that the result of the ramming would be to bring the moisture to the surface, and leave the lower portions of the layer without any cement. Such objections were calculated to lead to the consideration whether, after all, the other method of treatment might not be wrong. Yet, when such works as the

Vyrnwy were visited and the result witnessed of a treatment based upon obtaining the greatest density possible with artificial means, no doubt was left as to the soundness of the methods adopted. It might at once be admitted that with contract working it was difficult to insist upon proper manipulation. This was not only because the labour per unit of work was greater, but because the actual material used per unit of completed, and therefore measured, work was much greater when consolidation by ramming was carried out. Certainly 15 per cent. more aggregate was required. This pointed to the conclusion that, in making trial investigations as to the proper ratios of matrix and aggregate, the latter should not be measured loosely in a box, but should be laid in layers and rammed tight dry before any water was poured in for the purpose of ascertaining the voids. The extra materials and labour per unit of volume thus expended made the work more expensive, and with unimportant work it might be unnecessary; but in all cases where strength, stability, or watertightness were in any way involved, he thought, in view of the striking example of Vyrnwy, there could be no doubt as to the superiority of this method over that usually adopted. As to the objection that the layers were not homogeneous, examination of the sections, as well as the remarkable results of the specific gravity, quoted by Mr. Deacon, of the concrete from the drainage well, were a sufficient answer. This was quite in accord with the experience of others who had adopted the method of consolidation described in the Paper. Major Scott-Moncrieff.

The simple test for the presence of free lime in the cement was, so far as he knew, novel. The usual test was not very satisfactory, and, with some such test as that proposed, the tests also for weight and specific gravity might be dispensed with. The method with which the cement was stored was another notable instance of care in a matter too often neglected and of the greatest practical importance. It was not stated, however, whether any tests of the quickness of setting, with the Vicat needle or otherwise, had been made. This appeared a matter of importance in connection with the length of time that ramming might be permitted, as well as the time that should not be exceeded between the mixing and the deposition *in situ*.

The care with which the disadvantages of temporary cessations were reduced to a minimum was also most instructive. Many engineers, no doubt, had had, as he sometimes had, to work without cessation for weeks, without any Sunday rests, sometimes by night as well as by day, in order to prevent the deterioration to the work that cessation would produce. Such constant work

Major Scott-Moncrieff. was good for neither mind nor body, and any procedure which would relieve such continuous strain, while providing for the excellence of the work, should be welcomed with satisfaction.

Mr. Hill. Mr. G. H. HILL, in reply to the Correspondence, remarked that the cost per head for any waterworks depended so much upon the circumstances of each case, such as the distance the water had to be brought, the natural configuration of the sites for reservoirs, and the geological formation, as well as upon other matters, that it was impossible to lay down any rule of general application as a guide in arriving at the cost per head.

Mr. Deacon Mr. DEACON observed, in reply, that Mr. Percy Griffith appeared to have omitted from the figure of £1 per head, which he gave as the cost of small waterworks, exclusive of service reservoirs and distributing mains, the capitalized cost of working and maintaining the pumping stations upon which they were dependent, and which must be added before any accurate comparison could be made between gravitation and pumping works. It was no doubt true, however, that pumping schemes, favourably situated, were cheaper than impounding schemes, mainly for the reason that while pumping schemes often had their sources close to the population to be supplied, impounding schemes involved aqueducts of more or less considerable length; but there was no such difference in favour of pumping as the two to one which Mr. Griffith's figures would suggest. The Vyrnwy aqueduct, like the Thirlmere aqueduct, was yet incomplete for the full quantity of water which Lake Vyrnwy would yield. At the present time the Vyrnwy aqueduct would supply 13,000,000 gallons to 14,000,000 gallons a day, and the cost had been about £2,300,000, but the next two equal instalments would probably be carried out for about £800,000 each.

In reference to Major G. K. Scott-Moncrieff's observations, where the aggregate of any intended concrete consisted (as he usually endeavoured to make it consist) of broken stone, and of the same stone pulverized, the method of filling the voids with water to ascertain their volume might be superseded by direct determination of relative density by weighing the stone before and after breaking. This test of relative density he always required to be made from time to time, the sizes of materials in the dry aggregate being so proportioned that the closest approach possible to the weight of the solid rock was attained. The volume of cement or lime required to produce, under the rammer, a jelly-like consistency, and consequent watertightness would then be a minimum, but would always somewhat exceed the volume necessary to fill the voids so measured. The use of the Vicat needle

had been referred to in a Paper which he had communicated to the Institution many years ago.[1] Cement which would bear the temperature-test he had referred to at p. 47, was necessarily slow-setting and the additional trial with the Vicat needle was not found necessary. Moreover, the conditions imposed in connection with the ramming of the concrete prevented any harmful effect, as would appear from the following considerations:—Unless the ratios of aggregate and matrix were suitable, and unless the cement was slow-setting, no amount of ramming would produce the jelly-like consistency; but in the alternative, that condition was rapidly produced after the first few inches of concrete had been laid, and when it was produced, there was no necessity for further ramming without new concrete. When a surface had attained to the proper consistency it shook like a quicksand and the shovel-men scattered more concrete thinly over it. Ramming then proceeded until the new work partook of the condition already assumed by the old, and so the work was built up. It was entirely a mistake to suppose that much labour in ramming was necessary. If the proportions of the materials were proper the labour was small, and the sufficiency of ramming was always immediately attested by the production of the very easily recognised condition of a jelly. It was not necessary or desirable to carry on the ramming until that condition disappeared, but while it freely continued, ramming had no harmful effect. Mr. Deacon.

[1] Minutes of Proceedings Inst. C.E., vol. lviii. p. 9.