DESCRIPTION OF THE LIFTING AND HAULING APPLIANCES IN PORTSMOUTH DOCKYARD.

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In addition to the hand-power appliances which are common to all such large establishments, there are in use in Portsmouth Dockyard, for the cranes, capstans, &c., three separate systems of Mechanical Power:—namely Steam, Hydraulic, and Pneumatic. The first of these, besides being employed for working several machines direct, is also used for producing the pressures required for the two other systems. There are in the dockyard, in almost constant use for various purposes, no less than ninety-six boilers, with an aggregate of 784 square feet of grate surface, burning about 10,000 tons of coal per annum, and developing an average of 3,150 indicated horse-power during working hours. Most of them are fitted with feed-water heaters, by which some of the waste heat from uptakes is utilized, and the feed-water is supplied to the boilers at a temperature of about 130° Fahr. The majority of the boilers are worked at pressures of from 60 to 80 lbs. per square inch.

Hydraulic Power.—There are three separate pumping stations for obtaining the pressure for the general service of the yard, that is to say for the ordinary cranes, capstans, &c. The pipes, of which the arrangement is shown in the plan, Plate 33, are connected, so that any of the pumps can be used on the system. Water being here cheap, there are no return pipes, but the exhaust water runs away into the drains.

The first hydraulic pumping station is at B, Plate 33, near the main entrance to the yard, and includes two separate sets of engines, each with a pair of pumps. The larger set has cylinders 26½ and 38

inches diameter with 2 feet stroke, the diameter of the pump plungers being $5\frac{7}{8}$ inches; and the indicated horse-power of the set is 128 I.H.P. The smaller set of engines is of about 40 horse-power, and is used chiefly as a stand-by. It is seldom required to keep more than one of the two sets of engines running for working all the hydraulic machines in connection with this station. These comprise eight cranes, with lifting powers varying from $1\frac{1}{2}$ to 10 tons, nine capstans, and nine lifts. The engines also supply pressure for working the chain-cable testing machines, as well as water for testing boiler and other tubes.

The second hydraulic pumping station is at the iron foundry V, where there are two sets of pumps worked from the shop shafting. These are primarily for the use of the foundry, in which there are three lifts; but being connected with the main pressure service pipes, the pumps can be used for the general service of the dockyard if necessary.

The third hydraulic pumping station is at the head of No. 8 dock, Plate 33, and the engine here is more modern than either of the others; it is compound, and capable of developing about 112 indicated horse-power.

The total length of pressure pipes is about 10,000 feet, or nearly two miles. The pipes vary from $1\frac{1}{2}$ to 4 inches diameter, and are placed entirely underground. There is therefore no serious trouble from frost during cold weather; all that is found necessary is to light small gas-jets in the various engine-boxes at the cranes and capstans.

In addition to this main hydraulic system, there are certain complete self-contained local systems. In the smithy K is placed one of these, comprising a 20 horse-power steam engine and accumulator, working two 40-ton cranes with travellers. In the boiler shop J there is another set of hydraulic plant for working the riveters, hydraulic presses, &c. Another application of hydraulic power is for stretching boiler tubes, and a machine for this purpose is now at work in the boiler shop. A commencement was made by stretching brass tubes which had been removed from boilers for cleaning; and new good ends were thus obtained for fitting in the

tube plates. After having been extended to iron tubes, the practice has now been further extended to steel tubes, which above a certain limited size, say $2\frac{1}{2}$ inches diameter, require heating before being stretched. Tube-stretching machines with hydraulic jacks have since been supplied to all the foreign dockyards of H.M. Government, so that tubes of boilers which have been removed for cleaning can now be stretched and put back again, instead of new tubes having to be used as formerly.

An additional complete hydraulic system with boilers and engines is now being fitted by Messrs. Tannett Walker and Co. at Coaling Point, at the north-western corner of the tidal basin, Plate 33. It is intended for coaling the fleet either direct from the shore or by means of lighters; and, besides ten 30-cwt. travelling cranes, it will comprise three 10-ton coal tips, with the necessary capstans, weighbridges, &c. This hydraulic system is fitted with return water-pipes.

Compressed Air.—In the most modern part of the dockyard the lifting and hauling appliances are worked chiefly by compressed air; the only exceptions are the heavy cranes and sheers, which are worked by steam-power direct. The air is compressed to 60 lbs. pressure per square inch into eight wrought-iron receivers, having a total capacity of 18,000 cubic feet. The compressing is done by one or other of two separate sets of pumps. One set consists of two pairs of compressing pumps worked through gearing, either separately or together, by a pair of simple engines of 90 indicated horse-power. The other set of pumps is worked by a pair of compound beam-engines of 200 indicated horse-power. This machinery is situated at the main pumping station R about the centre of the yard, Plate 33; and besides the air-compressing machinery the same building contains the main dry-dock pumping machinery of 1,000 indicated horse-power, and two pairs of 120 horse-power engines for general fire and dock-drainage purposes. The larger set of air-compressing pumps will fill the eight receivers to 60 lbs. pressure in one hour. No case of a receiver bursting has occurred here; and there is no record of a pipe having been replaced during the last two years. There is

also less trouble with air joints than with steam and hydraulic joints.

The air pipes, which have a total length of 14,000 feet or about $2\frac{3}{4}$ miles, and vary from 3 to 12 inches diameter, extend round the large basins, as shown in the plan, Plate 33, and are connected to forty 7-ton capstans, to five 20-ton cranes, and to the machinery for working seven caissons Z and numerous penstocks, besides driving a small workshop engine. The air pressure is also used occasionally for driving small engines for carrying out machine-work on board ships building; and it has also been connected with the auxiliary steam-pipes of some of the larger battle-ships, so that air-pressure could be used instead of steam for driving the hydraulic pumping engines on board the ships for working the gun gear for drill purposes, and also for driving the electric-light engines and other auxiliary machinery on board. This obviates the necessity of getting up steam in the ships' boilers, thus admitting of their being kept systematically in a certain condition, either closed and dry, or quite full of water: which would be impracticable if they were being used at irregular intervals and at short notice.

Steam Power.—The direct use of steam for the lifting appliances is almost entirely confined to the heavy cranes and sheers, to the portable machines, and to a few cases where there is steam power conveniently near. The large tripod sheers U at the east end of the repairing basin, by Messrs. James Taylor and Co. of Birkenhead, have a working capacity of 80 tons and have been tested to 120 tons; their height is 140 feet, and they can overhang the basin wall 40 feet, the back leg being worked in and out by means of a screw. Two 50-ton steam cranes by Messrs. Cowans Sheldon and Co. are also situated at this part of the yard, one on the south side of the rigging basin and the other on the south side of the tidal basin. At the steam basin there are a 40-ton steam crane by Messrs. Fairbairn and Co., and a pair of 40-ton sheers worked by steam, the legs of the latter being shifted in and out by guys moved by steam crabs; also a 15-ton steam crane and two hand cranes, one for 15 tons and the other for $7\frac{1}{2}$ tons. On the harbour side at X, there is

a pair of 50-ton sheers with fixed legs ; and opposite to these, on the side of the ship basin, another pair of 25 tons. In addition to the above, there are several smaller steam and hand cranes and capstans, spread about the yard ; also various travellers in the shops, worked by ropes, by shafting, and by hand.

The travellers in the iron foundry offer a good example of the saving of labour due to the application of power. These 24-ton travellers were originally manual, and required eight men to work them during the pouring of the metal for a moderately large casting. Since power has been applied to them, all the operations can now be performed by two men at the most, and with much greater certainty.

Comparative Advantages.—Steam power, as already stated, is almost entirely confined to single machines and central stations. If it could be used without being condensed or cooled in the pipes, it would of course be more economical than either air or water, because it would save all the efficiency lost in the air compressor or in the hydraulic pump. But it is quite out of the question for any extended general service over such a distance as a couple of miles of pipes, and cannot therefore be considered in comparison with the two other systems in regard to general convenience and economy. Comparing however the various advantages possessed by the hydraulic and pneumatic systems, the dockyard experience is greatly in favour of the latter. For a number of machines working with a certain amount of regularity, perhaps the hydraulic system would be the better as regards economy ; but with work like that in the dockyard, which includes the use of a large number of machines spread about at considerable distances from the source of power, and with extensive variations in the demands made on the power, it is found that the requirements are best and most economically met by the compressed-air system. By means of the air receivers, sufficient power can be stored up to work about half the machines connected therewith for about two hours ; the air-compressing engines can therefore be worked at regular speeds, and stopped if necessary for repairs, without fear of the various

cranes and capstans being suddenly brought to a standstill for want of pressure; and it is hardly ever necessary for the pumps to be driven at their utmost speed, even when considerably more than ordinary demands are made upon the pressure. Consequently the necessity of working the boiler fires harder for only a few minutes' spurt is avoided, together with the waste of fuel due to steam blowing off at intervals. By pumping the receivers up in the evening before the yard closes, power is available for opening a caisson or penstock or working a capstan during the night, without having to start the compressing engines at all. Experiments made here show that the relative economical values of the air and hydraulic systems when applied to capstans are as 13 to 11 respectively, while the great balance of convenience is also in favour of the former: in addition to which it is found that the wear is much less in the air machinery than in the hydraulic, and moreover that the engines worked by air are less easily disarranged or put out of working order than those worked by water.

Machinery for working the Sliding Caissons.—In Figs. 1 to 4, Plates 34 and 35, is shown one of the sliding caissons, which consists of a number of horizontal compartments. Of these the lowest is an air chamber, containing some pig-iron ballast; and the next above is a water space, open at the ends. The third compartment is an air chamber, fitted with a water-ballast tank T at each end, and pumps P midway between, by which either tank can be pumped out or filled independently of the other; and the compartment above this is an air chamber A, in which are the cranks &c. for working the pumps. The next two compartments above are open at the ends, and together form a strongly bracketed structure for carrying a floor, to which is transmitted all the weight that passes over the upper platform F. The chamber or recess R into which the caisson floats when opening is covered over and forms part of the roadway; the upper platform of the caisson with its stanchions and hand-rails is therefore arranged so as to lower down sufficiently to pass under the road. The engines, which are situated at E and are worked by compressed air, have cylinders of 16 inches diameter and 17 inches stroke, and are

arranged so as to open or close the penstocks of the docks or basins adjacent, to drive the shafting S for lowering the upper platform of the caisson, and for working the pumps P for pumping out the ballast tanks, besides hauling the caisson itself by means of chains. For lowering and raising the platform F, there are in the uppermost chamber a pair of carriages CC drawn together or moved apart by a shaft with right-and-left-handed screws, Fig. 4; and these carriages are connected to the platform above by sixteen pairs of links L. When the two carriages are furthest apart, the platform is up, and all the links are vertical, thus forming a rigid roadway for the heaviest traffic; but when by means of the traversing screws the carriages are brought together, the links become inclined and the platform is lowered. The stanchions and hand-rails are all jointed, and so connected to the caisson that, as the platform is lowered, they stow horizontally so as to clear. To prevent undue stress on the raising and lowering gear, the moving platform F is counterbalanced by weights W below.

In Figs. 1 and 2, Plate 34, is shown the lead of the chains which move the caisson. The chains on the lower barrels B draw the caisson into the recess, while those on the upper barrels U pass over sheaves or fair-leads secured to the masonry, thus forming loops, which, being connected below the fair-leads to projecting arms on the caisson, haul it outwards across the dock entrance. While the lower chains are winding on their barrels, the upper are unwinding, and *vice versa*. The caisson while being moved is of course kept floating, the water-ballast tanks affording a ready means of regulating its displacement according to the height of the tide.

Dock Pumps.—Of main dock-pumps there are four sets. The oldest set, situated at G, Plate 33, comprises five chain-pumps, working in 24-inch barrels and driven by a 40-H.P. engine. These, though old-fashioned, still do good service in pumping out the docks in the old part of the yard. They are good for 1,600 tons per hour from an average depth of 15 feet; and besides pumping out docks they are used also for pumping up the old ship basin when it is necessary to have an extra depth of water over the dock sills.

The second set of dock pumps is situated at the back of the factory J, and consists of six single-acting lift pumps, with barrels 3 feet diameter and having a stroke of $2\frac{1}{4}$ feet; the power is obtained by means of gearing from a set of 300 I.H.P. compound engines. The aggregate capacity of these pumps is equal to 2,500 tons per hour.

The largest and most important dock pumps are the third set, situated in the main pumping station R, Plate 33. The engines, by Messrs. James Watt and Co., are of 1,000 I.H.P.; and the pumps have been made and fitted by Messrs. Easton and Anderson. The steam cylinders are 40 and 64 inches diameter by 5 feet stroke; boiler pressure 80 lbs. The pumps are single-acting, 8 feet diameter and 6 feet stroke. They were originally double-acting pumps, 6 feet diameter and 6 feet stroke, and were capable of pumping out one of the largest docks in $3\frac{1}{4}$ hours, which gave a rate of 20,500 tons lifted per hour from a mean depth of 23 feet. The wear and tear on the pumps was very great, and they were eventually changed for the present single-acting pumps, and the speed was slowed down, so that it now takes about 4 hours to pump out a dock, giving a rate of about 16,500 tons per hour.

Close at hand at M is the fourth set, comprising a pair of centrifugal pumps, 6 feet diameter, driven by a compound engine, with 27 and 50-inch cylinders and 3 feet stroke, working 31 revolutions per minute and developing about 400 I.H.P., and driving both pumps at 130 revolutions. These also are by Messrs. James Watt and Co. The pumps together lift at the rate of 7,500 tons per hour from the mean depth of 23 feet. In designing these centrifugal pumps it was intended that the two should work together until about 20 feet was pumped out of the dock, and then they were to be worked in series, the delivery from one pump becoming the suction for the other. But on the trials it was found that much better work could be done by letting the two pumps both go on drawing direct from the dock; and though the extreme depth from suction to delivery is 40 feet, yet the pumps continue to work efficiently to the end.

Discussion.

Mr. WALTER HUNTER was sure any one who had had an opportunity of visiting Portsmouth dockyard must have been struck with the complete nature of the appliances for lifting and hauling throughout the works, as described in the paper; and the same conclusion must be evident also from the fact mentioned in Mr. White's paper (page 242), that the "Royal Sovereign" had been built, completed, and commissioned within so short a time as only two years and eight months from the laying of her keel. It would be impossible for a ship to be so speedily and economically constructed unless the mechanical appliances available were of a high class. At the same time there was one particular in which it appeared to him that the naval dockyards were not up to the practice of the present day in regard to their lifting appliances, as compared with large mercantile docks and harbours. In the docks of London and Liverpool floating cranes were now in constant use for shipping and unshipping heavy weights, having practically superseded the fixed sheers formerly employed for this purpose; and he thought that any one experienced in lifting in docks would come to the conclusion that floating cranes gave the greatest facilities for loading and unloading in the shortest space of time. Two floating cranes which he had supplied to the St. Katharine's Docks and the East and West India Docks in London were of 50 and 30 tons lifting capacity. The 50-ton crane "Leviathan" was capable of masting the largest ships coming into the port of London; it was similar to the floating crane seen by the Members in their visit to the Tilbury Docks in August 1886 (Proceedings, page 451). It had lifted three boilers, weighing 55 tons each, on board H.M.S. "Blenheim" in one day, between nine o'clock in the morning and five in the afternoon, which he thought was a good day's work. He was informed by Mr. Robert Carr, chief engineer of the London and India Docks Joint Committee, that in 1891 in twelve months the "Leviathan" floating crane had lifted 3,740 tons, and the 30-ton floating crane, the "Titan," had lifted 3,112 tons; while in the first six months of the present year 1892 the larger crane had lifted 2,772 tons and the smaller 1,445 tons.

(Mr. Walter Hunter.)

The advantages of floating cranes were numerous. They took up no quay space themselves, and obviated the necessity for removing a ship from her berth to the sheer legs when heavy weights had to be taken off or put on board; the removal of the ship for such a purpose was always attended with some risk and considerable expense, besides entailing the stoppage of all unloading and loading of cargo while the ship was away from her berth. A floating crane could steam alongside a ship, take out or put in a crank-shaft, boiler, gun, or armour-plate, and move any other heavy weights, while the ordinary discharging or loading of cargo was being carried on from the quay, and without shifting the ship from her moorings. The hulls of the floating cranes were so constructed that guns or boilers or other heavy loads could be placed upon their decks, and conveyed to or from a ship, wherever she was lying. The crane could also lift weights out of a ship, and deposit them in a barge on the other side of its own hull, without moving from alongside the ship. It could be fitted with single-purchase gear when desired, for lifting lighter weights at a quicker rate, and so facilitating the ordinary unloading or loading of cargo or stores. The cranes could be fitted on a sea-going vessel to steam to any port, and the vessel could be arranged for carrying heavy guns out to a blockading fleet, so as to prevent a war-ship with damaged armament from having to come home in order to refit; the crane hull could further be fitted with machinery for executing repairs for the fleet. In times of war, if damaged ships came into harbour for repairs, a floating crane would be of the greatest service for enabling the work to be quickly performed; because there would be no absolute necessity for the ships under repair to lie alongside the quay, and they would not have to wait their turn to go under the sheer legs for getting heavy weights moved. It had already been remarked by the President (page 255) that in the present age wars were shorter, while the preparation of the means of defence was longer; and it was therefore of greater importance that the dockyards should be equipped with the best appliances for saving time when ships came in for repairs and equipment. With a view therefore to the efficiency of the navy, upon which the safety of the country was mainly dependent, it

seemed to him most desirable that floating cranes should form part of the equipment of every naval station.

Mr. CHARLES COCHRANE, Past-President, enquired what was found to be the loss of pressure in the working of the pneumatic cranes. It appeared from page 297 that the air was compressed to 60 lbs. per square inch in the receivers, and was conveyed through pipes varying from 3 to 12 inches diameter ; and he had been given to understand that it was so conveyed in some cases to a distance of as much as half or three-quarters of a mile from the receivers. It was an important matter therefore to know what loss of pressure there was in going such a distance.

Sir FREDERICK BRAMWELL, Bart., Past-President, had no doubt it would be generally agreed that one of the most important matters which mechanical engineers had to deal with at the present day was the transmission of power to a distance. A description had been given in Mr. Corner's paper of two modes of accomplishing this which were well known, namely by compressed air and by hydraulic pressure : both of which were undoubtedly serviceable modes. There was also an allusion to the direct use of steam, which naturally brought to mind the attempt that had been made in New York to transmit power in that way. He did not know the present condition of the enterprise, having heard nothing of it for the last two years ; but when he was there eight years ago it was already coming into use, and he knew that since that time it had been largely extended. Some interesting results had been obtained with regard to the rate of condensation in pipes buried under the surface of the ground. There was also another mode which had been much thought of, but which the paper had not dealt with, being confined to methods actually in use at the dockyard : namely the transmission of power electrically.

In reference to the pneumatic transmission of power he should be glad to know what difficulty, if any, was experienced with the engines worked by compressed air, from moisture freezing in their outlet passages, and how it was got over ; or whether it was a fact that, as the engines were crane engines or capstan engines, and were therefore

(Sir Frederick Bramwell, Bart.)

working only a few minutes at a time, there was not sufficient time for any formation of ice to take place. The great success of the pneumatic system at the dockyard he had not the least doubt was due to the enlarged views which had led to putting up the eight storage receivers having such an ample capacity as 18,000 cubic feet. This provision no doubt enabled the air-compressing engines to work continuously into the receivers, and also provided large storage for meeting any peculiar demands upon them. It had been a most wise course he thought to incur the considerable expense which must have been incurred in providing such large storage capacity. He should be glad if the writer could give any information as to the absolute power obtained from an engine worked by compressed air, compared with the power exerted for the compression of the air; and also the same information with respect to the hydraulic method, although the latter was pretty well known. Repeating the calculation which he had made at the York meeting of the British Association in 1881 (Report, page 504) about the transmission of power hydraulically, he found that a 10-inch pipe one mile long with the usual pressure of 700 lbs. per square inch would convey 300 horse-power with a loss of head of only 35 feet, or about 14 or 15 lbs. per square inch, being only 2 per cent. of the initial pressure. As he had already mentioned on more than one occasion, in earlier days he had been enabled to see the mode of transmitting power which was invented by Mr. John Hague, to whom he was then apprenticed; but it did not come into extensive use, because he was before his time. The principle was the converse of pressure, namely the exhaustion of air, maintaining a vacuum of 10 lbs. per square inch in the mains, and working the engines at the further end by the pressure of the atmosphere passing through them and going into the mains. It worked for a distance of over a mile and answered extremely well. One use made of it was for engines driving gunpowder machinery, the exhausting steam-engines being away from the building in which the pneumatic engines were placed; that application also worked very well. The whole subject of power transmission was highly important, and it was seldom that a record was obtained of an undertaking carried out on so large a

scale as that at Portsmouth dockyard, and described by a gentleman so thoroughly competent to explain it as the writer of this paper.

MR. JEREMIAH HEAD, Past-President, said that the important question raised by Mr. Cochrane (page 305), as to the loss of power when conveyed to a great distance either by compressed air or by water, recalled the discussion that had taken place at a recent meeting on the supply of motive power by water pressure in Liverpool (Proceedings 1892, pages 55-6). The great cost of power conveyed by water through a line of pipes to a distance, and there used intermittently and in small quantities, he thought was scarcely appreciated by engineers generally. In Liverpool it appeared that, whereas the cost of a horse-power in pumping into the supply reservoirs was only from a halfpenny to a penny per hour, yet when the water reached the warehouse cranes in the lower parts of Liverpool its cost amounted to between 13*d.* and 14*d.* per hour per horse-power actually used at the cranes. This showed the great loss that must be allowed for in conveying hydraulic power through a long line of pipes for intermittent use.

THE PRESIDENT asked for a little more information about the process of stretching boiler tubes by hydraulic power, as mentioned in the paper (page 296). It was quite new to himself, and appeared to be a most interesting operation. There were various questions that might be asked, as to whether the tubes were much thinned by the stretching, and whether their diameter was reduced, particularly at the ends; and in regard to other practical details of the process further information would be acceptable.

MR. CORNER said his paper had not been written with a view of putting forward any novelties, but simply to give a general account of some of the useful appliances at work in the dockyard, so that the members in their visit to the establishment might know where to find these, and might there make any enquiries they wished about them.

(Mr. Corner.)

With regard to the recommendation to use floating cranes (page 303), these had already under a different form been used in the navy for many years. Before the construction of the present large basins and wharves, nearly all the lifting had been done by means of cranes mounted upon old sheer-hulks. The masts used to be floated down a slipway into the water, and towed off, and lifted into their places by these cranes. If they could only have lifted a crank shaft in the same way, they would have been still more serviceable ; but as crank shafts were not so manageable in the water, it was preferred to bring the ships to the stationary crane or sheer legs on the wharf ; and this plan he thought would be found to be the most economical and convenient in a place like a dockyard. No doubt if there was a large dock area with limited lifting power, it was an advantage to be able to move the crane about and take it from ship to ship ; but in naval yards he thought there would not be found much use for the floating crane. As mentioned in Mr. White's paper (page 247), there was at present to be seen in the dockyard the "Vulcan," fitted with two 20-ton hydraulic cranes and two 10-ton hydraulic derricks. One intention of this ship was to take the place of a floating factory in the fleet, and also to serve as a floating crane. Moreover every battle-ship and first-class cruiser was fitted with a derrick capable of lifting nearly 20 tons. It would therefore be seen that there was now plenty of lifting power afloat, without going back to the old sheer-hulk.

With regard to the loss of pressure in the air pipes and also the increase of temperature due to compression, he had found that, in pumping up the air receivers from 40 lbs. to 60 lbs. pressure with a temperature of 75° Fahr. in the engine-room, the maximum temperature of the lubricating water drawn off from the bottom of the receiver, which approximately represented the temperature of the compressed air, was 118° ; and the highest temperature that could be measured by fixing the thermometer directly upon the shell of the receiver was 106° : so that there was not any considerable or dangerous increase of temperature in the compression. The loss of temperature at a distance was found to be very small. The pipes themselves were good, and were made with flanged joints, faced and

bolted together, which were found to keep tight; there was no record of any trouble having been experienced with the pipes during the last two years. With these tight joints and while all the machines were standing still, the pressure all over the system was practically uniform; but with a small draft from the pipes, perhaps for two or three capstans, there was a loss of from 3 lbs. to 5 lbs. of pressure. When there was a larger demand for air, the pressure went down to 20 lbs. or 35 lbs. less than that in the receivers.

With regard to formation of ice (page 305), the engines worked by air had not been troubled to any extent in this respect, as they did not work usually at any high rate of expansion. When they were linked up for a light load, as was sometimes the case to the extent of cutting off at one-sixth of the stroke, ice formed at the exhaust ports, especially in damp cold weather; but the exhaust ports had never become choked up, because they opened direct to the atmosphere; the engine, after two or three strokes, coughed and cleared itself, and then no more ice or snow came out for some time.

As to the relation between the power stored in the receivers and that given out by the compressing engine and the air-driven engine, he found that the compound air-compressing engines, in pumping up four receivers from 0 to 60 lbs. pressure, gave out $122\frac{1}{2}$ horse-power in their steam cylinders, and did the work in half an hour. The air-compressing pumps of these engines developed 80 per cent. of the engine power, which was further reduced to 71 per cent. by friction in the pipes leading to the receivers, and probably also by the circulating water cooling the air a little: so that there was 71 per cent. of the engine power stored in the receivers. During experiments the work developed at the capstans in each case was measured by a friction dynamometer, consisting of a strap passed round the drum on the capstan head, and connected by long levers to the dynamometer spring; and allowance was made for the friction of the levers, as well as for the ropes not being exactly at right angles to them in all positions. The percentage of the air-compressing engine power that was obtained at the capstan engines at a distance of two miles from the receivers, with the heaviest load on the capstan that the dynamometer would admit of, was about

(Mr. Corner.)

20 per cent., with 60 lbs. pressure in the receivers. With 30 lbs. pressure in the receivers and the load on the capstan diminished to about two-thirds of the previous load, the efficiency was increased to about 30 per cent. With hydraulic engines and capstans, on the other hand, the percentage of efficiency was greater as the work increased: for at full capstan-power the percentage of main-engine power at the capstan engines was 40 per cent. with water pressure, against 20 per cent. with compressed air; but when the load was reduced to one-third of the full load, the hydraulic efficiency fell to 22 per cent.

Throttling the water to diminish the speed of hydraulic capstan-engines diminished the efficiency; while with air capstan-engines the efficiency remained practically the same with loads much varied. If half the actual maximum load used on the trial of these capstans were taken as the average work required, the air capstan cylinders gave 24 per cent. of the main-engine power, as against 29 per cent. for the hydraulic capstan cylinders. But comparing the work actually done by the capstans, it had to be noted that the air capstans were not working up to more than one-fifth of the power of which the capstan-engines were capable. By calculations made from the friction diagrams taken from air capstan-engines, it was found that with the full power the capstan would be doing at least 55 per cent. of the capstan-engine power. The efficiency of the hydraulic capstan with maximum load was actually 43 per cent. of the capstan-engine power. Hence the total efficiency of the air capstan would be $24 \times 55 \div 100 = 13$ per cent. of the main-engine power, against $29 \times 43 \div 100 = 12\frac{1}{2}$ per cent. of the main-engine power for the hydraulic capstan. In this calculation the work was assumed to be continuous; but as a matter of fact it was very irregular, and on this account the pneumatic system with its large receivers had a decided advantage over the water system. It was therefore necessary to modify the above percentage for water power, inasmuch as coal consumption trials showed that the hydraulic system suffered to the extent of at least 12 per cent. from irregular working, whilst the pneumatic lost none of its efficiency on that account. The total efficiency of the hydraulic capstan was thus reduced to $12\frac{1}{2} \times 88$

$\div 100 = 11$ per cent. of the main-engine power. The relative efficiencies of the pneumatic and the hydraulic capstans were accordingly as 13 to 11, as given in the paper.

The tube-stretching machine employed in the dockyard had been used at first for stretching brass tubes. In the navy there were a number of boilers that came in for cleaning, and it had been found cheaper to take the tubes out than to send a man into the boiler to clean down between the tubes. But the number of times the tubes could be taken out for cleaning was limited by the great expense of putting new tubes in; and this was now got over in a measure by stretching the tubes by hydraulic power, making fast a clamp at one end and fixing a hydraulic jack to the other end, and stretching the tube by pumping water into the jack. A mandril was inserted in each end, in order to keep the ends of the tubes up to the full diameter. The tubes were not stretched much; a tube 6 feet long was stretched about 2 inches or 1-36th. The reduction in the thickness of the tube was therefore very little indeed; even the reduction in diameter was hardly perceptible, and in thickness it was still less. By drifting the ends as before, after cutting off the ragged or burnt extremities, a good tube was obtained, long enough to be refixed in the tube-plates for use over again. In this way it had been found that the brass tubes could be stretched cold five or six times. Iron tubes had then been tried, and it was found that these also could be stretched cold as well as the brass tubes. With steel tubes the pressure was not enough to stretch them cold, so that they were obliged to be warmed up to nearly a red heat; and by cooling the ends and driving a mandril into them the ends were kept sufficiently near their original size to fit into the tube-plates again properly. This process had had its origin in Portsmouth dockyard, and had been developed to such an extent that many of the ships now drew their own tubes for cleaning, and by means of one of the small hydraulic jacks stretched them, and then put them in again, which formerly was almost impracticable. The tubes required careful drawing, in order to admit of their being put back again into the boiler with their old ends. This process had proved a highly valuable one for the navy, and also very useful for engineers in general.

The PRESIDENT was sure the members would wish to join him in a vote of thanks to Mr. Corner for his most interesting paper, giving an insight into one of the many important features of Portsmouth dockyard.

DOCKYARD LIFTING AND HAULING.

Plate 34.

Sliding Caisson. Fig. 1. *Plan.*

Fig. 2. *Longitudinal Section.*

Mechanical Engineers 1892.

Scale $\frac{1}{320}^{th}$

10 Feet 0 10 20 30 40 50 60 70 80 90 100 Feet

Plate 34.

Recess

cess