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PNEUMATIC TOOLS.

(By ARTHUR P. SMITH.)

In the last few years the use of compressed air as a motive power for machinery has wonderfully increased, especially for portable tools. This is mainly due to the advantageous qualities of compressed air over steam, the principal of which are:—

First: Stability, or, in other words, non-condensation, permitting to be stored indefinitely, or to be transported long distances without loss of pressure, other than that due to leakage and friction of the conduit.

Second: Low temperature at which it can be used in hand tools. Such tools could also be run by steam, but they would become so hot that a man could not hold them in the naked hand.

Third: The exhaust consists of fresh cool air, adding to the ventilation and comfort of the workroom or mine, whereas the exhaust from steam motors has to be disposed of outside, and is a nuisance, and, with hydraulic systems, the waste water must be carried away in pipes.

Fourth: It can be used at any pressure and is easily produced, and its expansive qualities, while not on a par with steam, owing to the absence of heat, yet can be utilised with good results—a feature entirely absent in hydraulic systems.

Against these advantages are opposed some few disadvantages, such as the losses of power in the compression of air, due to the absorption of energy in the generation of heat, and the subsequent loss of pressure in the air, as it cools down to the temperature of the surrounding atmosphere. The losses of the steam end of the compressor are similar to those of any steam engine, and are well known to all of you.

The absorption of heat from surrounding media, caused by the sudden expansion of compressed air, often to such an extent as to freeze any moisture in the air or immediate neighbourhood, will often prevent the use of high pressure air expansively unless the air be re-heated. This re-heating of compressed air can be done at very small fuel cost for the benefits attained, and is used in many places.

These points, however, are well understood, and compressed air is used intelligently.

With these few reminders of the qualities of compressed air, the subject of its application to the percussive tools comes up, which can be better understood by considering an outline of the development of percussive engines of different types.

Percussive force, as regards the actual work done upon the object struck, is applied in two ways:—

First: Directly, when the tool itself is propelled through space and strikes the object, when practically all of the energy of the moving mass is expended on the object struck. The commonest examples are the hand hammer, sledge, steam hammers, rock drills, mining stamps, and others of similar character.

Second: Indirectly, when the moving mass strikes an interposed tool, through which the energy is transferred to the object. In this case a portion of the energy is consumed in overcoming the inertia of the interposed tool, the remainder only performing useful work on the object. The energy thus consumed in overcoming the inertia of the interposed tool, supposing the energy of percussive force to be constant, varies, by well-known laws, according to the weight or mass of the interposed body. The mathematical discussion of inertia is out of place in this paper, but those interested in the subject can find full discussion of it in Weisbach's, Rankine's, and other works on applied mechanics. Examples of this second type of application of percussive force are the mason striking his stationary chisel, the quarryman's drill struck by the sledge, and the chisel struck by the piston of a pneumatic hammer.

After hand hammers, which have been used from time immemorial, perhaps the lifting of a weight and subsequent dropping of it was the first step in advance, and one which is still in daily use in drilling oil wells and driving piles.

Trip hammers of crude form were in use as early as 1500, and, before them, spring catapults were used to throw great stones against castle walls. In a manner these may be classed as hammers of the first type, as the projectile certainly struck a blow, as do those of our great modern rifles, with a little more force.

Nasmyth's steam hammer, invented in the early forties, was a great step forward, and undoubtedly led to the invention of the rock drill, although as far back as 1683 a drill of the oil well type was used for rock, but only vertical holes could be drilled.

In 1844 one Brunton suggested compressed air in a cylinder as a convenient means of working a hammer to strike a drill, and in 1859 Nasmyth, at a meeting of the British Association for the Advancement of Science, suggested that the loss of energy in overcoming the inertia of an interposed tool could be overcome by lancing or projecting the tool itself against the work, and exhibited a sketch of an ingenious machine having a piston with a tool attached to the piston rod, working in a cylinder, closed at the lower end and open at the top, so arranged that when the piston was mechanically pulled to the back of the cylinder a vacuum would be created below it, and on releasing the piston the atmospheric pressure would drive it down with a constantly increasing velocity. This device, he pointed out, could be used to drill holes at any angle, as it was independent of gravity for its power. On October 15th, 1851, Cave, a Frenchman, patented a machine for rock drilling, run by compressed air, in which the valve was actuated by hand, and the drill rotated by hand. It was a double-acting engine, and was successfully used, and was the pioneer rock drill in Europe. Couch, an American, patented a rock drill in 1849, in which both the valve motion and the rotation of the drill were automatically performed by the piston in its motion; and while it was a cumbersome machine, requiring cranes to handle it, it was in its essential features the rock drill of to-day. Since that time there have been wonderful improvements in detail, and numberless devices made for regulating and controlling the different parts, yet to America belongs the credit of the real development of the rock drill.

There are three methods of automatically controlling the admission of motive fluid in rock drills and other percussive engines.

First: The tappet valve type, in which projections attached to the reciprocating part strike triggers or other devices which in turn move the valve. There are several objections to this type. The clearances are necessarily large, the liability to breakage is great, due to the intricacy and multiplicity of parts: the small variation of stroke permittable, and the fact that the valve must be moved before the piston has completed its stroke. This is a good feature on the back stroke, as it permits of forming a sure cushion preventing piston striking the back cylinder head, but on the front stroke it is bad, as it allows initial pressure air to bear against and partially check the velocity of the piston, hence weakening the possible blow. Owing to the skill and care with which machines of this type are constructed, most excellent results have been and are now being accomplished with them, and such well-known manufacturers as the Ingersoll Rand Company continue to sell them in large quantities.

Second: The fluid moved valve type, wherein the piston itself, at certain parts of its travel, admits a supply of motive fluid to move the valve or to move a supplementary piston which in turn moves the valve. Such machines, if well made, are not liable to get out of order, but the stroke is subject to limitation within narrow range of length, and air is admitted before the end of out stroke, as was described of the tappet valve type. In neither type has there been much attempt to use the air expansively, as the decreased velocity due to decreasing pressure, and the additional mechanical complications, did not seem to warrant it.

The Optimus Drill, of English make, is an exception. It belongs to the fluid-valve moved type, using the motive fluid compound. The initial fluid driving the piston outward is used expansively to effect the return stroke. It is much in use abroad, but has not met with much favour here.

Third: The so-called valveless type, in which the moving piston acts as its own valve, as in its stroke it alternately opens and closes certain ports, so that the fluid acts on each end of the piston in turn. The progenitor of this type was invented by John Darlington on May 13th, 1873, in England, and a great many were used, though now superseded by the modern drills of the first and second types described. In this machine, the motive fluid acts constantly on the smaller area of the piston. When the piston is at the outer end of its stroke, the space in the rear is open to the atmosphere and the constant pressure on front area forces the piston back. In its motion, it closes the exhaust port and a back cushion is started in the rear. At a certain distance before the motion of piston is entirely checked by the cushion, a by-pass leading from front to rear end of cylinder is opened, this by-pass being a little longer than the main body of piston. Fluid rushes through this passage to the space in rear of piston, pressing on the large diameter of same with initial pressure, drives piston forward against the pressure on small diameter, with a force due to the excess of area, under the same pressure per square inch. Very early in the down stroke, the by-pass is closed again by body of piston, and further force is derived only from the expansion of the body of high-pressure fluid, locked in the rear of piston. Against this decreasing pressure of expansion is opposed the constant pressure on the small front area, so that the net forward force is constantly decreasing, although sufficient, combined with the momentum already acquired, to propel piston in its entire stroke with considerable velocity, utilised in effective work on the object struck by the tool. When nearly at the end of the out stroke, the exhaust in the rear is again opened, so that further travel is entirely due to the acquired momentum. As soon as the blow is struck the piston is stopped, and immediately is pushed back by pressure on front area and the operation repeats. The conception is unique, the drawback being the loss of velocity on the out stroke, as described. The action of this tool has been explained in detail, as it was in the endeavour to overcome this defect that experiments and study were made of the problem.

In Darlington's drill, the initial pressure was used for the back stroke, and the expansive force used for the out stroke. April, 13th, 1880, Wm. L. Neill took out a U.S. patent for a valveless rock drill, reversing this action, so that the effective out stroke was due to initial pressure, and the return stroke to expansion. This device was never used practically, as far as can be ascertained, probably due to the fact that a cushion was formed in front of the piston, when the exhaust was closed, increasing in force as the piston progressed, and decreasing the velocity thereof.

Having thus examined the three principal types of valve motion in ordinary use, we come to the development of the Pneumatic Hammer, which consists essentially of a small portable cylinder in which a piston reciprocates very rapidly, striking a great number of blows per minute on the end of a tool inserted in the end of the cylinder. It belongs to the second class of percussive tools, having a tool interposed between the hammer and the work. McCoy may be said to be fairly entitled to the credit of the first application of such tools to heavy work, such as chipping metals, caulking boilers, cutting stone, etc., that had been done previously by hand and hammer. He exhibited his device before the Franklin Institute, which awarded him a medal for a new and meritorious invention of real utility. He was not, however, the originator of the broad idea, as long before he perfected the tool for heavy work it had been used as a dental plugger, a device working with compressed air in a cylinder so that a piston struck the end of a tamping tool, used to insert gold into the cavities of teeth.

There were several patents taken out for such tools, and successful results attained in the seventies.

The pneumatic hammers followed in a general way, the valve motions used in rock drills, with modifications adopted to smaller and more portable tools. The valveless, as also tappet and fluid-moved valve, types are used. Of the former, the Q.C. tools are quite well known. For work within their range they are admirable, owing to their simplicity of design, small size, and great rapidity of short stroke blows. For light chipping, caulking, and other similar work they can hardly be excelled. A somewhat similar tool, the Kotten, is made for use in carving stone and marble, diesinking, and other delicate work, and has a very short stroke, about $\frac{1}{4}$in. to $\frac{1}{2}$in., running as high as 10,000 or more strokes per minute.

The use of pneumatic tools for cleaning and chipping castings is not new. Certain defects in the old style of construction, the want of knowledge of how to operate them, together with the prejudices of ignorant workmen, have resulted in eight cases out of ten in the condemnation of the tools for foundry use. The first thing we will deal with will be the objectionable features of the old style of tools, of which the recoil or kick was the most noticeable. This recoil or kick has done more to prevent the adoption of large size pneumatic tools than anything else, as it has enabled the workman who is afraid of losing his place to say with some appearance of truth that holding the tool was injurious to him, producing a paralysis on his arm, etc. To this, he would say from experience that he had known of men who have been running pneumatic tools continuously for the past five years and who have not been affected in the slightest by them in any way whatever. The improved valveless tool is so constructed and so evenly balanced that all kick has been eliminated from it, because it has an air cushion so placed that when in operation the workman is really pushing against air, the elasticity of which takes up all shock and vibration. Another important objection that is made to the old style pneumatic tool is that so many small parts, valves, springs, etc., enter into its construction. Such a number and variety of parts make the tool very delicate and liable to get out of order.

The improved valveless tool consists of but three parts or pieces—a cylinder that is bored out of a solid piece of steel, a hammer or piston made of tool steel, and a butt piece or plug to close the end of the cylinder. The only part of it that moves is the hammer, and that is not dependent on the movement of any other part for its own motion. If it is given fair treatment and regularly oiled, it can be depended on for a long period of steady and reliable service, and, knowing this, we are warranted in guaranteeing it against all repairs for two yers. This shows plainly and conclusively to any investigator that the objectionable features in the pneumatic tool of the past are not to be found in the improved tool of to-day.

With regard to the ignorance of operating and the prejudice existing against pneumatic tools and the reason therefor. No doubt some of you have had pneumatic tools tested in your foundries, and, perhaps, successfully. Have you, however, considered in such a case how this test was made? Pneumatic tools are made in many sizes, and to use them to advantage they must be used for the purpose to which they are adapted—that is, a small tool for light work and a large tool for heavy work. Then again, at what air pressure did you try this tool? Do you know whether the pressure used was high enough to develop the efficiency of the tool? And, last, but not least, in whose hands was the tool placed for trial? Was he a man who would work for your interests, forgetting his own, or was he opposed to the tool because it was a labor-saving device, and because its adoption was liable to bring about the discharge from employment of himself or some of his shopmates? These are all-important considerations, and may explain to you why the test of pneumatic tools in your shop was a failure, if such it was. The best way to introduce the tools is to place them in the hands of young men, who are, as a rule, ambitious, and who will take a pride in running a new machine. Let them know that the successful operation of the tool will mean a slight advance in their wages. If on the contrary, however, you give tools to a man who believes only in hand methods, then the amount of work that he will turn out will be, comparatively speaking, small. The average amount of work that can be done with these tools is as follows:—In removing sand from large and heavy castings one man, with a medium-sized tool and a broad chisel, can readily do as much work in a given time as six men could do by hand methods. One man with a tool can do as much light, fine chipping as is generally done by three or four men with the hammer and in rough or heavy chipping one man with the proper sized tool can do about the same quantity of work that is generally done by three or four men with the hammer and chisel. It is sometimes necessary to do chipping to a line, or true surface. A man who is skilful enough to do this class of work with a hammer and chisel can accomplish just twice as much in the same time by using a pneumatic tool for the purpose. The operator has absolute control over the tools used for this fine work, striking a light or heavy blow as he desires, governing the force of the blows by the simple pressure of his hand, and not by throttle valves, etc., that are so liable to wear out. If anyone should doubt the possibility of the operator being able to cut to a line, or having this perfect control over the tool, he would call attention to the marble and granite cutter, who not only does the most delicate carving and lettering with the tools, but does it on a substance that is vastly more friable and brittle than cast iron.

First take the pneumatic hammer which has been in use for some years. In their early days they were very unsatisfactory, as they could not be kept in constant work owing to mechanical defects in their manufacture. At the present time they are very near to perfection, and are coming into general use wherever good workmanship is desired. These tools operate most successfully on air pressures of from 80 to 100 lbs. to the square inch, they strike very hard blows, and as the piston on the return stroke cushions on live air, they cause practically no jar on the operator's arm. In the early days of these hammers they were condemned on account of the jarring on the operators causing temporary paralysis; this is now overcome in the Imperial hammer, sample of which is before you. The valve of the tool is particularly simple, consisting of one solid cup-shaped piece moving in the same direction as the piston, which on the return stroke travels within the valve, giving it a long piston stroke with a short cylinder. The valve design is such that its motion is positive, eliminating the fault of fluttering. The hammers are made in a number of sizes, from small stone-working and carving tools weighing a few ounces to the long stroke riveter which weighs 23 lbs. and will drive rivets up to 1¼in. in diameter; the piston in this hammer has a stroke of 9in. The air consumption of the hammers is from 6 cubic feet free air per minute to 22 cubic feet for the large riveter. With the riveter it is always essential to use a duplex holder, on which takes the place of the ordinary dolly bar used when hand riveting and is intended to hold the head end of the rivet up against the work while the hammer is upsetting and forming the other end; its small size and light weight make it suitable for use in contracted places where the dolly bar can only be used with great difficulty. By the use of the duplex arrangement with an inner piston having two faces upon which the pressure is exerted, the set is held against the rivet head with a pressure of about 900 lbs., which is equivalent to twice the pressure obtained with the ordinary construction, upon which the pressure only acts on one face. The holder on is attached to the hose the same as a hammer would be. The air passes under the piston head, forcing the piston forward and almost immediately opening a port admitting air also to the front end of the piston. There are therefore two pressures, one acting on the piston head and the other on the piston. The air required to operate the holder on is 5 cubic feet free air per minute; weight of tool complete, 18 lbs.

Care of Hammers.—It is doubtful if any piece of machinery pays greater profit on its cost than a pneumatic hammer in good working condition. It is also doubtful if any piece of high-speed machinery is so much abused as to cleaning and oiling.

It is essential to the good working and durability of all pneumatic tools that they be kept clean and well oiled. This should not be delayed until the tool stops working on account of dirt or gummed oil or rust. It should be cleaned thoroughly with kerosene or benzine before oiling; when ready to put the tool in operation, do this by immersing the whole tool in kerosene—or, better still, by keeping the tool immersed in kerosene when not in use. The hammers should be oiled through the hose nipple or the end of the handle before being put in service. Only good light body oils should be used; heavy oils should be avoided, as they gum up and cause the tool to work sluggishly, with consequent loss of power. It will handsomely repay any user of pneumatic tools to keep the inside of the tools as clean and as well oiled as a sportsman his gun. He had known instances of a riveter that had been kept in good condition, driving as many as half a million rivets, without any cost for repairs. Good air hose is essential, as faulty hose will shed its inside lining and clog the inside of the tool.

Drills.—The best-known and most satisfactory portable piston drills are of the three cylinder reciprocating type, for drilling, reaming, tapping, and flue rolling. The cylinders and pistons revolve around a strong and rigid main bearing, which serves as a valve seat for the rotating valve, which is carried by the cylinders. This one valve acts for both the admission and exhaust of all three cylinders, and the air pressure exerted between the piston and the cylinder head on the forward stroke of each piston automatically presses the valve against its seat during the entire stroke, resulting in a tight valve during the admission of the air to the cylinder, and in the automatic take-up of any wear which may occur between the valve and its seat. Most of the parts are of drop forged steel, which ensures great strength and lightness. A special feature of the drill is that the main pin forms a Corliss valve for the admission and exhaust air. These drills are made reversing and non-reversing; they are extensively used for boring in both wood and metal. They consume from 20 to 40 cubic feet free air per minute, according to the size. They are used for flue rolling up to 4in., reaming to 2½in., boring in metal up to 3in., and wood up to 4in. They vary in weight from 27 to 70 lbs.

Another tool that is coming into general use is the pneumatic yoke riveter, and is adapted for such riveting as tanks, stacks, bridges, ships, and general steel structional work as the hydraulic and pneumatic press riveter has heretofore been employed for. It is much lighter than a compression riveter of corresponding size, and therefore easier handled; and as the same operating mechanism can be attached to different sizes of yokes, the proper size of yoke can be used according to the reach of gap necessary upon the work to be done. This riveter is positive in its action. All the movements are under the control of the operator by means of one throttle valve. The first movement of the lever causes the hammer cylinder to move out against the rivet, the next movement causes the hammering piston to drive the rivet, and, when the rivet is completely headed up, a reverse movement of the lever causes the stoppage of the hammer and the hammer cylinder withdraws into the casing. The air consumption is at the rate of 25 cubic feet free air per minute.

With pneumatic riveting hammers two men and one heater can, in ten hours, put in 500 rivets as against 250 rivets, which was considered a good day's work for three men and one heater. The work done is far superior to hand work less loose rivets, heads invariably perfect, shank of rivet filling the hole, and in every way superior to that done by hand. Special attention should be called to the benefit of reamed holes in assembling joints made by pneumatic drills over the drift pin work so much in use, where hand riveting prevails. The rapidity at which air drills are run reduces the expense of reaming rivet holes to a minimum.

To give some idea of the comparative cost of hand and hammer rivets, the following figures may be of service to members of this Association. The figures are given in dollars and cents, as they are based on American data, but the relative saving will be apparent:—

DRIVEN BY HAND.

Labour, 2 men at $2.40 per day	$4.80
Labour, 2 men at $2.20 per day	4.40
Total cost hand-rivet gang	$9.20

DRIVEN BY HAMMER.

Cost per day to operate compressor plant ($3.00), on basis of running three riveting hammers and forges, equals cost for one hammer of	$1.00
Oil for hammer per day	.12
Labour, 2 men at $2.40 per day	4.80
Labour, 1 man at $2.20 per day	2.20
Total cost to operate one hammer per day	$8.12

The hand-rivet gang averages 200 rivets per day at cost of $9.20, or, per 100 rivets	$3.68
Cost per rivet, hand driven	.0368
Each riveting hammer averages 500 rivets per day for $8.12, or an average per 100 rivets of	1.62
Cost per rivet, hammer driven	.0162

THE SAVING.

500 rivets—2 days' work for hand riveting gang at $9.20	$18.40
500 rivets—per day, per hammer	8.12
Saving per day, of each hammer on 500 rivets	$10.28
Saving on each rivet driven by hammer	.0206