Correspondence.

Sir JAMES ALLPORT communicated (1) The original report, dated May 26, 1848, of Mr. (now Lord) Armstrong, as to the first application of hydraulic power to railway-station work; (2) His own note upon it, made as General Manager of the York, Newcastle, and Berwick Railway, for the information of the Board; and (3) Extracts from a letter from the late Mr. T. E. Harrison, Past President, dated February 20, 1888, showing that the cranes then erected had worked satisfactorily and economically to the present time. Sir James Allport.

(1) *Observations respecting the Application of Hydraulic Power for Cranage at the New Goods Station to be erected near Trafalgar Street in Newcastle-upon-Tyne.*

The Whittle Dean Water Company has a 10-inch main which proceeds from the reservoir at Carr's Hill, down the High Street of Gateshead, and through part of the streets of Newcastle. The elevation of the reservoir is very great, and at the level of the proposed station the water supplied from it would exert a pressure of 140 lbs. on the square inch, and would thus afford a most energetic power for the purpose in view. It would be necessary, however, that the 10-inch main should be extended to the station from the nearest available point, without any diminution of its diameter, and I have reason to believe that the Water Company would undertake to do this upon terms which would not be considered objectionable. With respect to the advantage of hydraulic power as applied to cranes, I may state that this power is characterized by great accuracy and softness of movement, and is peculiarly adapted for lowering as well as for lifting goods with gentleness and safety. It is extremely easily controlled, so that boys may manage it with precision, and it is entirely free from the dangers which attend the use of steam. It is always ready for operation at a moment's notice, while steam requires preparation, or is costly to maintain in readiness for action. In a system of cranes worked by shafting from a steam-engine, every crane must be worked at one speed, and, however fragile the package may be, it must be taken up with such a velocity as the speed of the shaft shall determine, whereas in hydraulic cranage each crane, being independent of the rest, is at liberty to work fast or slow, as occasion may require. The rapidity of action attainable in hydraulic cranes depends solely upon the size of the supply-pipe, and I have no hesitation in saying that, where this is sufficient, much greater despatch may be realized with hydraulic cranes than would be consistent with safety where steam or any other power was used. The first cost of a system of hydraulic cranes would, I have no doubt, be less than of steam-cranes, and the expense of maintenance would be merely the water-rate, which I conceive would be considerably less than the expense of maintaining a steam-engine of adequate power. As compared with manual labour, hydraulic power would not only give an immense increase of despatch, but the saving of labour it would effect could not fail to render it equally superior in point of economy. It is quite practicable to avoid all expenditure of water by causing the cranes to discharge into the low-pressure mains of the water company, or into the tank for supplying the

Sir James Allport. locomotive engines, but this would be attended with some diminution of power, and I scarcely think that the quantity of water which would be required to work the cranes would be sufficiently large to justify the expense of the additional apparatus which would be necessary to save it from waste. The cranes might be made either single-powered or with variable powers for different weights. If single-powered, part of them might be adapted for lighter goods and part for heavier; this would be the cheapest way of carrying out the plan, but there would be great convenience in the variable powers, which would adapt every crane either for light or heavy goods, and the increase of expense would not be very considerable. The change of power would be effected by the mere adjustment of a valve, which would be accomplished in a moment without any alteration of gearing. If it should be desired that I should furnish any plans, estimates, or designs in reference to this subject, I shall be glad to receive instructions to do so.

W. G. ARMSTRONG.

Elswick Engine Works, 26 May, 1848.

(2) After a careful examination of the experimental hydraulic crane erected by Mr. Armstrong on the Public Wharf, Quay Side, Newcastle, also witnessing its working, I invited him to give me a report upon the adoption of that system of cranage at the new goods warehouse in Newcastle. The above is Mr. Armstrong's report, and after giving it my best consideration, and coupled with my having seen the practical working of the crane on the Quay Side, I am satisfied it is a system admirably suited for railway goods stations, and I strongly recommend its adoption at the Manors Station, where it will have a fair trial.

Gateshead, June 1848. JAMES ALLPORT.

(3) *Extracts from a letter from the late Mr. Thomas E. Harrison as to working of Cranes.*

North-Eastern Railway, Newcastle-on-Tyne,
February 20, 1888.

MY DEAR ALLPORT,—

The first cranes worked by hydraulic power which were ever used for this (railway) purpose were those put up at the Trafalgar Goods Warehouse, The Manors, Newcastle, by Messrs. W. G. Armstrong & Co. They are now in daily use, and have always done their work admirably and at a minimum of cost for repairs. They have gone on since their first construction without alteration, and are now at work daily. The result of the working of these cranes at the Trafalgar Station induced me to use them more extensively at the Forth Goods Warehouse, where hydraulic power does everything inside the warehouse, and no locomotive or horse ever enters the warehouse for moving a single wagon. It is a power requiring comparatively little repairs, and is easily kept in order, and is decidedly cheaper in respect of manual labour in working. I went, a few days ago, to look at the cranes at Trafalgar Station, and I should like you much to see them, as also the arrangements at the Forth Goods Warehouse, which are most complete. Believe me, yours truly,

THOS. E. HARRISON.

Mr. Chatwood. Mr. S. CHATWOOD stated that he had designed, so far as he knew, the first hydraulic-balance lift, and had exhibited it at the Paris Exhibition of 1878. In all essential features it resembled the examples shown by Figs. 1, 2, and 3, Plate 4. He was pleased to find the invention worthy of being brought before the Institution, although his name had not been mentioned in the Paper. Mr. Chatwood.

Mr. J. Coates thought that compressed air would never be able, in practical working, to compete with hydraulic power in economy; and also that the American or Otis Elevator Company must change low pressure to high pressure, in order to secure the same efficiency as in water-balanced lifts. Having said this generally, he would remark that it would have been interesting to know at what point of power required it became desirable to have a separate installation; or, in other words, was it more economical to work a block like the Kensington Court with a separate installation? In regard to the test made as to the loss of pressure when passing water through 5 miles of pipes, the time it took to raise the light accumulator to the top had not been stated, whether long or short; this would have been a guide as to the friction. No clear reason had been given for the increased strength of the pipe-flanges. In the systems adopted by Messrs. Armstrong and others in the extensive docks in this country, there had never been any difficulty, and there should be none, provided the pipes were cast in the right way. The slip of 5 per cent. in the vertical engines adopted by the London Hydraulic Power Company seemed to him excessive. A pair of horizontal high-pressure engines, with double-acting pumps of the Armstrong type, had been tested at Newcastle-on-Tyne a few months ago, and when running at 300 feet piston speed, the slip was rather under $2\frac{1}{2}$ per cent. He should have expected even a better result than this, if the pumps had been ram-pumps, as in the case of the engines described by the Author. He much preferred the horizontal engine with double-acting pumps placed in front, or directly behind the steam-cylinder; or, if space was available, he should prefer the same class of engine with ram-pumps, one in front and one behind the steam-cylinder. In the scheme he was carrying out for the Melbourne Hydraulic Power Company, he had adopted compound non-condensing horizontal engines, each capable of delivering about 250 gallons of water per minute. There would be two accumulators, each 20 inches in diameter, and of 20 feet length of stroke. The boilers were of the multitubular type, as they were easier to ship than the Lancashire type. They would be fitted with Vicars' self-acting stokers. There would be about 6 miles of pipes, and he anticipated that the Company would be in a position to supply power by the beginning of 1889. Since the passing of the Act, the value of land had considerably increased in Melbourne; one of the reasons being that, with this power always at hand, much higher buildings could be Mr. Coates.

Mr. Coates. worked from the power-supply mains than heretofore. He might add that about 500,000 gallons of water, which had hitherto been wasted by the lifts worked from the town-service, could now be saved, which was an important consideration in a dry country like Australia.

Prof. Smith. Professor R. H. SMITH submitted the following formulas as being convenient for calculation. The hydraulic HP. transmitted at any point where the flow was V cubic feet per second, or Q gallons per minute, and the pressure p lbs. per square inch, was—

$$\text{HP.} = 0 \cdot 262\ \text{V}p = \frac{7}{10^4}\text{Q}p.$$

If ϕ was a coefficient such that $\phi\, v^2$ was the hydraulic resistance due to friction and viscosity in lbs. per square foot of contact surface between water and pipe, where v was the velocity in feet per second; then the frictional and viscous loss of power in a length L feet of pipe, with water section A square feet, and mean hydraulic depth δ feet, was—

$$\text{Frictional loss of HP.} = \frac{\phi}{550}\,\text{V}^3\,\frac{\text{L}}{\text{A}^2\,\delta} = \frac{\phi}{29 \times 10^9}\,\text{Q}^3\,\frac{\text{L}}{\text{A}^2\,\delta}.$$

For a round pipe, d inches in diameter, the water running full bore, this became

$$\text{Frictional loss of HP.} = \frac{2 \cdot 6}{10^{10}}\,\phi\,\text{Q}^3\,\frac{\text{L}}{d^5} \text{ with Q in gallons per hour}$$

$$= \frac{5 \cdot 6}{10^5}\,\phi\,\text{Q}^3\,\frac{\text{L}}{d^5} \text{ with Q in gallons per minute.}$$

The ratio of HP. lost through friction and viscosity to the total HP. transmitted was—

$$\frac{\phi}{144}\,\frac{\text{V}^2\,\text{L}}{\text{A}^2\,\delta\,p} = \frac{\phi}{144}\,\frac{v^2\,\text{L}}{\delta\,p} = 0 \cdot 1013\,\phi\,\frac{\text{L}}{\text{A}^2\,\delta} \cdot \frac{\text{HP}^2}{p^3}.$$

For a round pipe, the water running full bore, with $\phi = 0 \cdot 007$ the ratio became

$$1{,}144\,\frac{\text{L}}{d^5} \cdot \frac{\text{HP}^2}{p^3}.$$

ϕ, according to Froude's and other experiments, might vary from $0 \cdot 002$ to $0 \cdot 008$, and the ordinarily accepted formulas of hydraulics were based on the assumption that it was about $0 \cdot 007$. The formula quoted by the Author (p. 8) corresponded to $\phi = 0 \cdot 0074$. The experiment he referred to in the next paragraph gave

$\phi = 0 \cdot 0065$, but it was to be remembered that the pipes were comparatively new and clean. Corresponding to ϕ = about $0 \cdot 007$, a convenient formula for the frictional and viscous loss of head in feet, was— Prof. Smith.

Loss of head in feet—

$$= \frac{1}{10^4} \frac{V^2 L}{A^2 \delta} \text{ for any section, dimensions feet and seconds.}$$

$$\left.\begin{aligned} &= \frac{2}{10^7} \frac{V^2 L}{D^5} \\ &= \frac{1}{3 \times 10^6} \cdot \frac{Q^2 L}{d^5} \end{aligned}\right\} \text{for round pipe, the water running full bore, diameter D feet or } d \text{ inches, and Q in gallons per hour.}$$

The above ratio of loss to total HP. transmitted was an "inefficiency." Call it β. Then for a given HP. to be transmitted a length L feet through a round pipe with pressure p lbs. per square inch, size of pipe required for a given desired inefficiency was—

$$d \text{ inches} = 4 \cdot 09 \sqrt[5]{\frac{L \, HP^2}{\beta \, p^3}}.$$

This seemed to be the rational formula for the selection of the size of pipe to be used in the hydraulic transmission of power. Of course the power in each of these equations was that transmitted at the point where the pressure was p; thus, if p was the pressure at the generating station, the HP. was the original power; but if it was taken as the pressure at the end or any other point of the transmission, the HP. in the formula was the power that reached that point.

The following was a solution of the problem to find the commercially most economical diameter of pipe to employ for hydraulic transmission of power; the method being similar to that used by Sir William Thomson for solving the similar problem for electrical transmission. Let H_1 and p be the HP. and pressure required to be delivered at the distant end of a transmission. The power lost was as above $a \frac{L H_1^3}{p^3 d^5}$ where a was a numerical coefficient. The whole power needed to be generated was therefore—

$$H = H_1 + a \frac{L H_1^3}{p^3 d^5}.$$

Let q = cost per hour of 1 HP. at generating station as delivered to the accumulators, and T the total number of hours per annum

Prof. Smith. the power was required. The thickness of metal required in the pipes $= A + \frac{p\,d}{B}$, where A and B were constants. The prime cost of pipes and pipe-laying might be taken as the sum of two terms; the first a constant multiplied by the length of the line, and the second another constant multiplied by the quantity of metal used in the pipes. This might therefore be written—

$$D\left\{C\,L + L\,d\left(A + \frac{p\,d}{B}\right)\right\}$$

where D and C were two other factors, the values of which depended on the price of iron and the nature of the ground in which the line had to be laid. If, now, r was a rate per annum covering interest and depreciation on prime cost, the total annual cost of the transmission was

$$q\,T\left\{H_1 + a\,\frac{L\,H_1^{\,3}}{p^3\,d^5}\right\} + r\,D\left\{C\,L + L\,d\left(A + \frac{p\,d}{B}\right)\right\}.$$

To find the most economical diameter, this had to be differentiated with respect to d, and the differential coefficient equated to zero. L disappeared from the resulting formula, showing that the best diameter for a long length was also the best for a short length for the same power to be delivered at the extremity. The result was—

$$d^6\left(A + \frac{2\,p\,d}{B}\right) = \frac{5\,q\,T\,a}{r\,D}\cdot\frac{H_1^{\,3}}{p^3}.$$

Since $\left(A + \frac{2\,p\,d}{D}\right)$ was only little more than the thickness of metal in the pipe, and could be approximated to by preliminary guesswork, it was not difficult to solve this equation by a few trials.

Mr. Webster. Mr. JOHN J. WEBSTER observed that the rapid and extensive development of the system of supplying hydraulic power to the public, in London and elsewhere, was sufficient proof that the many advantages of co-operation and centralization were being fully recognized and appreciated. He was intimately acquainted with the system as adopted in Hull, and in Liverpool, and knew of many instances where small consumers of power were anxious to adopt hydraulic power for working their cranes, lifts, and other machinery; but the prime cost, and subsequent working expenses of a private installation, had prevented them from doing so. With the introduction of the public supply, however, they were enabled to dispose of their existing machinery, and used the power with considerable advantage. Referring to the formula given for the loss of head due to friction in the pipes, he was afraid that, although the formula was correct, the results given might be very misleading. For instance, the loss of head calculated by the formula was given as 22·896 feet per 1,000 yards; this result was quite true if the velocity at the end of 1,000 yards remained the same as when entering the mains; but practically, the velocity was diminished after passing each machine, and it was thus quite possible for the loss of head at the end of a long length of mains to be less than that of a shorter length. From this it was evident that the actual loss on this account was much smaller per 1,000 yards than the amount given; and in any case was insignificant when compared with the loss in the pipe-bends, and in the contracted valve-ports, this amount being very considerable. The statement referring to the result of experiments with the two accumulators differently loaded, at the end of a circuit of 5 miles, required a little further explanation; for it only appeared natural that, if one accumulator was loaded to 40 lbs. per square inch more than the other—equal to a difference of head of about 97 feet—the heavily-loaded one should, in time, raise the lighter one. The statement that the pressure in the mains had been observed to be better maintained at all parts of the system when there was a considerable demand for power, although apparently paradoxical, was undoubtedly true, and the explanation given by the Author was most probably the correct one. The momentum of the long column of water in the pipes must be very great; and on the principle of the hydraulic ram, if the velocity of the column was arrested, the work done was of course equal to the force necessary to retard the given column of water, the difference of the velocities, and might be calculated approximately by the formula— Mr. Webster.

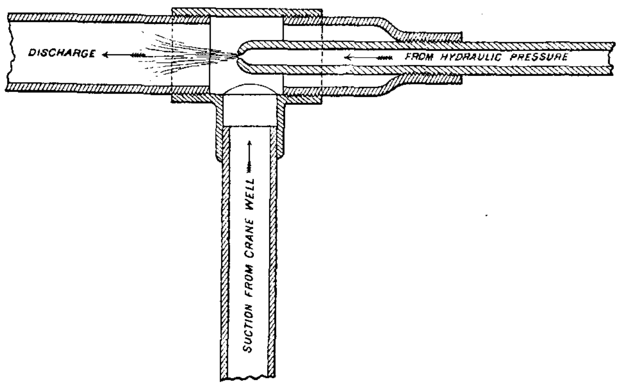
$$\text{Work} = \frac{W\,(v^2 - u^2)}{2\,g},$$

where v and u were the two velocities, W was the weight of the column of water in motion, and g was gravity. It was quite conceivable that, in a length of about 27 miles of main, many machines might have the supply shut off almost simultaneously, when the pressure developed must be very great. It would be interesting to have a number of automatic registering pressure-gauges fixed along the line of pipes, so as to have a record of the actual pressures. Relief-valves were already fixed at intervals, and he should like to know if there were any means of recording

G 2

Mr. Webster. the number of times the valves might have lifted during the day, for they would give a rough record of the existence of the above increased pressures. The form of pipe-flange designed by the Author was undoubtedly stronger than the old one, on account of its increased depth when treating it as a beam; it would be of interest, however, to know the nature of the experiments made to determine the comparative strengths of the two forms of flanges as given in Appendix II. The fracture of the lugs being no doubt due, as stated by the Author, to either the settlement of the ground, or an excessive strain in screwing up the joints. To ascertain the strength of the flanges the pipes should be tested if possible under similar conditions of strain. This could be accomplished in the first instance by submitting two pipes bolted

FIG. 14.



together, and supported at the ends, to an external load, as in testing a beam—the load representing the earth-pressure; and in the second instance, by bolting blank flanges to the pipe, and applying hydraulic pressure internally, when the pressure on the flange would be transmitted through the bolts to the lugs, and so represent the strain of tightening up. It would be noticed that, when the pipes were submitted to a vertical load, the position of the flanges must have a very considerable influence on the strength of the joint; if the flanges were placed horizontally, as they were in practice, the effective depth of the pipe as a beam was the distance between the centre-line of the bolts and of the faces in contact, equal to about one-half the external diameter of the pipe; if, however, the flanges were placed vertically, the effective depth of the beam was the distance between the centres of the two bolts, and was equal to about twice the external diameter of the pipe.

From this it appeared that if the flanges were placed vertically, with an external vertical load on the pipes, the lugs were submitted to a strain of only one-fourth of that due to the load when the flanges were placed horizontally. There was a practical objection to placing the flanges vertically, on account of the difficulty of screwing up the bottom bolt in the trenches; but there were conditions when the flanges might be placed vertically with advantage. Hydraulic pressure might be used with advantage to create an induced flow of water, on the same principle as Giffard's injector. About nine years ago he successfully adopted this plan for emptying the pit of a 3-ton crane fixed on a dock quay. The pit was several feet below the water-level, was constantly being flooded, and had to be pumped out by hand. As the hydraulic-power mains were subsequently laid for working the crane, he had an apparatus made as shown by Fig. 14, and although it was only made from tee-irons, couplings, &c., in stock, it worked most satisfactorily. Mr. Webster.

Mr. E. B. Ellington said there was very little in the correspondence needing reply. He had not entered into the history of hydraulic lifts in the Paper. He was afraid Mr. Chatwood would have been dissatisfied with the position accorded to him in any such historical retrospect. Mr. Coates had quite misunderstood the statement as to the slip of the pumps. The 5 per cent. was an empirical amount, intended to be ample to cover all contingencies during prolonged periods of work. Experimentally he had obtained in some cases of hydraulic pumps as much as 99 per cent. Mr. Coates did not give any reasons for his preference for horizontal engines. At any rate no results equal to those obtained with the engines at Falcon Wharf doing the same kind of work had, he believed, been published. Whether engines were better placed vertically or horizontally was, after all, very much a matter of convenience. As to the pipe-flanges, experience had conclusively proved that the flanges as now used in London were stronger than the older form. Mr. Webster had indicated the true reason for this. Failures of pipes had occasionally occurred in docks and other places, though the particulars might very well not have come under Mr. Coates's observation. In reply to Mr. Webster, as to the conditions of the experiment of one accumulator raising the other, the normal difference of head was stated to be 20 feet in the Paper. In using the formula given for pipe-friction, the velocity must be known before the calculation could be made, and judgment must be exercised as to the margin of pressure to be allowed. Mr. Ellington.