Correspondence.

Mr. Headland. Mr. HENRY HEADLAND observed that the Papers by Messrs. Hellstrom and Rennie were clear and concise, yet full of valuable detail information. In design and methods of construction the Chenderoh hydro-electric station resembled the Waitaki scheme which had recently been put into operation in New Zealand. The large floods to which the Perak river was subject, and the resulting problems of water-control, dam-design and power-station and tail-race layout clearly indicated the valuable assistance which could be afforded by hydraulic models, and it was apparent that the greatest use had been made of them in the design of the scheme. He would suggest that the experimental work carried out in that connection should be presented as the subject of another Paper.

The use of a hollow spillway dam must have introduced considerable savings in first cost; it would, however, appear that that design somewhat limited the possibility of further extending the scheme. He would like to know whether the Chenderoh station had been fully developed; if not, could some estimate be given for the cost per kilowatt for subsequent extensions? A comparison of the cost of the hollow dam with that of a solid concrete structure would be of considerable interest to engineers.

The large variations in the turbine head which might result from floods would seem to indicate that the use of Kaplan turbines would have been economical, as the size of the units was such that machines of that type could have been installed at a cost comparable with that of Francis turbines, and as turbine-efficiencies of 88 to 90 per cent. would have been obtained at all gate-openings with machines of that size. It was noted that the runner-blades were of cast steel, and it would be interesting to know whether, after some years of operation, any signs of cavitation had been observed, and, if so, to what extent.

The difficulty of making works tests on large vertical generators nearly always resulted in such machines being tested on site, and in that connection the retardation method was of considerable use; it would have added to the value of Mr. Hellstrom's Paper if the various retardation-curves from which the losses were determined had been reproduced. The accuracy of the method depended almost entirely on the precision of the time—speed measurement, which should preferably be made by means of a continuous chart-record. Perhaps Mr. Hellstrom would give further details of the procedure and equipment used, and would also state whether tests were made to determine the flywheel-effect of the machine, and, if so, indicate how closely the calculated and measured values compared. The relative amount due to the turbine-runner would also be of interest. Had any effort been made to check the alternator-losses by the air-calorimetry method? He would also like to know whether any difficulties had been experienced due to the condensation of moisture on the generator-windings after shut-down, owing to the high humidity in the Malay States. **Mr. Headland.**

It would be interesting to know the reasons for placing the earth-wire below the 6,600-volt lines; particulars of the trouble experienced with cement on the post-type insulators and of the method of overcoming it would also be appreciated. The use of the alternators in the Malim Nawar station as synchronous condensers would necessitate the uncoupling of the steam-turbines. Had any special arrangements been provided for that purpose? The various items of construction and power-station equipment were given in Mr. Hellstrom's Paper, but its value would be considerably increased if the erected costs of the separate items were available.

Mr. A. W. LASH observed that in a comprehensive Paper such as that by Mr. Hellstrom there might hardly be space for a detailed description of the various considerations leading to the actual design adopted. However, there were several points of that nature on which additional information would be of considerable value. In the first place, the function of the under sluice-gates was not altogether clear. It was stated that they were only intended to be used for discharging water during construction, yet for that purpose they seemed unnecessarily elaborate, and furthermore it was apparent that the flood-discharge capacity of the sector-gate and spillway with water at El. 218 feet would fall far short of the maximum probable flood of 470,000 cusecs. Presuming that the under sluice-gates were to be used for passing extreme floods, was there not some risk of those openings being partially choked with floating trees, "dead-heads" or other debris? If, in addition to the sector-gate, several large fixed-roller or Stoney type sluice-gates had been provided the undersluices could have been eliminated from the permanent works. **Mr. Lash.**

The problem of dissipating flood-discharge energy, amounting under extreme conditions to over 1,000,000 HP., must have been one of the most interesting facing the designers. The jet-divider and deflector was a novel device and, from the data given with regard to the flood of December, 1931, seemed to have worked well. The provision of retarding walls or sills had become a usual feature of spillway-design where scour was anticipated, but the equal

Mr. Lash. importance of appropriate training walls was, however, frequently overlooked. In connection with the subject of scour, it would be of interest to know why it was considered necessary to place 3 feet of concrete on the granite bedrock.

Apparently it was intended that the spillway should take all surplus discharge until the water reached El. 198 feet, when the sector-gate would be opened. If it could be assumed that no damage would result to riparian interests up the river with water at that level, would it not have been economical to have provided additional discharge-capacity in the form of sluice-gates, combined with a higher spillway-crest? Alternatively, some form of needle-gate might have been placed on the spillway so as to get a higher head under low-flow conditions. While there was much to be said in favour of a long unobstructed spillway, it might be an expensive luxury in low-head plants. In Canada the advantage of a long spillway was often attained by the use of ordinary flashboards, which were removed prior to the spring break-up, when large quantities of ice had to be passed over the spillway. All normal floods were passed through the sluice-gates, the fixed-roller type of which had, in general, been found most satisfactory, so that the flashboards were only removed once during the year. In a plant containing several units the risk of the power-supply being entirely interrupted at a time when power was required to open the gates should not be a severe one.

The Ambursen type of dam appeared to be well suited to the location, in view of the cheap labour and expensive haulage. Lumber for forms must, however, have been an expensive item, and it would be of interest if Mr. Hellstrom would compare the cost of the dam with that of an equivalent one of gravity type.

The arrangement of having the power-house separate from the intake seemed a little unusual in a low-head plant. With suitable modifications in the design it would appear that the upstream wall of the power-house could have been moved up to the downstream wall of the intake, thus saving concrete and eliminating the penstocks.

The speed adopted for the turbines was conservative. For the maximum output of 11,300 kilowatts at 60 feet head the specific speed worked out at 69 revolutions per minute. A specific speed of about twice that figure had been the rule rather than the exception in Canadian practice since the installation of two propeller-type units at the Great Falls plant of the Manitoba Power Company, Ltd., in 1924. The Table on p. 393 gave particulars of some of the larger installations of high-speed units.

While the higher-speed unit, whether of Francis or propeller type, showed much poorer efficiency at part gate openings than did the slower-running unit, the efficiency at full gate was about the same in both cases. As noted, the hydro-electric plant would naturally carry peak-loads and the steam plant base-loads during periods of low river-flow. During high-flow periods, aggregating from 7 to 9 months of the year, economy of water at part load was not therefore an important feature. By using higher-speed units there would have been a marked economy in generator-cost; for instance, a speed of 167 revolutions per minute, corresponding to a specific speed of 123 revolutions per minute, would probably mean a reduction of 35 to 40 per cent. in generator-cost. Mr. Lash.

As Mr. Lash's experience in hydro-electric work had been mainly confined to Canada, he felt some diffidence in contributing to the

Plant.	Company.	Head: feet.	Rating: HP.	Speed: revs. per minute.	Specific speed: revs. per minute.	Date installed.
La Gabelle .	Shawinigan Water & Power Co., Ltd.	60	4–30,000 1–32,000	120 120	124 127	1925 1932
Great Falls .	Manitoba Power Co., Ltd.	56	6–28,000	138·5	151	2–1924 1–1927 1–1928 2–1929
Chats Falls .	Ottawa Valley Power Co., Ltd.	53	4–28,000	125	137	1933
Seven Sisters	North-Western Power Co., Ltd.	Pres. 38 Ult. 66	3–37,500	138·5	143	1932
Bryson . .	Ottawa River Power Co., Ltd.	60	2–25,700	120	115	1–1926 1–1928

discussion of works in such a different environment. However, The Institution with its world-wide membership was in a unique position for comparing practice in different countries, and for that reason it was of the greatest value to have the fullest details possible of the reasons leading to the adoption of a particular design, especially where, as in the case under discussion, the environment was rather unusual. In limiting his remarks to matters of design he had in mind a contribution to the correspondence made by Mr. R. F. Legget, dealing with the methods of construction.

Mr. R. F. Legget observed that the two Papers under discussion would be of special interest to engineers in Canada, in view of the importance of water-power in the life of the Dominion. That special interest had led him to make an unusually careful study of the Papers, in conjunction with Mr. A. W. Lash, and the following notes dealing mainly with practical aspects of the work were thus complementary to Mr. Lash's notes on its design. Mr. Legget.

Mr. Legget. The two Papers together occupied 105 pages, whereas many Papers descriptive of much larger and more complicated works had been much shorter. Were all the material of unusual value, that remarkable length would be welcome, but it was largely made up of a mass of detailed information which, although interesting and useful, was not of major importance. On the other hand, both Papers were almost devoid of information regarding the reasons governing the design and construction of the works described, whilst the omission of almost all details of cost hindered discussion of their most important aspects. The true tests of engineering works were surely their fitness and economy; as the one aspect had been so fully dealt with, it was to be hoped that the Authors would be able to give some details of cost, and so justify the selection of features of design which, without such information, did not appear to be truly economical.

The attention which had been devoted to the scientific design of the concrete used for the works was most welcome, and the concrete technique utilized was excellent, although not unusual on the North American continent, but the devotion of 20 pages to a detailed description of almost every phase of the concrete design seemed to suggest that most of the material presented was new. That was certainly not the case. For instance, Table VIII showed nothing which had not been repeatedly demonstrated in the past. The attention paid to concrete design was the more surprising in view of the almost complete neglect of methods of placing in Mr. Hellstrom's Paper, and of the invariable use in both Papers of the word "pour" to indicate the placing of concrete in the forms. Concrete might nowadays be regarded as a structural material of predeterminable strength and general physical characteristics, especially when so carefully designed and tested as indicated in Mr. Hellstrom's Paper, but it was not the finished product as investigated in the testing laboratory until it had been placed in its final position and there consolidated and cured. The general neglect of methods of placing was indeed one of the strangest phenomena of recent concrete work, especially in view of the growing appreciation of the desirability of the lowest practicable water/cement ratio. It was the attention paid to the latter point on the Perak river work that made the placing of the concrete by shoots so hard to understand. Would the Authors explain whether other methods now widely used were considered, and, if so, why shoots were preferred? Some details of the arrangements of shoots used would be of great interest, especially with regard to the angles at which the shoots worked, the segregation of the concrete so transported, and the maintenance of the correct water/cement ratio. The excellent testing laboratory on the job must have been useful, but would Mr. Hellstrom give the cost of, and explain the economic justification for, the provision of the 400-ton testing machine? Was the application of vibration to the placing of the concrete in the forms considered at all? Did the Authors not agree that, in the light of recent work, the use of vibration might have given the required watertightness by virtue of the consequent density of the concrete alone, without the provision of extra and costly waterproofing membranes? Mr. Legget.

In view of the unusual nature of the site and climatic conditions, it was not easy to discuss the constructional aspects of the scheme. The use of A-frame type cofferdams was most interesting, but could Mr. Rennie give details of the difficulties (if any) encountered in sealing the planking used? In view of the trouble encountered with timber, was consideration given to the use of all-steel A-frames with skin-plates of interlocking steel sheet-piling? Some of the data given with regard to timber were surprising, especially the decay of the European timber in little more than a year. What was the primary cause of that? Finally, could Mr. Rennie give some explanation of the most surprising figure of all in the two Papers—the camp population of almost 5,000. On a similar job in Canada, of about one-half the physical size, carried out with much greater speed and under temperatures ranging from 98° F. to —40° F., with all the attendant difficulties, the maximum camp population was about 300. The discrepancy defied normal explanation.

Mr. Howell Ritson observed that the complete history of the project given by Mr. Hellstrom, from the preliminary reconnaissance to the starting-up of the Chenderoh station, was of great interest. It was to be regretted, however, that he did not go into a little more detail on certain matters; for example, some details of the reinforcement would have been very instructive. Mr. Ritson remembered that the reinforcement was extremely close and heavy, especially in the upstream slabs of the hollow dam, in the concrete beams of the turbine-house floor, and in portions of the intake, so much so that it was almost impossible for the concrete to be worked after placing; it was therefore necessary to use a concrete with a much greater water-content than would otherwise have been desirable. He believed that that was one of the reasons which persuaded the engineers to have the upstream face of the dam "gunited," a procedure not contemplated in the original scheme. He would be glad to hear Mr. Hellstrom's remarks on that point; did not Mr. Hellstrom think that a slightly thicker slab with lighter reinforcement would have been more economical for a tropical job? The subject of water/cement ratio was very important, and was probably the chief cause of trouble to clerks of works and resident Mr. Ritson.

Mr. Ritson. engineers even in Great Britain, where climatic conditions were favourable and skilled workmanship available. He thought Mr. Rennie would confirm that at Chenderoh it was extremely difficult to get the European gangers and inspectors, as well as the native workmen, to realize the importance of the water-supply to the mixers not being excessive. When it was recognized that the concrete flowed down the shoots of the Insley plant more easily and was placed with less work and trouble when it was over-watered, it was a great temptation to all, especially during night shifts, to increase the water-supply. That point was often neglected by designers, who did not always realize that reinforced concrete to be carried out in the tropics should be reinforced as simply as possible, with ample space between individual bars, so that a fairly dry concrete could be worked into place by ignorant labour without excessive trouble.

Mr. Hellstrom's remarks on the expansion-joints were very interesting, but he would like to have seen some mention of the original sealing device shown on the working drawings, and of the reasons leading to the substitution of the very simple and effective device described and illustrated in his Paper. The original idea was to have a V-shaped groove at the joint, into which a thick rubber tube was to be pressed by an angle-iron of "Armco" ingot iron. The angles were to have been attached to the concrete by means of bolts, and the tightening of the nuts on the bolts was to have pressed the rubber tube into the groove and made an effective seal. Mr. Ritson believed that that device was abandoned because of the difficulty of forming an accurately-shaped groove on the top edge of the slabs, owing to the impossibility of filling the moulds quite full, the shrinkage of the concrete always leaving a slight air-space at the top of the box. He could remember the care required to get those grooves even approximately well formed, and the engineers were to be congratulated upon their readiness to abandon an unworkable device for a simpler one when the difficulty was realized.

The Contractors were to be commended for the way in which the whole work was carried out, especially the portion of the dam with bottom outlets. Mr. Rennie would doubtless remember some of the remarks passed by the fixers of reinforcement in the cramped spaces under the bottom-outlet steel plates, with the tropical sun overhead turning the spaces into an oven. It reflected great credit on all concerned that the work should have been so well done under such conditions.

Mr. Temple. Mr. F. C. TEMPLE remarked that the velocities at different levels in the river were observed, presumably on several occasions with different water-levels. It would be very valuable if a curve of average velocities at different flood-levels were published. It often Mr. Temple. happened in India that the only precise current-observations were taken during a medium flood, but such a curve would make it possible to calculate what would be the velocity during a higher flood.

The provision made to secure water-tightness at construction-joints was most interesting, as for many years much too little attention had been paid to them. It was particularly important in tropical countries to remember that movements in large structures were inevitable, and it was no use to talk of monolithic structures, because their monolithic character was to a large extent destroyed by the construction-joints. The only safe method was that which had been employed at Chenderoh, namely, to recognize that the structure would move and to make provision for the movement, so that when it occurred it would do no damage.

The tests on the cement were interesting, and confirmed experience common in India. The results of compression-tests in particular should be regarded with suspicion, because it was possible to make the indicators show a much higher reading than the true figure. A 6-inch by 6-inch by 6-inch block of concrete in one test he had seen failed completely at 22,000 lbs., but the indicator gave a momentary reading of 29,000 lbs.

Mr. HELLSTROM, in reply, observed that Mr. Headland and Mr. Mr. Hellstrom. Lash had anticipated that the hollow dam was cheaper than a solid gravity-dam. That was so, and comparative estimates had been given on p. 384 in his reply to the Discussion.

The power-station at Chenderoh utilized as much water as could be dealt with economically, but provision had been made to raise the water level by 5 feet, as and when required, by placing flash-boards on the crest of the spillways and by the erection of an auxiliary sector-gate on top of the existing gate. The cost of the additional power thereby gained would be very low. In 1926, when the station was planned, large Kaplan turbines for a head of 60 feet had not been built, and it was not certain that even now such turbines would be better than Francis turbines for the work described. No cavitation of the turbine-runners had so far been observed. The speed adopted for the runners was conservative, it having been decided upon with a view to obtaining good efficiencies at light loads. It would also help to avoid cavitation. A speed of 167 revolutions per minute would have been excessive.

The purposes of the bottom outlets and the Taintor gates were as follows: (*a*) to discharge water during the construction-period, (*b*) to regulate the water-level during the first period of operation when the sector-gate was being erected behind a temporary fixed

Mr. Hellstrom. closure, (*c*) to empty the reservoir above the dam in case of emergency, and (*d*) to remove silt, if and when required, at a future date. Of those points, (*b*), (*c*), and (*d*) could not have been met if resort had been made to a simpler design, such as stop-logs. He admitted that when the bottom outlets were opened there might be a risk of floating trees choking them, but that had not occurred during the construction period.

Mr. Legget had referred at some length to the method of placing concrete. That had been done in the ordinary way by men tamping the concrete in the moulds. Shoots were used because the contractors wanted them, and the engineers did not raise objections. As the concrete was very plastic much handling had not been required. Vibration required dry mixes, and had not been considered, as fairly wet mixes were to be anticipated. In addition, in those days there was a lack of suitable plant for vibration. A fairly large proportion of the Paper had been devoted to the investigation of the concrete because such a comprehensive series of tests had rarely been made in the tropics, and the results published.

Mr. Howell Ritson had referred to the " guniting." The upstream-face of the dam had been " gunited " as an additional safeguard to ensure watertightness. The intake had not been " gunited " and repair work there could, if necessary, be carried out by closing the intake-gates. It was interesting to note that the intake was just as watertight as the dam. No experience about the watertightness of the actual structures was, however, available when a decision had to be made about " guniting," and the cost thereof was considered as a reasonable premium for a good insurance. He disagreed with Mr. Ritson that thicker slabs and less reinforcement would have been more economical.

Mr. Temple had asked about the velocity of the water in the river at different water-levels. The figures were given in the following Table :—

Water-level : El. feet.	Discharge : cusecs.	Average velocity : feet per second.
140	26,000	5·4
150	74,000	7·0
160	133,000	7·9
168	200,000	9·0
173	245,000	9·6
179	310,000	10·4

The figures referred to an average cross section of the river at Chenderoh, where the average elevation of the river-bed was about

129 feet. He had not found any fault with the compression-testing machine for concrete cubes used at Chenderoh, and in the case referred to by Mr. Temple a non-calibrated testing-apparatus giving an error of over 30 per cent. appeared to have been used. Mr. Hellstrom.

Mr. Headland had referred to the testing of the generators by the retardation method. The procedure adopted was the usual one, and the equipment provided was quite simple, as it merely consisted of a Cambridge recording chronograph of the laboratory type, an independent exciter-set, and the necessary oil-switches. A continuous record of speed and time was taken, but difficulty was experienced during the tests due to the breaking of the rubber belt, which deteriorated very quickly in the tropics. Attempts were made to check the flywheel-effect by the input method, but the attempts were not successful on account of excessive hunting. The losses were therefore based on the calculated flywheel-effect, using retardations and instantaneous speeds corrected to the third degree. The turbine-runner was disconnected during the tests so that the loss due to it was eliminated. No attempt was made to check the alternator-losses by any other method, and no trouble had been experienced from condensation on the generator-windings. When running as synchronous condensers the alternators at Malim Nawar were uncoupled from the turbines, the couplings having been designed for that purpose; otherwise no special arrangements, except for the electrical starting of the machines, were provided.

The reason for placing the earth-wire below the 6,600-volt lines was one of economy, as it enabled one line-conductor to be placed on the top of the pole, and the protection from the earth-wire below the conductors was almost as efficient.

He was indebted to Mr. A. E. Hughes, M. Inst. C.E., for the answers to the electrical questions.

*** Mr. Rennie's reply will be found on p. 643.—Sec. Inst. C.E.