PORTABLE PNEUMATIC TOOLS.

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Since the Paper on Portable Pneumatic Tools was read before the Members of the Institution in 1900,* many improvements have been made in the tools then described, and many new tools have been brought out. In the present Paper the author briefly describes the improvements effected in the early tools and the most important new tools. The principal uses to which the various tools are put, and the effect of their use on the cost of production of the work on which they are employed, are also briefly gone into, and it will be seen that very considerable progress has been made during the last six and a half years in the tools themselves and the range of work to which they are applicable. It will also be seen that the engineers of Great Britain and the Continent are now as fully alive to the very important advantages to be derived from the use of pneumatic tools as the engineers, shipbuilders and others in America, where such tools were first used on an extensive scale.

At the present time it is not too much to say that pneumatic tools will be found in use in practically all engineering works, shipyards, and

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mines, not only in America and Great Britain, but all over the world, and in addition, they are largely used by contractors everywhere on constructional work of steel, stone, and wood. Not only have the various trades concerned availed themselves largely of the advantages offered by these tools, but at the present time there are many engineering firms in this country engaged in their manufacture; also, the tools produced by them compare very favourably, with regard to accuracy of workmanship and quality of the material employed, with those made on the other side of the Atlantic. Users doubtless might be found who would say that there is still considerable room for improvement, and that the length of life of all kinds of pneumatic tools is not what it should be; but when the amount of work performed and the speed at which the tools work are taken into account, it will probably be admitted that while there is still room for improvement both in design and construction, the results achieved so far have only been made possible by the employment of the greatest care in their manufacture and the use of the most modern machinery and methods.

In the following descriptions of pneumatic tools, their characteristic features only will be mentioned, and no attempt will be made to follow out accurately and explain the means whereby the complete cycles of operations are attained, as such complete descriptions of the tools would necessitate explanations much too long for this Paper.

HAMMERS.

Commencing with pneumatic hammers for caulking, chipping, and riveting, it may be as well to mention first the work for which they are principally used, and to give some particulars of work done. That the demand for pneumatic hand-hammers for these purposes continues to be brisk may be gathered from the number of new hammers that have been brought out in recent years. These chipping and caulking hammers are principally employed for all kinds of caulking work on boilers, tanks, ships' plating, pipes, etc.; for all kinds of chipping; fettling castings in steel, iron, and brass foundries; for erecting-shop work; in shipyards on new work and on

repairs. They are also used for beading tubes, cutting out tubes, scaling tubes and boilers, and removing old paint from ironwork.

Generally speaking, ordinary work is now done by these tools at a price for labour equivalent to a reduction of from 35 to 60 per cent. off hand-labour rates; but on work which is at all awkward to get at with hand tools, the reduction would be greater still, for while the pneumatic hammers can be used on any job, provided there is sufficient room for a man to hold the tools in position, much more room is required in which to swing a hand hammer, and if the necessary space is not available the hand tools either cannot be used at all, or only at a great expense of time and labour.

To mention a case in point: quite recently at Aberdeen the joint of the bottom mud-door in the front of the boiler of the steam-trawler "Welfare" between and below the two furnaces could not be kept tight, and examination of the edge of the plate—which was flanged inwards—on which the joint was made showed the face to be deeply scored across at one place, necessitating its being refaced. This job could not have been done by hand in three days, and as the boat could not wait, the John Duthie Torry Shipbuilding Co. were asked if they would face this joint with a pneumatic hammer; the ship was towed to their wharf and one of their men put on to do it. The mud-door measured 14 inches by 9 inches, and the plate had to be chipped from $\frac{3}{8}$ inch deep at one side running out to nothing at the other. In 9 hours after starting work the boiler was ready for steaming, the edge of the plate having been chipped and filed up true in that time.

With regard to scaling boilers by pneumatic hammers, Messrs. John Allen and Sons, of Kilburn, give the following comparative figures, one boiler (Cornish, 30 feet by 6 feet) only being referred to, the average thickness of scale being $\frac{3}{8}$ inch. The two pneumatic hammers used weighed $9\frac{3}{4}$ lbs. each, with pistons of $1\frac{1}{16}$ inch diameter and $1\frac{3}{4}$ inch stroke.

By hand.—Eight men at 9d. per hour were employed for 9 hours per day, each man receiving 2s. 6d. per day extra as "dirt" money. The job took 6 days.

	£	s.	d.
Cost per day : eight men at 9s. 3d.	3	14	0
Cost for the 6 days	22	4	0

With two pneumatic hammers.—Four men employed, two using the pneumatic hammers and two their hand tools, the same job taking but three days.

	£	s.	d.
Cost per day : four men at 9s. 3d.	1	17	0
Cost for the 3 days	5	11	0
The saving in labour thus being	16	13	0

Taking the above figures to be correct, it is seen that the two pneumatic hammers did no less than seven-eighths of the work, and that they could have done the whole of it in a trifle less than $3\frac{1}{2}$ days, for which time the cost of labour would have been £3 4s. 9d. only, and the saving £18 19s. 3d.

The riveting hammers are now capable of driving rivets up to $1\frac{1}{2}$ inches in diameter, and are employed in all kinds of constructional ironwork both in the yards and in the field; on boiler work, on furnaces, combustion-chamber and shell plating, and in shipbuilding for both shell, bulkhead and deck riveting. The use of pneumatic riveting hammers for all these classes of work is extending rapidly, proving beyond question that the quality of the work done is satisfactory, and that it is done at a cost which shows the acquisition of pneumatic tools for this work to be a remunerative investment.

Of all shipwork, deck riveting is perhaps the easiest to do, because the deck below usually forms a convenient means for supporting the pneumatic holder-on, and where an open hatchway occurs, a plank can readily be laid across. The riveting hammer too, being used in a vertical position and downwards, is easily held and directed. With practice many riveters become so expert that they prefer to dispense with the carriages provided to support the hammers, Fig. 5 (page 650), and, given a good run of work, reamed holes, plates well bolted up, a good rivet forge and a smart boy, will make good money at a rate only one-half of that given for similar work done by hand. Much bulkhead riveting is done with the aid of the spring dolly-bar, Fig. 3 (page 645), for holding up, especially

under conditions in which it is difficult to arrange to support the ordinary pneumatic holder-on.

For heavy shell-work it is necessary to use the more powerful riveting hammers, which have to be supported on suitable frames or carriages, and very excellent work is now done by them, especially on the bottom plating. On side-shell riveting $\frac{3}{4}$ -inch rivets are being driven by the ordinary riveting hammers without support, and an expert workman can drive $\frac{7}{8}$ -inch rivets on this work without having the hammer supported. In many cases, however, the hammers are attached to a light frame, which is secured to the ship's side by one bolt only, thereby relieving the riveter to a great extent of the weight of the hammer. As an example of what may be accomplished under favourable conditions by expert men, it may be mentioned that as many as 463 rivets ($\frac{7}{8}$ inch) were driven by one machine in the side shell-plating of a ship, building in the Imperial Shipyard at Wilhelmshaven, Germany, in $7\frac{1}{4}$ hours. The rivets were countersunk on both sides of the plating, the hammer used being one of the most powerful of the long-stroke hand-riveting hammers made, and weighing 23 lbs. The diameter of the piston was $1\frac{1}{16}$ inch, stroke 9 inches, weight $15\frac{3}{4}$ oz., and the approximate number of blows per minute, using air at 100 lbs. pressure, 840.

The amount of boiler riveting done by pneumatic hammers is gradually increasing, and pneumatic tools are today employed on all types of boilers, the rivets so driven in many marine boiler shops satisfactorily passing the tests imposed by the Board of Trade and Lloyd's Surveyors.

Locomotive builders, both the large railway companies and private firms, are making increased use of pneumatic hand-riveting hammers in their boiler shops, and find the work done stands the present high steam-pressure well. Most of the under-frames and bogie-frames for locomotives, carriages and wagons are, by many makers, largely riveted up by these tools, the results being highly satisfactory. For the erection of tanks, girders, bridgework, and other constructional ironwork on permanent sites, these hammers are now invariably used, the erectors' plant including the necessary air-compressor, receiver, and piping required to operate the air-tools.

The pneumatic holder-on used with riveting hammers has also been improved in common with other tools, and the type perhaps most favoured now has a double-piston. The construction is clearly shown by Fig. 1 (page 645), and it will be seen that the air-pressure acts directly on the back half of the piston A, and that the front half B, into which the rivet snap is inserted, is carried by a strong steel spring C placed between the two.

In use, the air-pressure at back of piston A which supports the snap D is sufficient to prevent any appreciable rebound of this piston on to the snap D and rivet-head, but the piston B is supported by a spring of suitable strength, which permits this piston to strike a rebounding blow on the shoulder of the snap at each blow of the hammer, tending to put the rivet-head tight up against the plate and to fill the rivet-hole. Practically no hammer action is induced on the rivet-head when the ordinary holder-on with single piston is used, but the action of the double-piston holder-on approximates more closely to the hand methods of holding up rivets, and it is interesting to know that a holding-up hammer fitted with a long shaft and supported by a hook-bolt used in conjunction with a pneumatic riveting-hammer gives excellent results.

The improvement in pneumatic riveting by the use of the double-piston holder-on was so marked that a hammer-type holder-on is being introduced, the piston of which is really a valveless pneumatic-hammer, Fig. 2. Its piston is actuated by the air which is admitted to the back end of the containing cylinder to drive it forward. In use, both hammers strike the rivet together, but, after the head of the rivet has been well set up, the holder-on hammer is stopped by closing the exhaust passages and the point of the rivet finished off, while the head is supported by the holder-on acting in the usual way.

By the use of a pneumatic hammer in combination with a holder-on, the operation of which is under control, it will be seen that, under all ordinary conditions of working, the rivet-hole at the head can be quite as well filled as at the point, provided the rivet is well heated its whole length, and that it is also ensured that the head itself shall be tight up against the plate.

FIG. 1.—*Double-piston Holder-on.* FIG. 2.—*Hammer-type Holder-on.* FIG. 3.—*Spring Dolly-bar.*

A spring dolly-bar, Fig. 3, though not a pneumatic tool, is now largely used to hold up rivets against pneumatic hammers. Its action is on the same principle as that of the double-piston type of pneumatic holder-on, a spring of suitable strength being fitted to take the blow transmitted to the holder-on snap, which causes the piston of the holder-on to react strongly on the snap at each blow struck on the point of the rivet. One of these dolly-bars weighing only 17 lbs. will successfully hold up $\frac{3}{4}$ -inch rivets against a pneumatic hammer with a minimum of discomfort to the workman, and calls for the exertion of only a moderate amount of strength; but,

FIG. 4.—*Locking Device for Hammer.*

as in hand riveting, it is advisable to let the riveting hammer strike lightly at starting and upset the rivet somewhat in the hole before letting it strike at full power, which will ensure the head of the rivet being kept up and make much easier work for the man holding up.

Descriptions of the later Pneumatic Hammers and of improvements made to the older ones.—The Boyer chipping and caulking hammer has already been very fully described,* but the new locking device now fitted for preventing the hammer coupling-sleeve becoming loose is worthy of notice. Fig. 4 shows this coupling-sleeve S screwed home into the hammer-handle H. It is seen that ratchet

* Proceedings, 1900, Part 1, page 126.

teeth are cut on the outer end of this sleeve, and that similar teeth cut on the end of a locking-ring R engage closely with them. This locking-ring is prevented from turning by a key K, which is let into the hammer-barrel B and is held securely in place by the U-shaped circular spring-clip C, which is sprung over and embraces both locking-ring and coupling-sleeve in the manner shown. The part of the key let into the barrel of the hammer is circular in shape, and fine adjustment to the nearest half-tooth is provided for by the key being formed off the centre line at a distance equal to half the pitch of the locking teeth (*see plan view of key*). With this locking device a hammer coupling-sleeve, if screwed hard up and the locking teeth are properly engaged, cannot become loose.

The Doughty Hammer is, like other valve-hammers, operated by a valve possessing differential pressure areas, but in this hammer the valve-chamber is formed in the base of the hammer-handle and at right angles to the cylinder bore. The handle is secured to the hammer-barrel or cylinder by a coupling-sleeve, which is locked by the device used for locking the coupling-sleeve of the Boyer hammer already described.

The Haesler Hammer, for Chipping, Caulking, and Riveting, possesses a distinctive valve of its own, which rotates about an axis or trunnion placed centrally with, and in the same direction as the bore of the hammer-cylinder, its movement about this axis being limited. There are two projections, unequal in length, one on either side of the valve and placed diametrically opposite, which fit into corresponding grooves in the valve-case. The shorter projection is subject to constant pressure, and the larger to air-pressure and atmospheric pressure alternately. This arrangement provides for the rotation of the valve backwards and forwards on its axis, during which movements the air and exhaust passages are opened and closed at the proper times, and the required reciprocating movement of the hammer-piston secured. Hammers of this make for riveting are provided with a longer piston-stroke than the chipping and caulking hammers.

The Howard Chipping and Caulking Hammer is one of the latest hammers which have been produced. In general appearance it is much like other hammers, and its distinctive feature is the valve-chamber, which is situated outside the hammer-cylinder altogether, but parallel with it and at the rear end, a form of construction permitting the longest possible piston-stroke in a hammer-cylinder of given length.

The Imperial Pneumatic Hammer has for its distinctive feature a cup-shaped cylindrical controlling-valve, the back end of which is closed, and which works on the outside of a flanged bushing constituting part of the hammer-bore, and on the inside of a valve-box. This valve is moved to its rearward position by compression of the air trapped in itself by the piston at the end of its return stroke, when pressure is admitted to drive the piston forward, and the front end of the hammer-bore is opened to exhaust. The return stroke of the piston is brought about by the valve then being moved to its forward position admitting pressure to front end of piston through the ports provided, and at the same time opening the rear end of the hammer-bore to exhaust. This hammer is also fitted with a regulating device by means of which the admission of air, and consequently the power of the hammer, is controlled.

The Keller Chipping and Caulking Hammer is of the usual reciprocating-valve type, the distinguishing feature of which is that the valve is designed to move in the same direction as the hammer piston. It is claimed that the valve is more firmly seated at the end of its stroke by this method of operating than valves which travel in the opposite direction. This hammer has been in use since 1899, and is better known on the Continent and in America, where it is more used than in this country.

The Stoax Hammer for Chipping, Caulking and Riveting is, as to outward appearance, similar to hammers of other makes, and the component parts are disposed in the customary way. It differs materially, however, in the method by which it is used, inasmuch

as two different air-pressures are employed, a high pressure for the working stroke of the piston and a low pressure for the return stroke, the object being to reduce vibration to a minimum. Where there are many pneumatic hammers employed, it is recommended that both a high and low pressure air-service be laid down, each having its separate air-compressor, pipe lines and connections, each hammer being coupled to two flexible air-pipes, one from each service.

The Thor Chipping and Caulking Hammer possesses two separate piston controlling-valves which work one at each end of the same chamber or valve-case, and in a direction at right angles to the bore of the hammer-cylinder. Both valves control the admission of air for the working stroke of the piston, while one valve only regulates the admission of air to the front of piston for the return stroke and opens the front end of hammer cylinder to exhaust, the remaining function of the other valve being to open the rearward end of cylinder to exhaust. The other features of this type of hammer are similar to those of other makes and perform similar functions.

The Tierney Hammer is made in sizes suitable for chipping, caulking, and riveting, and is, as to outward appearance, similar to other makes of hammers for these purposes. Its operation is controlled by a reciprocating valve possessing differential areas (but no internal ports or passages), working in the same directions as the hammer-piston and situated at the handle end of the hammer-barrel or cylinder. Air-pressure is admitted by a throttle-valve in the handle actuated in the usual way by the thumb of the operator.

The Boyer Deck-Riveting Hammer of the long-stroke type, Fig. 5 (page 650), is used for flush work in ordinary decking. To steady the tool and assist the workman to keep the snap on the rivet, the hammer is attached to a carriage and weighted as shown. It can be moved round the rivet-head quite freely. Any size of hammer can be mounted in this way.

FIG. 5.—*New Style Deck Carriage.* FIG. 6.—*Jam-Riveter.*

The Boyer Jam-Riveter, Fig. 6, is operated by the same distributing or controlling valve as the ordinary chipping and caulking hammer of this make, the riveting hammer and all its parts, however, being much larger. The hammer itself is contained in an outer casing or cylinder out of which the hammer can work to a certain extent when air-pressure is admitted at the rear end of the outer casing and behind it. It is intended for working in confined spaces, as for example, between a ship's frames; and to support itself while at work the casing at its rear end is provided with a centre. On air-pressure being turned on, the hammer is forced out against the rivet, and the whole tool is supported by the pressure exerted on the centre and rivet at either end. The space in which the tool works determines the amount of travel of the hammer outwards from the containing cylinder. When required to operate between wide supports, a piece of gas or steam-piping is screwed into the rear of the outer casing to make up the necessary length, in exactly the same way as the ordinary pneumatic holder-on would be adapted. This arrangement allows heavy riveting to be done in confined spaces with ease by the operator, who has only to place the hammer in position and turn on the air.

The new Boyer Long-stroke Hammer has replaced the original long-stroke hammer invented by Mr. Boyer, and is one of the best and most generally used of all pneumatic riveting hammers at the present time. It differs from the older hammer by having one distributing valve, which is placed at the rear end of the cylinder, instead of two distributing valves, one at either end. The air-ports in the valve and cylinder of this hammer are so designed that the full air-pressure is available to drive the piston forward on its working stroke, but the ports in valve and cylinder provided for effecting the return or idle stroke of the piston are of smaller area, so that the pressure used for this work is considerably reduced by wire-drawing, and the piston is returned practically without shock to the operator. The vibration of these hammers is thus reduced to the minimum. The illustration Fig. 7 (page 652) shows this hammer fitted with the handle generally used, the handle with automatic

New Single-Valve Long-Stroke Hammer.

FIG. 7.—Section.

FIG. 8.

Handle with Automatic Safety Controlling-Valve.

FIG. 9.—Safety Push-Handle.

safety controlling-valve, Fig. 8, being now fitted only when specially required. The action of this valve may be shortly explained. Referring to Fig. 8, the valve P is shown seated at D and closed. Its function is to prevent the hammer being inadvertently set working, through accidental pressure, on the trigger G, whereby the throttle-valve would be opened and air admitted to the hammer. Should the throttle-valve be accidentally opened, the spring R is of sufficient strength to keep the valve P closed against the pressure acting on its exposed end surface. Air-pressure passes through the passage E into the interior of the valve P, and through the small holes in this valve at F into the space O, whence it flows through the passage U₂ into the annular space U₁, Fig. 7, formed in the rear end of the valve-casing L, and thence down the long port U, which runs the whole length of the hammer-cylinder, passing into the atmosphere at the front end under the shoulder of the rivet snap. As the valve P has not been moved off its seat D, no air will have been admitted to operate the hammer. When, however, the shoulder of the rivet snap is pressed tight against the end of the hammer-cylinder, as is the case when the hammer is offered up to drive a rivet, the end of the long passage U is closed, and the air in the space O, instead of escaping, exerts pressure on the end of part K of the valve, forcing the valve off its seat D to open position, thereby admitting pressure from the passage E and thence through the passage S into the controlling valve-case, and the tool is set in operation.

In Fig. 9 (page 652) is shown another and later form of safety-device termed a safety push-handle, in which the throttle-valve V is normally closed by the four springs S acting on the plate P. This throttle-valve is opened by applying pressure to the handle in the act of pressing the rivet snap up to its work, when air-pressure is admitted to operate the hammer, and is closed by the springs S when the hammer is withdrawn. In this case it will be noticed that air is not admitted through the grasping part of the hammer handle.

The Boyer Shell-Riveter, as its name implies, is a hammer of this make which is mounted in a gimbal attached to the end of a steel

pipe of sufficient size and strength to support the hammer when working, the pipe being secured to a ship's side or bottom plating in such a way as to permit the hammer covering a large area of plating at one setting.

The workman, being relieved from the weight of the tool, is enabled to drive rivets in the bottom or side plating of a ship with comparative ease.

FIG. 10.—Arrangement of Disc Holder-on and Riveter.

Fig. 10 shows a disc-rig for supporting a shell-riveting hammer and the method of attaching it to the outside shell-plating of a ship, and a similar rig attached to the inside of the same plating to provide a support for a pneumatic holder-on.

The *Keller Long-stroke Riveting-Hammer* is operated by a similar valve to that employed in the chipping hammer of this make, as

described on page 648, and it is also provided with a safety device by means of which the hammer cannot be operated unless the rivet snap or tool is hard against its work. This device consists of a stop-valve placed at the rear end of the tool, arranged to close the air-ports admitting air to the back of piston when the tool is not pressed home, that is, when the hammer is not in use.

The Thor Riveting-Hammer is of the usual long-stroke type, but differs from other hammers for the same purpose by having the grasping handle made integral with the cylinder or barrel, while the valve is outside the hammer and works in a chamber bored in a projection on the barrel itself situated at the handle end, the object of this method of construction being to provide a tool consisting of a minimum number of parts which shall require nothing special in the way of locking devices to keep them in place when the hammer is at work.

PNEUMATIC DRILLS.

These machines continue to form a most important item in the machine equipment of nearly all engineering and shipbuilding works, and, since the reading of the last Paper in 1900, the number of these machines in use in this country has increased tenfold, a fact strikingly significant of their general utility.

On work to which these machines were first applied, such as drilling out stays in repairing boiler fire-boxes of all kinds, driving combustion chamber and firebox-stay taps, stay-tube taps, turning in stays after tapping the holes, all kinds of drilling and reaming in shipbuilding work, drilling on constructional ironwork, etc., they have more than held their own, and the portable electric drill has not yet ousted them from the premier place. The rates paid for pneumatic drilling now vary from 40 per cent. to 75 per cent. off rates paid for hand-drilling, depending on the nature of the work.

In many shipyards, including the Government dockyards, all rivet-holes are now reamed out by pneumatic drills.

In the construction of the steel girders for the Vauxhall Bridge, London, a number of Little Giant drills (No. 2 size) were used, and an average of 500 holes, $\frac{1}{8}$ -inch diameter per 10-hour day per drill, through plating $1\frac{1}{8}$ inch thick, made up of one $\frac{1}{2}$ -inch and one $\frac{5}{8}$ -inch plate, was maintained after the men had got used to handling the tools.

High-speed twist-drills were employed, and the men ground their own drills by hand at the start, but the rate of progress was then not very good, and it was found necessary to grind the twist-drills on a proper grinding machine. The saving in time effected by this change of method will be realised when it is stated that it was found by actual trial, that where a twist drill, newly ground by hand, took 50 seconds to drill one of these holes, a newly machine-ground twist-drill took only 35 seconds. The machine-ground twist-drills did not take so much power to drive, and the pneumatic drills employed stood up to their work much longer, without needing adjustment or repairs.

In tapping holes in tube-plates of marine boilers for stay tubes, a powerful drill of the reversible type is used, and one machine, attended to by one man and a boy, tapped 220 holes $2\frac{3}{4}$ inches diameter at front tube-plate and $2\frac{1}{2}$ inches diameter at back tube-plate in nine hours, the thickness of tube-plates being 1 inch. To have done this work by hand four men and a boy would have had to be employed. The taps used for this work are advantageously made with longer taper than usual, and one tap should cut in advance of the other, the second tap beginning to cut when the first is almost through, the first tap being made long enough to serve as a guide to the second tap. With stay-tube taps made in this way $3\frac{1}{4}$ -inch and 3-inch-diameter holes may be tapped by a large reversible pneumatic-drill, weighing from 50 to 60 lbs. and developing from $1\frac{1}{2}$ to 2 H.P.

All sizes of boiler-tubes are now expanded by pneumatic drills, and the work is done quickly and well. The largest tubes dealt with so far are $3\frac{1}{8}$ inches diameter and $\frac{5}{16}$ inch thick, the length of tube expanded being about $1\frac{1}{2}$ inches. This heavy work was done by a No. 12 Keller rotary drill, after other large drills had been tried and had failed.

Pneumatic drills are now used by salvage companies, which include these tools in their plant, for conducting salvage operations. For this work they are preferably fitted with the special gear-case described on page 662 (Fig. 14).

They render valuable aid, too, in the construction of wooden piers, wharves and jetties, where bolt-holes have to be bored through the piles and other timbers. Many of these holes are $1\frac{1}{2}$ inches to $1\frac{1}{2}$ inches in diameter by 3 feet long, and are bored in one-tenth of the time required to drill a hole of this depth by a hand augur, and this whether above water or below.

As an example of the saving of time effected, particulars of some wood-boring under water recently done at a wharf near the dock gates of the Surrey Commercial Docks, London, may be of interest. A long cofferdam had first to be built to allow a wharf to be put up behind it, and when the wharf was completed it was necessary to cut off the piles of the cofferdam as low down as possible, to allow barges to come alongside the wharf. A diver would spend about four hours under water during a working day of eight hours, in which time he would, by hand, drill through two piles measuring about 12 inches square, putting $1\frac{1}{2}$ -inch-diameter holes through each. The piles, after drilling, were broken off by means of a capstan and a rope attached to their top ends, two piles per day per man being considered a fair day's work. With a slow-speed pneumatic drill—the only drill available—it was found possible to drill through and break off ten piles per man, and this rate of work was kept up till the job was finished. Had a high-speed drill been used, the speed of which was suitable for wood-boring, this rate would have been much exceeded, as the holes would have been put through in half the time taken by the slow-speed machine.

To obtain the best results with wood augurs operated by pneumatic drills running at a speed of from 400 to 650 revolutions per minute, the screwed points of the augurs should have a pitch not coarser than twenty threads to the inch. The pitch of the screw, on the point of the ordinary hand-augur, is from 8 to 12 to the inch generally, and is much too coarse. Attention to this detail is of the greatest importance. Most of the difficulties attending the use of these portable drills

for mining work—drilling or boring in coal or ores—have now been overcome, and various sizes and makes of drills, fitted specially for the work, are now in regular employment, and the number is steadily increasing.

In mining work at Messrs. Pease and Partners' Lingdale Mine, boring holes in 35 per cent. iron-ore, a No. 8 Whitelaw drill, fitted with the ore-boring attachment described on page 667 (Fig. 16), bored 40 holes, $1\frac{1}{2}$ inches diameter, averaging 4 feet deep, with an air-pressure of 50 lbs. per square inch, in one shift, from 6 a.m. to 2 p.m., three drill-bits of varying lengths being used to obtain this depth.

At the Cowpen Colliery in Northumberland the No. 1 Little Giant drill, fitted with the ore-boring attachment described on page 663 (Fig. 15), and having a feed-screw of five threads to the inch, drilled a $1\frac{3}{4}$ -inch-diameter hole into stone (locally termed "blue metal") 2 feet 10 inches deep in 3 minutes 35 seconds, including the time occupied in changing the drills, the same work taking from 20 to 30 minutes by hand. In coal, at the same colliery, a $1\frac{3}{4}$ -inch-diameter hole was bored 3 feet deep in 2 minutes 50 seconds as against 10 minutes by hand. The air-pressure in the above two instances was 75 lbs. per square inch.

PNEUMATIC DRILLS AND ATTACHMENTS.

The Chicago Midget Rotary-Drill, Fig. 11, is claimed to be the smallest pneumatic-drill made. It has a capacity up to and including $\frac{3}{16}$ -inch holes in steel. Its weight is $2\frac{1}{2}$ lbs.; the overall length from top of breast-plate to end of spindle is $7\frac{5}{8}$ inches; the diameter of the motor casing is 2 inches; the motor revolves at a speed of no less than 22,000 revolutions per minute, and the spindle speed is 2,000 revolutions per minute. It is especially adapted for drilling tapping holes for screws for electric-lighting fittings, tell-tale holes in fire-box stays and other light work.

The Little Giant Corner-Drill, Fig. 12 (page 660), is specially designed for drilling in close quarters, in such places where the casings

of the ordinary drills with centrally-placed spindles are too large in diameter to admit of such machines being used. It is also extremely handy for use in places where the overall length of the ordinary type of drill is too great, the length from point of feed-screw, when run down, to end of drill-spindle, being only $5\frac{7}{8}$ inches. This machine will drill up to 2 inches in diameter if required, and will drill holes the centres of which are as close as $1\frac{5}{16}$ inches from a

FIG. 11.—Rotary Drill.

vertical partition. Its weight is but 35 lbs. The arrangement of engine and gearing is clearly shown in the two views of this tool shown by Fig. 12.

Little Giant Improved Reversible Drills.—The principal features of these drills are the valves by which they are operated, which are of the Corliss type and placed as close to the cylinders as possible, and the reversing mechanism, by which the machines can be instantaneously reversed without turning off the air supply. They are more economical in air consumption than the ordinary Little

Giant drills, which have longer air-ports between the valves and cylinders.

FIG. 12.—*Corner-Drill.*

Sectional views of the general arrangement of these machines are shown in plan and elevation in Fig. 13. The two valves VV each operate two of the four cylinders of the engine, and are

provided with four sets of pressure and exhaust ports, two sets to each cylinder, one being for the forward and one for the reverse drive, the valves in their raised position (as shown) driving in the forward direction. To reverse the engine the valves are lowered by means of the reversing-sleeve S, which has a toothed rack on its flange at *g* gearing with the pinion T, which is keyed to the reversing-crank C, the pin of which fits a slot in the reversing lever L at *a*. The two arms of this lever are attached to the upper part of the valve stems at *bb*, and it will be seen that, by withdrawing the reversing-sleeve S from the pin *p* (which locks it in either the forward or reverse positions) and turning it in the required direction, the valves, by means of the crank C and reversing lever L, can be raised or lowered at will. The reversing-sleeve is kept in the desired position on the locking pin *p* by the spring *s*. The required movement of the valves for operating the engine is secured by means of the eccentrics EE on the engine crank-shaft, the eccentric rods RR, and the wrist plates WW. The eccentric rods are attached to the wrist plates by the pins PP, the travel of which is equal to twice the throw of the eccentrics. The wrist plates are a sliding fit on the valve stems, and drive the valves by means of feathers or keys. The valves are balanced and move quite freely in the valve-bushes, which is very necessary seeing that the crank-shafts of these engines run at speeds of from 1,350 to 2,200 revolutions per minute, depending on the size of drill.

Special Gear-Cases for improved reversible Little Giant Drills,
Fig. 14.—These gear-cases are fitted when the drills are required to work under water, a special exhaust-passagage (indicated by arrows) being provided to carry off the exhaust air by means of a hose-pipe attached to the internally-screwed boss B, the free end of the hose-pipe being held above the surface by a float or other means, thereby giving the diver (when working in clear water) a good sight of his work, which he would not obtain were the exhaust air discharged in the usual way, as it would then rise to the surface in a continuous stream of bubbles between him and his work. By carrying off the exhaust air in this manner the back pressure in the drill-cylinders is

practically reduced to that of the atmosphere, and pressure due to head of water consequent on the depth at which the drill is working is done away with.

Split-Nut Ore-boring Attachment, Fig. 15.—This device is intended to be attached to the gear-case of a Little Giant, or

FIG. 14.—*Special Gear-Case for reversible Drill working under water.*

Improved Little Giant Reversible Drill, and to be central with the drill spindle. Its principal parts are the feed-screw C (the pitch of the screw being suitable to the material to be drilled) which carries the drill-bit or augur at its front end; the split nut EE in which the screw works; the nut casing or cage F; the bail J, which is held and prevents the nut turning with the screw; the

lever H and the links GG for opening and closing the two halves of the nut EE. The screw C has a keyway cut its whole length, in which the key D is a sliding fit, D being fixed in the gear-wheel W and spindle S. The screw C is driven by the pinion P at the end of the motor crank-shaft, through the gear-wheel W and key D, and as the nut EE is fixed it advances as it is turned, carrying the drill-bit forward with it. When the desired depth of hole is reached, the

FIG. 15.
Split-Nut Ore-boring Attachment.

nut EE is opened by moving the lever H in the direction of the arrow, when the screw and drill-bit can be withdrawn by hand.

The reversible drill has an advantage over the non-reversible machine for this work, for should the drill be too tight to withdraw by hand, the nut can be closed and screw freed by reversing the drill-motor and then withdrawn. The object of arranging that the screw and drill-bit can be withdrawn by hand is to save time. Plate 62 shows the method adopted for fixing this attachment for coal-boring.

The Howard Pneumatic Drill possesses an engine having two oscillating double-acting cylinders, and is in this respect the same as the Whitelaw drill.* The details, however, differ considerably, and the controlling valve is rotated round the inside trunnions to positions suitable for driving the engine in the forward or reverse directions, instead of being raised and lowered as is the valve of the Whitelaw engine, the valve-lever (which is the throttle-valve handle) being kept in either position by a toothed collar on the throttle-valve handle engaging with notches cut in a quadrant piece attached to the drill casing. This machine is made in several sizes possessing spindle speeds which adapt the drills to a wide range of work.

The Thor Pneumatic Drill is constructed with four single-acting cylinders placed in pairs at about an angle of 90° to each other, each pair being placed one above the other, the two pistons of opposite pairs being connected to the same crank-pin, the crank-shaft having a double throw; this arrangement of cylinders and crank-shaft and the method of driving being practically the same as that of the Little Giant and the Little Giant Improved Reversible Drills. The valves also are similarly placed and operated by similar means as the valves in the Improved Little Giant Reversible Drill, but the design of the air-ports or passages is different. The drill-casing consists, however, of only two parts, the casing proper and the gear-case, the usual separate top cover being one with the main casing.

A telescopic feed device, Fig. 18 (page 670), is fitted, giving a longer feed-travel to the drill than is possible with the ordinary fixed post and feed sleeve, unless these parts were made unduly long, which would add too much to the overall length of the drill and render it inconvenient for use in confined spaces.

The Whitelaw Drill has been materially improved, the object being to provide a drill, the mechanism of which can be readily adjusted and repaired at any shop without any special tools or

* Proceedings 1900, Plate 19.

equipment for the purpose. To this end the ball-bearings originally used for crank and cylinder trunnion-bearings have been replaced by plain gun-metal bearings which can be let together in the usual way, the other parts requiring adjustment being of equally simple design. A new feature of this drill is the arrangement of the gearing which admits of the drill being run at two speeds. In ordinary gear the speed of spindle is suitable for tube expanding, tapping or drilling in iron or steel, but by reversing the pinion-wheel on crank-shaft the revolutions of spindle are increased to a suitable speed for wood-boring. The exhaust air can either be discharged through the blank handle or through a deflector at the top end of the drill, which can be turned in any direction. For very heavy tapping work a larger size of this drill is made, fitted with a compound reducing gear which brings the spindle speed down to about 30 revolutions per minute, making it possible to drive large stay-tube taps for tapping the tube-plates of marine boilers. The casing of this drill being of aluminium reduces the weight of the complete machine very considerably, the largest of these drills, weighing 50 lbs., being equal in power to the largest Little Giant or Improved Reversible Little Giant drills, which weigh 66 and 70 lbs. respectively. The attachment for ore or coal-boring, Fig. 16, is also fitted to the largest sizes of these drills.

Ore-boring Attachment, Fig. 16 and Plate 62.—This device is designed for attachment to the larger sizes of the improved reversible Whitelaw drill, its function being to drive a coal or ore-boring drill-bit. The mechanism provides for the automatic withdrawal of the bit should it meet with any hard substance or undue resistance, and the feeding forward of the drill-bit when it has been withdrawn far enough to clear itself. The gearing is enclosed in the casing C, and is made up of the following principal parts:—A long feed-screw S having a socket at its front end into which the drill-bit is inserted, and a keyway extending its whole length, fitting the key K by which it is turned; a nut N on which is keyed the large gear-wheel G of the motor, which is in gear with the pinion P, driven by the intermediate motor gear-wheel J, which is driven by the motor

crank-pinion (not shown), the pinion O keyed to the front end of the nut N; the gear-wheel W, in which the driving key K is fitted; the clutch-gears H_1H_2 , which gear with O and W respectively; the spring R, which keeps the clutches engaged; the adjusting nut A to regulate the compression of the spring and the levers L_1L_2 for operating the clutches. On starting the drill-motor the nut N is rotated by the wheel G and motor-gears P and J, and motion is transmitted by the pinion O and the clutch-gears H_1H_2 to the gear-wheel W which turns the screw S by the key K. The gear-wheel G and nut N turn in the same direction as the gear-wheel W but at a

FIG. 16.—*Ore-boring Machine with automatic Feed and Withdrawal.*

Scale $\frac{1}{8}$ th full size.

slower speed, the difference in speed representing the advance of the screw and feed of the drill-bit. The illustration shows a double threaded screw of 2 inches pitch, the nut N in this case making 110 revolutions per minute, while the gear-wheel W makes 120, resulting in a feed of 20 inches per minute, which is found to be a suitable feed for boring in coal with a drill-bit $1\frac{7}{8}$ inch in diameter. Provided the drill-bit meets with no obstruction, and the resistance when drilling is normal, the bit is fed forward its entire length without a stop, but should the resistance be unduly increased the clutch H_2 disengages itself (the clutch-jaws being at an angle exceeding 90°) and the gear W and screw S cease to revolve; the nut N continuing in motion causes the withdrawal of the drill-bit at a rate

per revolution equal to the pitch of the screw, in this case 2 inches. The drill-bit continues its backward movement till the clutch H_1 (which is still turned by the pinion O) has made a complete turn, when it is once more engaged with clutch H_2 by the action of the spring R, and the mechanism once more feeds the screw S and drill-bit forward, and these alternate forward and backward movements of the drill-bit take place till the obstruction is overcome or the bit has freed itself. When a hole is drilled to the required depth the clutches are thrown out of gear by the levers L_1L_2 , when the drill-bit is quickly withdrawn entirely, as described above, by the nut N. For deep holes two or even three bits of different lengths are preferably employed both with this device and with the "split-nut attachment" described on page 663. Screws and nuts of different pitches are employed for drilling in different materials and the attachment has proved itself in practice to be a thoroughly efficient tool. The method of using this device for coal-boring is shown on Plate 62.

The Pneumatic Tube-Cutter, Fig. 17, is specially made for cutting out boiler tubes on boiler repair work or for cutting off tubes to length at the front tube-plates of locomotive and other boilers after they have been expanded.

The principal parts of this tool are the feed-cylinder A, cylinder-head B, piston C, spindle D, wedge E, cutter F, cutter-block G, internal-guide H, and guide-key J. It is attached to the spindle of a pneumatic drill by a Morse taper attachment as shown in Fig. 26 (page 680), the air-pressure required being conveyed through the tee-piece and hose-pipe, through the attachment and pipe-connection K to the feed-cylinder. On opening the throttle-valve of the pneumatic-motor the motor-engine is started and the motor-spindle and tube-cutter revolved with it. At the same time air-pressure is admitted to the feed-cylinder of the cutter in the manner described, and the cutter-block with the cutter is forced out by the wedge E and piston C, hard against the tube, which it is enabled to cut through by being turned round by the motor-spindle, and at the same time being kept hard against the tube by the air-

pressure acting on the piston C. The distance of the cut inside the tube-plates is determined by the position of the internal guide H (the front edge of which bears against the edge of the tube) which is secured on the spindle D, at one of the three grooves shown, by the guide-key J. The external guide L is fitted in place of the internal guide H when it is required to cut off tubes to length outside the tube-plate, the front edge of the guide in this case bearing against the tube-plate. Tubes up to 4 inches external diameter are dealt with in this way, but the cutter is perhaps used mostly on the smaller tubes of locomotive boilers.

FIG. 17.— $1\frac{1}{2}$ to $1\frac{3}{8}$ -inch Tube-Cutter.

Telescopic Feed-screw, Fig. 18 (page 670).—This feed arrangement is fitted to drills when a longer feed than ordinary is required, and practically doubles that obtained by the usual feed-screw fitted. It consists of a hollow fixed post D, which is screwed internally, a sleeve S screwed externally and internally, working in D, and a feed-screw F working in S. The length of feed obtainable by this arrangement is equal to the sum of the measurements of A and B.

Stone Trade.—Portable pneumatic tools now play a very important part in the granite and other stone industries, in all branches of work, from work in the quarries to the dressing and finishing of the rough stone in the workshops. In the quarries heavy pneumatic rock-drills mounted on tripods are used for drilling holes to take the blasting charges. Large stones are reduced in

size by means of hand-plug drills, which are used to drill holes along the line of desired cleavage, and into which the plugs and feathers (or wedges and half-rounds, as they are called in some districts) are driven to split the stone. One of these hand-plug drills, Fig. 19, (page 672) on average work easily does the work of three men using hand-tools.

In the workshops the large rough slabs of granite, marble, etc., are further dressed into shape and prepared for polishing under a pneumatic surfacing hammer, of which the Kotten, Oldham and

FIG. 18.—*Telescopic Feed-Screw.*

Keller hammers are perhaps the best known in the stone trade throughout the Aberdeen district. The hammers are mounted on a horizontal arm, which is supported by a vertical-pillar carried on a platform on wheels, Fig. 20 (page 674), the component parts of the machine being so arranged as to permit the hammer being easily traversed in any direction and to the full length of the horizontal arm, over the work below it.

Various tools are used, the "four-point" tool for roughing down the surface and various sizes of bush chisels, Fig. 20 (page 674), for finishing. The air-pressure employed for these hammers should not be less than 80 lbs., while 90 lbs. is not too high.

The rate at which these machines accomplish the work will be realised when it is stated that one of them is equivalent to six or seven men. In a working day of nine hours one machine is found to be capable of dressing from 60 to 70 feet of average granite for polishing purposes with about 1 inch of rough to take off, and for finely axed with the 10-cut tool about 25 feet per day. (These figures have been given by users of these machines in Aberdeen.) The quality of the work performed is also highly satisfactory, for on granite the surface of the stone is not "started," as is frequently the case when it is prepared by hand for polishing, and it is also left in a more uniform condition.

Of the smaller hand-hammers used for rough and intricate carving work of all kinds, there are many sizes and makes, among the best known being the Aberdeen Iron Grit Co.'s, the Boyer, Keller, Kotten and Oldham hammers.

There are two types of hammers, the valveless and valve; the valveless type usually having a straight handle, and the valve type a handle similar to that fitted to the ordinary chipping and caulking hammer for iron or steel.

Illustrations of both kinds of hammers are shown on Figs. 21 and 22 (pages 675 and 676). The sizes in most general use are the $1\frac{1}{4}$ -inch, 1-inch, and the $\frac{3}{4}$ -inch, which denote their piston-diameters.

The $1\frac{1}{4}$ -inch tool is used by the "cutter" for roughly shaping out carving work, for putting arrises on granite and for bringing more rapidly into shape for finishing, the mouldings, etc., met with in the course of this work.

The 1-inch hammer, however, being lighter and easier to handle, is often used in preference for the same work, and a skilled workman, proficient in its use, employs it in place of smaller and lighter hammers and with equal facility, for skin-work and letter-cutting.

Hammers are made with pistons of less than $\frac{3}{4}$ inch diameter, $\frac{5}{8}$ inch, $\frac{9}{16}$ inch, and $\frac{1}{2}$ inch, but these tools are only used for the lightest classes of work, such as finishing sculpture, cutting raised letters, and for carving, tracing, and engraving.

An air-pressure of about 50 lbs. per square inch is most suitable for these tools. Plate 62 shows what fine work these small hammers are capable of doing.

The use of these pneumatic tools in the stone trade has not only cheapened the cost of production, but has made it possible for work to be turned out in quicker time, and there is no doubt but that a larger demand for finished and ornamental granite and other stone work will thereby be created.

Boyer Hammer fitted with Rotating Device, Fig. 19.—This tool is principally used for drilling plug-holes in stone and for riveting

FIG. 19.

Hammer fitted with Rotating Device and special Chisel for heading copper stays.

over the heads of the copper stays used in the construction of locomotive boilers. The principal parts are the loose sleeve C, fitted to the front end of the hammer barrel, and which takes the shank of the tool D, which is square or hexagon in section; the casing J, secured to the barrel of the hammer by the bolts KK, in which are enclosed ratchet rings E and M and the pistons F and G which bring about the rotation of the tool. The teeth cut on the rings EM, engage with similar teeth cut at the end of the sleeve C at *tt*, the ring M being prevented from turning by the two lugs OO (one only shown), which fit into recesses in the casing J, and are held in gear with C by

the two springs NN, the ring E being held in gear with C by the two springs LL. On E is a tooth-like projection H, coming between the two operating pistons F and G. On air-pressure being admitted at back of piston F through the special port provided (the space at back of piston G being then open to exhaust), the tooth H is carried forward the extent of the travel of F, thereby turning ring E, sleeve C, and tool D. The locking ring M, which cannot turn on account of the lugs OO, is lifted by the teeth on C and forced back into gear at the end of the stroke of piston F by the springs NN. Pressure is now admitted at back of piston G, and exhausted at back of F, when the ring E by means of tooth H is returned in readiness for a fresh stroke, the sleeve C being prevented from turning back also by the locking ring M, which is held by the lugs OO (one only shown), E at the end of its return stroke being forced into gear with C again by the springs LL. As one forward and one return stroke of pistons F and G take place for each forward and return stroke of the hammer-piston, which strikes approximately 1,000 blows per minute, it will be seen that the speed of rotation is practically continuous. The revolutions of the tool are about 50 per minute. For stone drilling the usual drill-bits are used, but for riveting copper stays the special tool shown at Fig. 19 is employed, the centre being necessary to keep the tool on the stay-heads. This centre should be as small as possible.

These hammers are also fitted with a loose sleeve, into which the tool or drill-bit fits, for turning by hand by means of a projecting handle attached to the sleeve, the sleeve and tool in this case being turned backwards and forwards through an angle of about 90°.

The Stone-Dressing and Armour-Plate Scaling Machine mentioned above is shown on Fig. 20 and Plate 62. It is mounted on a framing made up of a base plate carried by four wheels, which are preferably flanged for running on a rail track. A brake is fitted to the wheels and holding down clamps to the base. In the centre of the base platform is mounted vertically a hollow steel column or standard

about 9 feet high, surmounted by a ball-bearing swivel-head or cap, carrying two pairs of sheaves arranged fore and aft. The vertical standard carries a radial arm which can be swung freely thereon, and also lifted or lowered throughout the entire height of the column by means of a hand windlass with a steel-wire rope attached, by which the radial arm is set at the desired height over the work.

FIG. 20.—*Stone-Dressing and Armour-Plate Scaling Machine.*

Piston:—Diameter, $2\frac{1}{2}$ inches. Stroke, $2\frac{1}{2}$ inches. Weight, $6\frac{1}{2}$ lbs.
Vertical movement of Tool, 5 feet 6 inches. Greatest radius, 8 feet 3 inches.

The pneumatic hammer is carried by a trolley mounted on the radial arm, the trolley being free to move along its entire length. Air-pressure is brought to the hammer by a flexible hose-pipe which is attached to the base of the vertical standard as shown, whence it passes up the standard, and by a second hose-pipe, attached to the standard, direct to the hammer, an air-cock or valve being fitted

at the hammer to control the admission of air. The "four-point" tool, which is used for roughing down, and the "bush chisel" for finishing, are shown at Fig. 20. These "bush chisels" are fitted with blades of varying thickness depending on the kind of finish required; one fitted with blades each $\frac{1}{10}$ inch thick, or ten to the inch, being called a "10-cut tool," and one with 8 blades to the inch an "8-cut tool," etc. For scaling armour-plates a round-nose tool is employed.

The Keller hammer for this work is fitted with a sleeve which can be turned on the hammer-barrel by means of the projecting handles shown below the hose-pipe connection. When turned hard over in one direction full air-pressure is admitted to operate the hammer,

FIG. 21.—*Valveless Hammer.*

but when turned in the opposite direction the larger of the two air-ports, leading from the controlling valve of the hammer to the cylinder bore, is shut off, resulting in a shorter, but quicker and less powerful piston-stroke.

By this means the power of the blow struck by the hammer-piston is under the direct control of the operator, who can alter the blow at will.

Straight-handled Valveless Hammers.—A sectional drawing of a 1-inch Keller valveless hammer is shown at Fig. 21. The construction is extremely simple and the tool consists of practically three parts only, the hammer barrel or cylinder B, the piston P, and

the inlet piece or cap C. The piston acts as the valve of the hammer, air-pressure being admitted through the cap C; and the chisel is inserted as shown.

Valve-hammers for Stone Working.—Fig. 22 shows in section a 1-inch Keller valve-hammer fitted with the usual grasping handle. The admission of air-pressure is controlled by the trigger T, which operates the throttle valve V, and the action of the hammer-piston is regulated by the controlling valve C, working in the casing B.

Pneumatic Scaling-Hammer, Fig. 23.—This tool is specially designed to operate in confined spaces and for scaling boilers,

FIG. 22.—*Valve-Hammer for Stone Work.*

paint and rust from constructional ironworks, ships' bunkers, tanks, etc. Its piston is $1\frac{1}{4}$ inches in diameter, and has a stroke of $\frac{5}{8}$ inch. The weight of the tool complete as shown is $4\frac{3}{4}$ lbs. The face of the scaling tool possesses four cutting edges in the shape of a +.

The Ratcliff improved direct-acting tube-scaling tool, Fig. 24, consists essentially of a circular cutter, which is just a free fit in a clean tube, having blades inserted in its front face; a pneumatic

hammer to operate it; a steel tube made in two or three pieces and serving to convey air-pressure and to pass the hammer and cutter through a tube; a handle clamped to the tube serving to turn the cutter, and a guide-bar and V block to guide it. To clean a tube the scale must first be removed from the end to a depth of about 6 inches by hand, so that the cutter can be inserted. The guide-bar and V block are then fixed to the boiler front in line with the tube and centrally with it. The cutter with hammer and guide-tube with cross-handle and base-pipe attached is now inserted, the guide-tube resting in the V block. While

working, the cutter is rotated backward and forward by the cross-handle, being kept up to its work all the time, till it has been passed into the tube to the extent of the length of the guide-pipe when an extra length of guide-pipe is added, the work proceeding in this way until the tool has cut its way through the tube. The tubes of a 50-H.P. Babcock boiler at the Sewage Disposal Works, Corney Reach, Burlington Lane, Chiswick, were recently scaled by this tool; and the resident engineer, Mr. J. H. Abbot, states that the scale was from $\frac{5}{16}$ to $\frac{7}{16}$ inch thick and as hard as slate, and that it had previously resisted removal by the tools they had

tried. It was, however, entirely removed by this tool without in any way damaging the tubes or starting them in the headers, and the boiler after cleaning passed the water-pressure test at 180 lbs. per square inch. A strong point in connection with the work done was the high rate of speed maintained and the absence of inconvenience, owing to the fact that air instead of water was employed for actuating the tool.

Pneumatic Sand-Sifters.—In the design shown at Fig. 25 a rectangular-shaped sieve is used, which is mounted on four rollers attached to the top horizontal bars of the frame. It is shaken or

FIG. 24.—*Direct-Acting Tube-scaling Tool.*

vibrated by a valve type of pneumatic hammer of simple construction mounted on the back bracket of the frame, the sieve being attached to the hammer-piston by a suitable connection. The sieve is slightly inclined downwards from the hammer, and the lower end is open and comes over the shoot. When working, the coarser parts of the feed are worked along down the incline and out of the sieve at the shoot, while the finer sand falls through between the four legs. Under ordinary conditions of working, these machines require two men to

shovel sand into the sieve, if they are to be kept fully employed. The sieve measures 36 inches by 18 inches, but is open for a length of 18 inches only, and the mesh varies from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch. The coarser material passes over the whole length of the sieve on its way to the shoot, and its thorough screening is thus ensured, while having the sieve open for only half its length prevents it being overloaded when working. Pneumatic sand-sifters are also arranged for fixing to a post or wall.

FIG. 25.—*Sand-Sifter.*

Pneumatic Sand-Rammers, Fig. 26, are now beginning to play an important part in general foundry and concrete work, such as ramming moulds and cores, tamping concrete, clay, road foundations, trenches, etc. Rammers, ranging from 7 lbs. in weight with pistons $\frac{7}{8}$ -inch in diameter and 4 inches stroke to those weighing 280 lbs. with a piston 3 inches diameter and a 10-inch stroke, striking a maximum blow of over 350 lbs., are now made and are in general use, but more so perhaps in the United States than elsewhere.

The general arrangement of this type of pneumatic hammer is shown at Fig. 26. The hammer-barrel is seen to be longer than that of the ordinary pneumatic hammer, giving a long piston-stroke, and the piston is hollow and projects through the front end of the

cylinder, the ramming-heads being attached to it. The lever for controlling the admission of air is placed so that the operator's hand covers it when the tool is held in the working position. The weight of the blow is regulated by the distance the rammer head is held from the work, the heaviest blow being struck when the piston is allowed to travel its full stroke, and lighter but more rapid blows when the rammer is held closer, consequent on the shorter strokes then made. The front end of the piston to which the rammer heads are attached is hexagon in shape, so that the head cannot turn except at the will of the operator. Rammers up to 45 lbs. in weight are handled by one man, but those above this weight are generally

FIG. 26.—*Sand-Rammer.*

suspended to a swinging arm in such a way that they can be readily moved about over the work and raised or lowered as required.

Concrete when rammed in moulds by these tools sets into sound hard blocks, as the frequent tamping works the air out and packs the sand and cement together very closely.

The small hand-rammers enable a man to get through a given amount of work in from one-half to one-quarter the time it would take were he using hand-rammers, and the largest rammer will do as much work as eight to twelve men with hand-rammers.

Upkeep and care of Pneumatic Tools.—It is now the custom where many of these tools are employed to adopt a regular system for examination and repairs, this work being preferably undertaken in the tool-room.

A small stock of new parts likely to require replacement should be kept, in order that defective tools may be put right quickly and re-issued. It is desirable, when pneumatic tools are in constant use, to arrange for their return to the tool-room for examination and cleaning at least once every two weeks, and, when it can be conveniently arranged, once a week.

These periodical examinations allow of bearings, etc., being adjusted, screws tested and tightened up and slight defects remedied which, if not seen to, would result in the breakdown of the tool at work and in a heavy repair bill. At first sight it might seem that such frequent examinations would be a considerable expense, but it may be pointed out that when a man has got used to this work he can take an ordinary hammer to pieces, clean and overhaul it thoroughly, and have it ready for work again in 20 minutes, and a pneumatic drill in from 30 to 60 minutes, depending on the make and size. Should any defect be discovered the owners will be glad it was found out in good time, but, should there be nothing to adjust or put right, the tool will be all the better for a good clean up.

Uses of Compressed Air.—Compressed air is now used to remove foul air or gas from ships' water- and ballast-tanks before scaling and painting. It is also used when patent pitch compound is being applied, to carry off the unbreatheable noxious yellow smoke given off, as the compound is put on over a coating of coal-tar at a temperature as near boiling-point as possible.

This work is done in dry dock, and the practice is, to knock out a shell rivet as far away as possible from the manhole in the tank top, and attach a hose-pipe to convey the air. When turned on, the air effectually drives out the foul gases, and makes it possible for men to remain in the tanks when the hot pitch compound is being applied.

In painting the inside plating of ships, the plates, when the ship is afloat, are often wet to a good distance above the water-line by condensation of moisture from the atmosphere on the cold surface. Paint will not adhere to plating in this state, but the surface may be easily dried by blowing compressed air over it for a short time and quickly made ready for painting.

Compressed air is also used to advantage in erecting-shops as a motive power for driving the turning engines for setting the valves of marine engines ; for testing Westinghouse brakes instead of using steam ; for operating steam-hammers ; for driving plate rolls, punching and shearing machines, etc., in shipyards, in cases where the steam supply is brought from a distance, the engines in these cases being used under the same conditions as when driven by steam. Also for driving ships' bilge-pumps when it is required to empty tanks, etc., in dry dock when no steam is up. Compressed air provides a very convenient means for cooling the bearings of electric motors. It can be freely used, as it has no deleterious effect on the motor windings, and is very efficient.

It is also found to be more economical under certain conditions of working to use jets of compressed air instead of steam in boiler furnaces fitted with patent fire-bars.

The Paper is illustrated by Plate 62 and 26 Figs. in the letterpress.

Discussion.

On the motion of the PRESIDENT, a very hearty vote of thanks was accorded by acclamation to Mr. Bing for his interesting and instructive Paper.

The PRESIDENT remarked that, before the discussion was proceeded with, he desired to announce that the following very courteous and kind telegram had been received from Dublin from the Earl of Aberdeen: "President, Institution of Mechanical Engineers, Aberdeen. Sorry cannot be present to take part in welcome. Best wishes for successful meeting. Aberdeen, Vice-Regal Lodge, Dublin." He proposed to send in reply the following message:—"The Earl of Aberdeen, Vice-Regal Lodge, Dublin. President, Council and Members of the Institution of Mechanical Engineers thank you sincerely for your courteous telegram, and had you been able to carry out your kind wishes would have greatly esteemed the honour of your presence at their Meeting."

Mr. GEORGE HUGHES said it had given him great pleasure to hear the Paper read, and he had further pleasure in stating that, as far as his personal experience went, the author had not overdrawn the statements he had made in regard to the cost of work done by pneumatic machine tools. Having said that, he did not think it wise to give at the present time undue prominence to the great saving effected by the use of those tools. At Horwich there were at least 100 machine and portable tools operated by compressed air. Sometimes the difficulty was experienced that there were too many tools; another compressor was then put down and for a time plenty of power was available, but a few months afterwards it was again found that the supply of power was short. That was additional evidence with regard to the use of pneumatic tools. He did not use

(Mr. George Hughes.)

pneumatic tools for the expanding of tubes, but a small electrical expanding machine made by Mr. Charles Wicksteed, of Kettering, which was so adjusted that when the tube was expanded to the correct degree the expander stopped.

On page 672 a diagram was given of a power hammer fitted with a rotating device. There were two of those hammers at Horwich, from which excellent results had been obtained. That point reminded him of the fact that when pneumatic tools were introduced into the boiler shop at Horwich, the Company contended that it would not be justified in using skilled labour. The boiler makers thought otherwise; but as they came forward and said they would work the tools at the same price as the unskilled labour, mutual terms were arranged, which was naturally a benefit to the Company.

With regard to the pneumatic rammers used in iron foundries, they had not been very successful in box work, because the rammer caught the ribs of the boxes, but it was used extensively in open floor work. In the carriage and wagon shops at Newton Heath there were quite a number of long-stroke pneumatic riveters for under-frame work, and in addition quite a number of pneumatic lifts.

Mr. EWART C. AMOS pointed out that the Proceedings of the Institution for 1900, Part 1,* contained the Paper which he read before the Institution on Portable Pneumatic Tools. Previous to that date he read a Paper before the Society of Engineers, which he believed was the first time the subject was referred to in public. He mentioned those facts in order to show how brief a time had elapsed since pneumatic tools were introduced into this country for practical uses. Although the subject, as the President had remarked, lent itself to very extensive discussion, it was not his intention to make any comparison between one make of tool and another. He thought the more interesting aspect of the question was whether pneumatic tools were of value, and what they could do for engineers in effecting savings over the present systems. The author had given a very able description of the machines that were in use at the present

* Proceedings 1900, Part 1, page 119.

time, and some very valuable data as to what they were capable of doing. It was in that direction therefore that information would doubtless be obtained in the course of the discussion. At the time his own Paper was read in 1900 it was a very difficult matter to convince people of what the tools would do, and many objections had to be overcome before the tools were even given a trial. In the course of that Paper he went into the history of the industry and also into the question of efficiency, and he saw no reason to alter the opinion which he summed up in the following words: "When making comparison of the cost of work between pneumatic tools and hand-labour (and it must be borne in mind that they compete largely with hand-labour), it is necessary to take into consideration three points. (1) That with the same sized shop and the same standing expenses in the form of rent, rates and taxes, and wages bill, a very great deal more work can be turned out in the same time. (2) That although against this there must be set off the cost of producing the compressed air, yet even supposing this equalled the cost of manual labour (which it does not) there would still be a considerable saving for the reason given in item (1). (3) That with hand-labour, especially in riveting, caulking and place drilling, work can only proceed at a comparatively slow rate, however many men be employed, and however closely together they work. This frequently becomes a serious matter in ship- and bridge-building, railway works, etc., and even were the cost double that of hand-labour, other advantages as regards speed, etc., would outweigh it; but, as a matter of fact, when properly carried out the saving is very considerable, and it is in the author's opinion only a question of time, and that not far distant, when every engineering shop will find it absolutely necessary, if it wishes to keep in the van of progress, to adopt the pneumatic, or some similar system of portable tools." He thought that condition of affairs had practically arrived, and that most works today realised the necessity for adopting pneumatic tools.

Complaint was often made that the life of the tool was not as long as one could wish it to be. He thought, having regard to the immense amount of work it did, the speed at which it worked, and

(Mr. Ewart C. Amos.)

taking everything else into consideration, its life was a good deal longer than might be expected. He often came across machines in which nearly every working part had been replaced, so that there was practically nothing but the original case of the machine left, and even then surprise was expressed that they were wearing out. If engineers gave other machines the same amount of work and made as much money out of them they would be quite ready to put them on the scrap heap, but they expected pneumatic tools to continue to work after their life was ended. The present makes of pneumatic tools lasted longer than they did six or seven years ago, for the reason that various improvements had been effected both in their construction and in the nature of the material used, especially in the adoption of the new forms of steel which had only come into vogue during the last few years.

In dealing with the question of the speed at which the tools worked, the author had referred to the very striking amount of work which had been turned out in one of the German yards. When he was in Messrs. Cramp's yard some four years ago he was informed that $\frac{3}{4}$ -inch rivet work which cost $2\frac{3}{4}$ dollars per hundred by hand was done by pneumatic tools for $1\frac{1}{4}$ dollars, which was a very large saving, and he had no doubt that figure had now been improved upon. He believed Messrs. Cramp used the pneumatic tool almost exclusively. He noticed that the air mains running through their works were 2 feet in diameter, carrying air at 120 lbs. pressure per square inch, which represented a large volume.

With regard to the question of high-pressure riveting, in the early days of pneumatic tools it was said it would be quite impossible to use pneumatic hammers for high-pressure boiler work. He pointed out at the time that there were certain rivets on a boiler which could not be closed by the hydraulic machines, but which were closed by hand, and he contended that in those instances better work would be done with the pneumatic hammer than by hand-labour. Of course he deduced from that, that if these could be done satisfactorily with the pneumatic hammer the others might also be done. The advantage of the pneumatic tool in riveting had advanced very much, owing largely to the improvement in the long-

stroke hammer, and just recently to the new holder-on, which had overcome very many of the difficulties which existed in the early stages in getting the rivet well up before it cooled round the head of the rivet.

He desired to point out in connection with the question of drilling that the introduction of the high-speed drills and new steels which were now being used were all in favour of the pneumatic tool, which was a high-speed machine. They were now able to get work out of the drilling machines which it was impossible to obtain when they were first brought out, and to which some objection was made on that account. At the end of the Paper the author referred to the uses of compressed air. He wished to add to that list the use of compressed air instead of steam for testing locomotives.

Mr. MICHAEL LONGRIDGE, Member of Council, said that, although he could give no information about the cost of work done by pneumatic tools, he might express an opinion as to their value for the two purposes of riveting and cleaning boilers. For joints intended to be tight, particularly under high pressures, he had his doubts about the efficiency of pneumatic riveting. Even with shell plates and straps bent truly to the required circles right up to the edge, and end plates flanged perfectly cylindrical so that when bolted together the point of a penknife could not be got between adjacent surfaces, he questioned whether the pneumatic machine would make tight work; and with the kind of plating seen in the majority of boiler shops he felt sure it would not close the seams properly. It was not easy to fit the thick plates needed for large high-pressure boilers so accurately that no pressure was needed to bring the surfaces close together; the only way of making tight joints without excessively heavy caulking, however carefully the plating might be done, was to nip them tightly while the rivet was being closed, and to keep the pressure on the rivet till it cooled sufficiently to keep up the nip given by the riveting machine. For such work he did not think the pneumatic riveter could compare with the hydraulic.

For cleaning dirty boilers quickly the pneumatic cleaner was an effective tool. He presumed that every member knew that boilers

(Mr. Michael Longridge.)

had now to be examined and certified every fourteen months, and that it was often very inconvenient to lay off a boiler for many days when the statutory period was about to expire. Under such circumstances a machine which would take off the most of a hard scale quickly was a blessing, and such he believed the pneumatic machine to be.

Mr. WILLIAM BROWN said he would not like the discussion on such a valuable Paper to close without mentioning a slight experience he had had in connection with boiler cleaning. Mr. Michael Longridge had mentioned that pneumatic tools were valuable for boiler cleaning ; but his own experience had not been such as to endorse that opinion. He could quite understand the value of pneumatic tools in boiler-building and in the ultimate destruction of boilers, but not for cleaning purposes, as it meant the destruction of it while the boiler in another sense was valuable. He obtained a pneumatic tool with a view to cleaning marine boilers, and in the first place, being suspicious about it, on receiving the tool he took some of the tubes, which were rather severely scaled, out of the boilers and expanded them well between fixed plates. The pneumatic tool burst every tube on which it was tried ; and if it had been put into the boiler under ordinary working conditions, and the ordinary man allowed to use it, there would not have been a good tube left in the boiler. That was his experience of the internal hammer (not in the water-tube boiler) but in the ordinary marine boiler.

He also desired to make a few remarks with regard to the riveting of high-pressure boilers with the pneumatic hammer, which he thought was an ideal method. It was all very well to close plates up with the hydraulic ram, but he had come across cases where the plates had been so inefficiently closed, owing to bad plating, that the boiler had been destroyed before it was put under pressure. If, for instance, a curved plate which had to go into the shell of a boiler were not properly closed, and the maker attempted to close it with a hydraulic ram, the plate immediately became torn. He had seen instances where the careless work of the plater had been got over by the pressure of the hydraulic ram, which was quite wrong. The

pneumatic riveter was, in his idea, the best tool which could be put on to a boiler, because the plate could not be closed with it; the plate must be closed by the plater. In taking old marine boilers to pieces where there had been very bad plating, it would be found that the hydraulic riveter had squeezed up a film or collar between the two plates, and that the film kept the plates from being closed and tended to defeat the tightness of the plating.

The author had referred to a Cornish boiler which had a $\frac{3}{8}$ -inch scale. However any engineer could allow a Cornish boiler to get such a scale he did not know, when there were such things as water-softeners and water-purifiers. The greatest saviour of all in connection with the boiler was to get an efficient water-softener; and if any of the members were in the neighbourhood of Woolwich he would have great pleasure in showing them something in that way, at Messrs. Siemens' works, which was very efficient. Although the water at Woolwich was almost the hardest in the British Isles, the boiler cleaning had been reduced to a minimum, and, instead of keeping twelve boiler-cleaners, only two were now employed. The old scale, which could not be got off in the marine boilers, and in the Babcock boiler-tubes, was now to a great extent going out simply by the application of a hose.

Mr. A. E. DOUGLASS desired to ask the author for some information with regard to boiler-cleaning. His company had spent in Birmingham about £500 or £600 a year in cleaning Lancashire boilers, and he thought he would like to try a pneumatic tool for the purpose. One was accordingly obtained, but the men who had charge of it did not seem at first to be able to get on very well with it. He thought that probably the men did not know how to use it properly, so he went into the boilers himself and tried the tool, and found it was not so useful as he expected it would be. Sometimes it cut the plates, which was a very serious thing, but with that particular tool it could not be avoided; in the instance to which he was referring he was using a chisel with a rather flat head. A special tool was mentioned in the Paper somewhat similar in shape to a rose-bit which might not cut the plates. Then, again, the tool

(Mr. A. E. Douglass.)

would hardly act at all between the shell and the furnace tubes. The man who was working the tool had to lie in a very awkward position on his stomach, and the tool generally slid off the scale, so that it was impossible to use it properly. He therefore wished to ask the author if the tools were used regularly for cleaning Lancashire boilers, and also what the cost would be for taking off a scale $\frac{1}{8}$ inch deep in a boiler 30 feet by 8 feet. It seemed to him that pneumatic tools ought to be able to be used for cleaning ordinary Lancashire and other boilers, but he was afraid, as the previous speaker had said, that users of boilers would still have to employ hand-labour or soften the scale by other means.

Mr. J. A. SNOWDON said a great claim was made in the Paper that pneumatic tools were very advantageous, and he had no doubt that claim was thoroughly sustained, as he had seen them doing good work in shipyards and boiler shops on the Tyne, the Tees, and the Wear. He had personally employed pneumatic chippers in cleaning steel castings, and would be glad to know from the author if there were any steel founders who were using those chippers for such work. The manufacturers gave him an opportunity of testing the machines, and he was able to take advantage of their offer. A number of wheels were being made at the time. The pneumatic tools were placed in competition with the workmen, with the result that the latter were far ahead. It was rather going backwards to find that machinery had to give place to the bone and muscle of the British workman. The firm which made the tools was not satisfied with the results and asked for a second trial, which was given, and the result was even worse. Personally he was still open to conviction, and would be glad to have the savings that could be effected at his works by the introduction of pneumatic tools, if they could be proved to be advantageous. If the author could state whether there were any places where the tools were being used with economy he would like to have the information.

Mr. JOHN BARR remarked that he would be glad to hear what experience the author had had with regard to the pneumatic rammer in

the foundry, as something was said about that tool in the Paper. One speaker had mentioned that the tool could only be used in bedded work. Personally he had not tried it for ramming, and he thought the objection to its use would be that the pattern would be damaged, in addition to the obstruction caused by the bars in the moulding boxes.

He would also like to ask whether pneumatic tools had been tried for the dressing or fettling of iron-castings. Five or six years ago he obtained a little pneumatic tool and tried it for fettling castings, but the muscle and sinew of the men beat the tool. He did not know whether that was still the case or not, or whether the tools had since been improved. He had seen pneumatic tools used for chipping steel-castings, and he would like to know whether any had been adapted for iron-castings.

Mr. R. GORDON NICOL said he had listened with very great pleasure indeed to the Paper, because it dealt with a subject which ranked in first importance in the engineering world. While the introduction of pneumatic tools had certainly been very rapid during the last few years, he was of opinion that they would come to be used for almost every purpose that the engineer required. Not that they might not be superseded in future by some more economical and useful method, but from the experience of the last few years at any rate the engineer had now a magnificent set of tools for carrying out work. He could not say he had much knowledge of the tool itself as a mechanical device, although he was interested in its mechanism, but he had had some experience of the work that had been done by pneumatic tools, particularly in bridge-construction. Some fairly heavy bridge-work which had passed through his hands during the last few years had been in certain parts riveted by the pneumatic hammer. The job was specified to be hydraulic riveted because he favoured that form of riveting, considering that there was no force which could be applied to a rivet that would squeeze it into the hole for which it was intended like the hydraulic nip of the accumulator. But while specifying that it should be done hydraulically, there were positions in which it was impossible to

(Mr. R. Gordon Nicol.)

put in a rivet hydraulically. The engineer knew that when he specified his work, but in doing so he had the reserve that, if the manufacturer could satisfy him with some other form of closing up the parts, he was protected against inferior workmanship. Where it was a case of closing up two plates or even three plates $\frac{1}{2}$ -inch or $\frac{5}{8}$ -inch thick with $\frac{3}{4}$ -inch to $\frac{7}{8}$ -inch rivets little difficulty was experienced with pneumatic tools; but the trouble began when it came to closing up four, five or six plates. In the case he was speaking of, it resulted in the job being rejected. He asked the maker to cut out a number of the rivets. The maker cut off the point, but he (the speaker) told him to cut off the head. When the point was cut off the rivet was driven back, and the part of the rivet which had filled the hole cleared its way through the hole. When, however, the head was cut off the rivet shank was exposed, and the clearance ring which had never been closed up under the head was clearly shown. He tried several rivets, and told the makers that unless they took out every rivet which had been put through over three thicknesses of plates he could not take the work. After a little experimenting, they arrived at the proper degree to which the rivets should be heated, because in such work the heating of the rivets was one of the most important factors, in addition to which the men had to be trained to apply the rivet quickly to the work while it was hot. Ultimately he was satisfied with this class of work, and he had come to the conclusion that if riveting was done by careful men who knew how to heat the rivets and were scrupulous in knocking the rivet up, that pneumatic riveting could produce excellent work.

Another feature of pneumatic riveting was the eccentricity of the head. With a careless workman it did not require very much carelessness to form the rivet-head almost off the shank of the rivet. He thought if some device could be introduced to keep the tool concentric with the rivet-hole, it would be of great advantage and would accelerate the introduction of pneumatic riveting. Many of the rivets in work which had been recently done for him showed from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch of the shank of the rivet after the head had been beautifully formed.

With regard to drilling, he had had no experience in Aberdeen except in the use of the auger, and with this tool most excellent results had been obtained. With a thickness of 5 feet of pitch-pine timber full of resinous matter, great difficulty was experienced in getting hand-labour to force an ordinary auger of from $1\frac{1}{4}$ or $1\frac{3}{8}$ inches diameter through such a thickness of timber. With the pneumatic twist-drill or auger marvellous results had been obtained at Aberdeen in the building of wharves. For that class of work its application would be very rapid.

Mr. J. W. KIDD said that, speaking as a locomotive-engine builder, he had found pneumatic drills and pneumatic long-stroke hammers most satisfactory, the drills having been successful in almost every work on which they had been used. The long-stroke hammers were excellent for building up locomotive frames and carriage and wagon under-frames, but he did not like the long-stroke hammer on steam-tight work, much preferring the hydraulic riveter. A tool was described on page 672 with a rotating device which was said to be suitable for knocking down the heads of copper stays. Locomotive engineers knew that the heads of the stays had to be knocked down cold, and that there was a very considerable number of such stays in a locomotive boiler. He was very anxious to get a tool which would do away with the use of at least one man on that class of work, and arrangements were made with the makers of the tool described to carry out some experiments with it. Various types of snaps were experimented with, but the rotary hammer proved a complete failure, two men and a holder-up with the ordinary hand-riveting hammers knocking the stays down in one-third of the time required by the pneumatic tool. He thought that probably the men were not giving the pneumatic tools fair play, and therefore asked the makers to send representatives to the shop to experiment with the tools. They did so, and after working for some time they came to the conclusion that the men could beat the pneumatic tool, the work being done cheaper and better by hand. The tool was taken back by the makers, and to-day he was still doing the work by hand and looking out for a satisfactory power-tool.

(Mr. J. W. Kidd.)

He might also mention he had heard that copper stay-heads which were knocked down by the pneumatic tool often afterwards dropped off, the material becoming very crystalline by the action of the hammer. He was very interested to hear Mr. Hughes say that two of those hammers were in use at Horwich, and he would like to know if any difficulty had arisen through the stay-heads dropping off after being clenched with the pneumatic hammer.

The illustration on page 670 of the special feed-device on the drilling machine showed a much-needed improvement. On the ordinary drilling machine, the operators frequently got the screw out to the last two threads, the result being that the thread was stripped, and this was repeated until the entire feed-screw was ruined. The attachment shown on Fig. 18 was certainly a great improvement on the feed-screws usually fitted.

Mr. ANDREW BROWN wished to make two small suggestions with regard to the application of pneumatic riveters. First of all, in work which he had been called upon to examine, he found, in a great many instances, that the blame for poor work was due to the fact that the pressure was too low. He thought an automatic arrangement might be easily added, so that when the pressure became too low the work would be automatically cut off, until the proper working pressure was again arrived at, because it seemed almost impossible to get riveters in the workshops to cease working, even if they knew they were making bad rivets. He had found that instead of the rivets being cup-headed they had been in the form of cherries, round in from the neck and almost helmet-shaped on the top, and practically not hammered down at all. If the foreman were about he would stop the work, but if he were not, the men carelessly went on. The inspector then had to exercise his discretion, and say that not only one or two, but almost the whole of the rivets in the barrel of a tank must be entirely taken out and proper work substituted.

In the riveting of girders his greatest difficulty had been, particularly where there was a cover joint on the main angles, to draw the plate-flanges together. If one imagined a joint of 100 or

200 rivet-holes, and that in almost every hole a $\frac{3}{4}$ -inch bolt had to be passed through, and every one had to be tightened up, if the plate were the least bit buckled or bent it was impossible to get the joint close. The result was that when the riveter put in one, two or three rivets, then drew one or two bolts and began to rivet where the bolts had been, the chances were that he would draw the plates a little closer than they had been, with the result that the first rivets became slack. He suggested that hydraulic engineers might come to the rescue and devise some kind of clamp which would do away with the necessity of depending entirely on the tensile strength of the bolt-head, so that five or six thicknesses of plates could be clamped down absolutely tight. The pneumatic riveter and the hand-riveter would then be able to come into play on exactly the same lines.

Mr. BING, in reply, said it had been a matter of great gratification to him to learn the interest his Paper had aroused. The discussion had been very instructive, because it had shown that the same results were not always obtained with the same tools in different places. Some of the speakers had mentioned that certain tools had given them every satisfaction on certain classes of work, while other users had said that the same tools had not given satisfaction at all. The tools particularly referred to had been the hammer fitted with a rotating device for riveting copper stays, the ordinary long stroke riveting hammer, the ordinary chipping and caulking hammer for cleaning castings, and the ordinary hammer which was used for scaling boilers. The use of those tools had evidently produced varying results by different people; and it might perhaps be well to call attention to the points which had to be taken into consideration before a pneumatic tool could be put to work in a proper and satisfactory way.

In the first place a pneumatic tool was brought into use, and the men who had to use it naturally thought that, if the tool were going to do in a quarter of the time the work they had been accustomed to do, a certain number of them would be thrown out of work; and as a result they did not look at all kindly on the introduction of such

(Mr. Bing.)

labour-saving devices. There was therefore some opposition to their introduction. Supposing there were no opposition to the introduction of the tools, the men who it was intended should use them were strange to their working. It took a little time to get into the way of using pneumatic tools, and what might be satisfactory at one place would not be satisfactory at another. The conditions of work also varied at different places, and slight modifications in the form of tools that were used with the hammers might be necessary in order to get satisfactory work.

There was one other point in connection with the introduction of pneumatic tools, namely, that perhaps the foreman or man in charge of a certain section of work was very well satisfied indeed with what he was doing. He was getting good work ; he was doing it in quite as good time and quite as cheaply as other firms in the same line of business. He was then asked to use pneumatic tools. In the first place he had to face probable trouble with his men ; he had all the bother of scheming out and getting the tools properly going, straightening out any little troubles that occurred, and making special arrangements in order that the work should be a success. For all that it was doubtful whether he obtained anything extra in the way of pay, and it was quite natural for him to think, although he probably would not say it, " Why should I take all this bother ; I am going on all right ; I shall get nothing more for this ; I shall get a lot of extra work and may not get anything for it." He would not like to say that all foremen argued in that way, because he fancied the majority of them thought quite as much of the work they turned out as of the pay they received for it ; but there were cases in which those sentiments obtained. There might be very few, but there were some.

With regard to the fettling of castings, especially steel castings, there were several firms who had cleaned their castings by means of pneumatic tools for some years. The Steel Company of Scotland had used hammers for some time, as far as he knew, with satisfactory results. Such tools were also used in the steel foundry at Horwich, and he understood the engineers would be very sorry to be without them. He would be able in his further reply to mention several

other steel foundries which used pneumatic hammers for fettling castings.

With regard to the question of boiler scaling, surprise had been expressed that the scale referred to in the Paper was given as $\frac{3}{8}$ -inch thick. That was also a great surprise to himself, but at the same time the scale was there and it had to be removed, and the figures in the Paper represented the cost of the operation. It was doubtless an exceptional case which personally he should not think obtained generally. [See page 699.]

Communications.

MR. WILLIAM DANIEL wrote that the author gave no information as to the quantity of air required to work the various tools described. This point was very important, when it was considered that in order to compress 100 cubic feet of free air to 100 lbs. pressure 18 H.P. was required with two-stage compression and over 20 H.P. with single-stage compression. The manufacturers naturally claimed that pneumatic tools were abstemious in their consumption of air, but when the actual users of the tools were asked their opinion, the reply was almost invariably to the effect that the plant they put down to supply air was not half large enough. From this it was safe to infer that the appetite of these tools was not a small one. He thought, therefore, it would be of great value if the author would, from his practical experience, state what capacity of compressed-air he would advise, say, for a definite number of hammers, drills, and riveters.

In the Paper some particulars of a drilling tool working on Cleveland ironstone were given (page 658). Thirty years ago his firm made a number of pneumatic drills under William Walker's design, and the best result obtained was 130 holes, $1\frac{1}{2}$ inches in diameter and 4 feet deep, in Stanghow Cleveland stone, in one shift of seven and a half hours. The highest speed was one hole of 4 feet 10 inches deep in fifty seconds. Mr. Walker informed the writer that the drills supplied thirty years ago were still running, and had not been equalled. Other pneumatic drills tried could not touch the Stanghow stone, which was too hard.

(Mr. William Daniel.)

The author referred (page 677) to the scaling of the tubes in a Babcock boiler with a pneumatic scaling-tool, but did not give the time required to deal with the fifty tubes. His (Mr. Daniel's) firm used a water-turbine to drive the tool for scaling their Babcock boiler tubes, by which 126 tubes 18 feet long could be cleaned in twenty hours. He would like to know if the tool the author recommended could beat that? If so, as it was a case where time was of more importance than cost, it might be worth while for his firm to change their method.

Mr. J. ROSSITER HOYLE, Member of Council, wrote that the experience of his firm, Messrs. Thomas Firth and Sons, had been entirely in favour of the use of pneumatic tools. They had used them in the forge department for ten years and in the foundry department for the last six years. In the former they were used principally for chipping all kinds of forged steel bars, varying in tensile strength from 28 to 60 tons per square inch, but usually those of a mild character. In the foundry the pneumatic hammers were used for removing brackets, scabs, etc. They had very little trouble with them, and considering the great amount of work they had done, and the great care necessary in their manufacture, the tools had proved very reliable. The trouble which a steel-maker complained of at the meeting would probably arise from one or two causes, or both, namely, a lack of knowledge in the use of the tools, or experimenting with an inferior make of tool. Of course no amount of skill would compensate for a bad tool, but, given a man who understood his tool, there could be no question as to the value of these pneumatic appliances. A good idea of the work they could do might be obtained from the fact that one hammer or chipper would do as much work in a given time as at least three or perhaps four men. Of course this did not mean that the economy in their use was represented by the wages of two or three men, as it was necessary to take into account the cost of the installation of the plant, that is, the engine, reservoir, pipes, etc. But even when these expenses were considered, considerable saving must result, on account of the increased output of work.

The weakest parts of pneumatic hammers or chippers were undoubtedly the valves, but experience showed that a new hammer would last about six months without repairs of any kind, provided it was kept clean, and after that a valve or chisel socket might have to be replaced once in about five or six months. A hammer would last three or four years without having to undergo general repairs, and some were still in use which were obtained ten years ago. A good make of hammer would cost from £18 to £25, according to size, but the actual cost of their use as compared with hand-work could scarcely be ascertained, as in his Works the air-pressure was used for a variety of purposes in addition to chipping, as, for instance, moulding rammers and sand riddles in the moulding shop, the latter doing with only one man twice as much work as could be done previously by two men. The same plant was also used for pneumatic hoists, both in machine and moulding shops, costing very little in repairs, saving a considerable amount of time and labour, and playing a very important part in turning work out quickly. Speaking generally as to the behaviour of pneumatic tools, he might say that, if properly understood, they would be found efficient and indispensable.

Mr. BING wrote, in further reply to the discussion, that with reference to Mr. Longridge's remarks (page 687) about riveting by pneumatic hammers, Fig. 27 (page 700) gave the dimensions and particulars of six large air-receivers built in the boiler shop at H.M. Dockyard, Devonport, for use in connection with the air-supply to the dockyard extension at Keyham. The receivers measured 33 feet 6 inches in height by 11 feet in diameter and were constructed of $\frac{3}{8}$ -inch plating. The circumferential seams were double-riveted lap-joints, and the longitudinal seams were treble-riveted butt-joints having straps inside and out. The rivets were 1 inch in diameter. These six air-receivers were riveted up in place by a large Boyer shell riveting-hammer (pages 653 and 654) and a hammer-type holder-on, Fig. 2 (page 645), the riveting-hammer being mounted on the special rigging shown in the illustration, Fig. 27. H is the hammer mounted in a gimbal which is carried on the cross-pipe A, and which has the

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pipe-leg B serving to keep the hammer in its proper position with regard to the rivet, by means of the adjustable bar C passing through its lower end. The hammer and its mounting is arranged to move freely up and down the two vertical pipes DD, and is supported by

FIG. 27.—*Special Rigging for Double and Treble Riveting at Devonport.*

Large Hammer, Fig. 7 (page 652), with Holder-on, Fig. 2 (page 645).

the counter-balance weights EE placed inside the pipes. The whole arrangement is supported on the edge of the top plate by the brackets shown at the top of the vertical pipes. The lower ends of these pipes were prevented by the circular band F from being forced outwards by the riveting-hammer. The apparatus was light enough to

be easily pulled round the work as riveting proceeded. The hammer type holder-on is shown in position at G. The hammer and holder-on were first tried on a small job which, after a little practice, was riveted up and tested by water-pressure to the satisfaction of the dockyard engineers, after which the riveting up of the six large air-receivers was proceeded with. The result was eminently satisfactory, the rivets being quite tight and sound, and these receivers were now used for storing compressor-air at 100 lbs. pressure. This information the author has been enabled to give through the courtesy of the late engineer manager of H.M. Dockyard at Devonport, Mr. R. H. Andrews.

Messrs. Day, Summers and Co., of Southampton, have used pneumatic hammers for the last four years on all boilers they had made ; for riveting up fire-boxes as well as for chipping and caulking, and pneumatic drills for drilling and tapping stays. The working pressures of the boilers made were from 90 lbs. per square inch to 200 lbs. per square inch. They also used the pneumatic riveting-hammers in the construction of shear legs, and stated that the tools were admirably adapted for this work. Messrs. J. and W. Martin, boilermakers of Aberdeen, also have adopted pneumatic hammers for riveting up boilers, for different working pressures, with very satisfactory results ; and most of the large railway companies also used pneumatic riveting-hammers for boiler work which was formerly done by hand.

With regard to cleaning boiler tubes, he would refer Mr. William Brown to the Ratcliffe improved direct-acting tube-scaling tool, Fig. 24 (page 678), and it would be seen that this tool could not possibly burst tubes. The tools which were used for cleaning various kinds of boilers and tubes were the tube-scaling tool mentioned above, the small pneumatic scaling-hammer, Fig. 23 (page 677), and the various sizes of chipping and caulking hammers. The kind of tool which should be employed depended on the amount of room there was in the boiler in which to work it, and on the thickness of scale to be dealt with ; the chisels or tools used should also be suitable. In addition to Messrs. J. Allen and Son, of Kilburn, who used pneumatic tools for cleaning boilers, Messrs.

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T. Poulton, of Manchester, the London Electric Supply Corporation, London, and Messrs. Maconochie Bros., of London, also worked them with entirely satisfactory results, which facts should encourage those who have tried so far unsuccessfully to cope with this work, to make further attempts.

In addition to the steel foundries mentioned in the Paper, Messrs. Cammell Laird and Co., Grimesthorpe Steel Foundry, and Messrs. T. Firth and Sons, both of Sheffield, and the Monkbridge Iron and Steel Co., of Leeds, have used pneumatic hammers for cleaning castings for some time.

In reply to Mr. Daniel's remarks (page 697) with regard to the quantity of air required to drive pneumatic tools, the author would recommend an air-compressor of not less than 240 cubic feet capacity of free air per minute for, say, six hammers, four drills and two riveters. This size of air-compressor was recommended on the assumption that the tools were of average size and of good design, and required an average amount of air to operate them. Under ordinary working conditions such a compressor should easily keep these machines at work. When only a small number of pneumatic tools were employed, it was necessary to provide for a larger average air-consumption per tool than would be the case with a larger number of tools.

A comparison of the Walker pneumatic drill for ore-boring and the No. 8 Whitelaw and No. 1 Little Giant drills was given on the next page, from which the merits of these machines could be seen.

The forward feed per minute of drill-bit in the Walker machine—machine running light—was found by actual trial to be 27 inches with 60 lbs. air-pressure. This machine therefore would have taken 2 minutes 3 seconds to drill a hole 4 feet 10 inches deep, clutch in gear the whole time, instead of the 50 seconds mentioned by Mr. Daniel, from which it would appear either that this result was obtained by a machine geared to give a more rapid forward feed per minute, or that an air-pressure of more than 60 lbs. per square inch was used. The Walker machine was principally used for drilling in "block" and the Whitelaw and

Comparison of Ore-boring Drills.

Particulars.	Walker.	No. 8 Whitelaw.	No. 1 Little Giant.
Dimensions . . .	Overall length of machine, including arm on which drill is mounted and balance - weight at other end, 20 feet fully.	Length overall, 20 inches. Width, 10 inches (not over throttle handle).	Length overall, 18 inches. Width, 9 inches.
Weight . . .	Weight of air-engine and drill head (approx.) $4\frac{3}{4}$ cwt. Weight of whole machine, which is mounted on a carriage and runs on a rail track, (approx.) 2 tons. Machine is horse-drawn.	73 lbs. Machine is portable.	50 lbs. Machine is portable.
Number of cylinders	Two (double acting).	Two (double acting.)	Four (single acting).
Diameter of cylinders	$4\frac{1}{2}$ inches.	2 inches.	2 inches.
Stroke . . .	$2\frac{1}{2}$ inches.	2 inches.	$1\frac{1}{8}$ inches.
Air - pressure at which tests mentioned were carried out.	Not stated (see page 702).	50 lbs. (see page 658).	75 lbs. (see page 658).

Little Giant machines for drilling in "block" and in "brokens," as their comparatively small size and weight enabled them to be used much more easily at the back of timbers, etc. From enquiries recently made by the author in the Cleveland mining district, it appeared that a good average performance for the Walker machines at present in use was about sixty holes from 3 feet to 4 feet deep per $7\frac{1}{2}$ -hour shift with an air-pressure of 60 lbs.

In the particulars given of the scaling of the tubes in a Babcock boiler (page 677), it was shown that the scale in these tubes was

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exceptionally thick, being from $\frac{5}{16}$ inch to $\frac{7}{16}$ inch thick and as hard as slate, and that other tools had been used on this scale and had failed. This was a very exceptional case, and was cited in order to show what the Ratcliffe tube scaling-tool was capable of doing. The rate of progress on these tubes on the thick hard scale was from 1 inch to 7 inches per minute, and the total weight of the scale removed from all the tubes of this boiler was no less than 6 cwts.

It was not possible to make an exact comparison between the job mentioned by Mr. Daniel and the work done on the boiler at Chiswick, as Mr. Daniel did not mention the thickness of scale in his case. It might, however, be sufficient to state that the Ratcliffe tool could remove scale of recent formation of from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch in thickness from ordinary Babcock boiler tubes at the rate of 2 feet per minute quite easily. The convenience arising from the use of air instead of water should not be overlooked when the features of the Ratcliffe tube-scaling tool were under consideration.

Monumental Work.

Ore-Boring.

Stone-Dressing.