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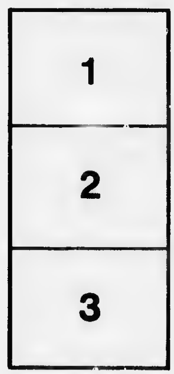

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INCORPORATED 1887.

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PNEUMATIC POWER APPLIED TO WORKSHOPS.

By John Davis Barnett, M.Can.Soc.C.E.

To be read Wednesday, 17th June, 1896.

In the early days of ironworking the tools were usually brought to the work, and they were manual. Later, as tools increased in size and stiffness, the work was brought to the machine and moved with it under or against the tool. To-day, in many operations, the bulk of metal to be handled is getting so unwieldy that it is again proving common practice to carry the machine tool to the work. Electrical and air motors are certainly factors in this evolution, even if not largely responsible for it.

This paper proposes putting on record the present position of air power, as part of a craft, illustrated more especially by railway shop-work.

A natural hope, then, would be that the author should give figures, comparative between air-driven, water-driven, electrically driven and shaft driven machines.* Such figures the author cannot give from his own experiment, and after wide search is of the opinion that at the present day they have not been obtained ; therefore, this paper must be qualitative rather than quantitative.

EFFICIENCY.

The author does not intend to say that air, for continuous work in plate flanging, or for high pressures in stamping and forging, is a more economical transmitter of power than water, or that pipes, air engines and motors are better or cheaper than wires and electric motors, or independent air driven tools than steam applied through shafting and belts to a compact group of machine tools, but he is of the opinion that if many widely scattered, different and intermittent operations are to be performed ; if a cold climate has to be fought ; if the technical skill and knowledge of the workman employed is limited ; and if the special and portable tools are more or less of home design and manufacture to suit the particular and limiting conditions of their use, then air has efficiency, economy, and a wide field of usefulness. For the many and varied services it now is used in and about a railway, see the appendix.

The common opinion that the compressing of air was costly and power transmission by it wasteful, has been the main obstacle to its more extended use. Prof. J. T. Nicolson, M.C.S.C.E., has (in Transactions, v. 7. p. 79) clearly proved that there is no difficulty or great first cost in securing a mechanical efficiency of 86 per cent., a thermodynamic of 92, and a main (pipe) efficiency of 96.2, and re-warming the air near to the motor ; that he recommends, the author finds in practice to be easy, cheap, and so effective as to tempt him to emphasize Prof. Unwin, who says (Proceedings I.C.E., v. 105, p. 202) heat applied in re-warming compressed air is used nearly five times as efficiently as an equal amount of heat employed in generating steam.

* For such an economical comparison between small motors see Proceedings I.C.E., vol. 105, p. 308.

COMPRESSORS.

The date and recorded experience in compressors and compressing is enormous, and does not require our attention, except to note that, for delivering small volumes of air, a staple article of machinery supply on the market to-day is belted-compressors, worked from the shop shafting, having single acting pistons, compound pump chambers, and intermediate air cooler, doing the compressing in two or more stages. They are automatic in action, that is, when the receiving reservoir is above normal pressure the driving belt is moved across from the fast to the loose pulley (both on the crank shaft) by means of a small air cylinder, whose piston rod is coupled direct to the belt shifter. The admission of the compressed air to this small shifting cylinder being controlled by the movement of a diaphragm, whose under side is open to the receiver pressure, and whose lift is controlled by an ordinary safety valve lever, carrying a sliding balance weight, adjustable at will. If the demand be very irregular as to amount, several such belted compressors have been used coupled up in automatic series. Also, pressure from the receiver has been used to throw a friction clutch in and out of gear and thus secure the intermittent action of a belted compressor.

For compressors generally it may be said that it is advisable, where possible, to use large units, run at fairly moderate speeds; to take the air in as free from dust as possible—the author takes it from under the external cavetrough—also to take in the coldest air possible, as for each 5° lower temperature of the entering air there is said to be a one per cent. increased efficiency in the compressor.

PIPES AND STORAGE.

The shop piping or main for ordinary pressures (80 to 100 lbs.) should not be less shan 1½in. diameter, the larger the better. The author having 4in. pipe spare on hand, used it with great satisfaction, as it gave ample power storage and little friction. Very slight provision is required for drainage. The main is best carried on the top of roof tie beam, and from the first should be liberally supplied with short branches and outlet valves, at least one to every 18 or 20 feet, with screwed ends to fit the union nuts of the flexible hose; the hose for hand tools and hoists varying from ⅜″ to ½″ diameter. Cords from the outlet valve lever run down to within 7ft. of the floor controlling the position of the valve.

Reservoir storage has to be proportionately the larger the more intermittent the work done,—that is, the greater the extreme call for air compared with the maximum delivery of the compressor. The pipes and reservoir together should be capable of holding the total delivery of the compressor (working at normal speeed) for half an hour, which is far cheaper than providing an excessively large size compressor, cheaper not only in first cost but in daily working. This refers to steam power compressors, which are run to disadvantage at speeds so slow as to make uncertain if the fly-wheel is going to carry the crank well over its dead centre, and also the condensation on the cylender walls, etc., is then excessive.

COMPARATIVE COST.

In ordinary compact factories, with fairly efficient steam plant, the gross cost of the motive power, that is, of fuel, oil and water, is but one per cent. of the total paid out in workmen's wages.

In ironworking, pneumatic power often increases a man's output of work 200 per cent. (threefold). For argument sake allow that it is only doubled. Then, if supplying one man with his proportion of the motive power were by the use of air to increase his proportion of the motive power cost by 50 per cent., it is evident we should then have a similar 50 per cent. margin for profit. As the actual cost is nearer 5 per cent. there is evidently a wide margin for extra outlay in machines or in their repair, which expenditure, per day or per man, is increased in the attempt to use pneumatic power, but in the cost of such tools as drills, rhymers, taps, boring cutters, etc., is not increased per ft. run of actual work done, when compared with manual labour.

Thus it is clear that if the additional machinery a factory makes or purchases in trying to use air as a distributer of power is confined to such tools as will be often or fairly continuously used, this outlay is justified, and the cost of compressing relatively to total wages is so small that tools evidently wasteful in the use of air are economical, or rather show a net balance to the good, if the men find them portable, easily adjustable and handy to use, and their simplicty of make and freedom from repairs and break downs, results in but few delays to the steady out-put of work.

ROTARY MOTORS.

It is evident that the use of compressed air has stimulated the use of rotary-motors, and not because it was believed that they were economical converters, but because their light weight and small bulk permitted them to be used by hand. However, the making of a more perfect air engine than the steam rotaries, for which so many designs were made and patents taken out between 1830-50, has been attempted, but it is questionable if any advance has been made. The author has no information as to any attempt to use a reaction or impact turbine as a portable air motor. What has probably discouraged this is that the necessity to gear down the high speed would make the engine weighty and the friction excessive, although, as air at the same pressure is twice as heavy as steam, it looks as if air would do well in such a form of reaction engine.

The most simple form of rotary motor is an excentric or cam, forming part of the central shaft, whose length is that of the cylinder in which it rotates, and whose outer surface (belly) touches in the course of one revolution the whole internal circumference of the cylinder. A reciprocating plate moved in centrally from the cylinder wall receives the backward thrust of the air. The admission port is in front of this plate, and the exhaust port at its rear. So made, the small sizes to be held by hand, when at work, give an irregular, wobbling motion, as the shaft—or plug as it is called—is unbalanced. This long ago provoked the use of two parallel shafts or cams geared together, but the author must confess to a failure in an attempt to reverse a form of the Root blower, using it as a small motor.

The later attempts make the cylinder in cross-section oval or elliptic, with several inlet and ports in its walls. The shaft, which is as large as the minor diameter of the ellipse, carries two or four movable blades or pistons in its body, whose outer edges are kept in contact with the varying walls of the cylinder, not by steel springs, but by the admission of compressed air to the bottom of the slots of the shaft in which each radial piston blade plays in and out.

Without dispute, the leakage is large, judged by the standard of a reciprocating steam piston, in part due to the several reciprocating blades being subject to wear on their three outer edges as well as looseness in their shaft slots, and also in part due to the fact that with air and steam under exactly similar conditions of surface, of metal, and of pressure, air will get past any packing more readily than steam will pass it. A suggested explanation for this is that the film of water that condensation leaves on the steam walls retards the passage of steam between smooth metal surfaces.

The dynamic efficiency of such motors is low, so low as to apparently discourage any attempt at metering, indicating or brake-testing them, yet many wideawake shop managers use them in direct application to drills and taps, because, communicating a cutting speed from five to twenty times higher than can be given to the same tool by hand, they therefore prove cheap, although lavish in the use of air.

RECIPROCATING ENGINES.

At the sacrifice of perfect portability much is gained by using small reciprocating engines, weighing from 100 to 200 lbs., with two to four cylinders receiving air pressure on one side only of the pistons.

Their light weight permits one man to readily move them over the shop floor; having no dead centre, gives prompt starting and regularity of turning movement; low centre of gravity gives steadiness; the strain being always in thrust, the engine is practically noiseless, and the elasticity of the air can be utilized in expansive working. The author uses double acting verticle engines (steam hammer type) of home manufacture, with single cylinder $3\frac{1}{2}$ in. diameter by 6 in. stroke, averaging, with 80 lbs. pressure, 225 revolutions per minute.

To re warm the air just before it enters the valve-chest, it is passed through a 30 in. length of thin copper pipe, $\frac{5}{8}$ in. outside diameter, bent into a four turn truncated coil, barely $3\frac{1}{2}$ in. diameter at base and $2\frac{1}{4}$ in. diameter at top, contained in a tin lamp 12 in. long by $3\frac{1}{2}$ in. diameter at bottom and $1\frac{1}{2}$ in. diameter at top. The lamp cistern carries a double "B" burner, using two $\frac{7}{8}$ in. flat wicks, and burns an imperial pint of common coal oil each 30 hours. No glass chimney is required, and the flames come close to inside of coil. This lamp is bolted on close to and parallel with the cylinder, and is cheap, neat and inconspicuous, working satisfactorily even when the engine is set at an angle of 15° or 20° out of vertical.

TRANSMITTING SHAFTS.

In transmitting motion from an independent engine on shop floor to the drill or tap, an endless cord $\frac{3}{4}''$ or $\frac{7}{8}''$ diameter has been used, with light weight grooved pullies, the whole kept in tension by counterweights. This gear proved to be a nuisance because of the amount of tackle and number of pulleys required to change direction of motion. The "Stowe flexible shaft" has also been used. Even this requires a universal coupling joint at one end to meet many conditions of shop service; lengthening it from 8 ft. to $8\frac{1}{2}$ ft., the total weight for a No. 8 size being 65 lbs. Its life is short, the repairs excessive, the power it will transmit is small, and to do it the speed of revolution must be high; thus the head for drill or tap must be geared down and therefore made larger and heavier than is required when shaft and tool are revolving at the same speed.

A shaft more certain in action, quite as portable, and having longer life, is made by using a steel rod 1 in. diameter, sliding freely inside an iron pipe 1 5-16 in. outside diameter, with a universal coupling at each end. A shallow groove the whole length of the shaft and narrow feathers on the inside of the pipe insure that both revolve together; the weight of the whole is 35 lbs., and it is usually sustained by a central cord counterweighted. The ordinary length is $7\frac{1}{2}$ ft., extensible to 12 ft., but by using standard gas pipe thread for all connections, duplicate parts can at any time, if required, be added, increasing the length. It effectively transmits from 200 to 300 revolutions per minute with either or both short ends set at an angle of 35° with the central length.

For the convenience of the workman the portable tapping head is a light frame, with two and even three handles, carrying a pair of bevel-toothed wheels changing the plane of rotation, and permitting the man to guide or to put personal pressure on directly behind the tap, while its spindle is receiving motion from the side. The speed is such that a tap of 11 threads per inch with rhymering ends to it, in all about 18 in. long, is screwed through both steel plates forming the water space inclosing a locomotive firebox, in from 50 to 60 seconds.

The drill press is of course somewhat stouter, having to carry the feed pressure screw.

HAMMERS.

The standard shape of pneumatic hand hammer (of any American patent) suggests an overgrown pistol, weighing from 8 to 9 lbs. In the smaller sizes the contained piston has a stroke of 2 in. or $2\frac{1}{4}$ in., and strikes directly on the end of the cutting chisel or other independent tool, which moves freely in a socket at the centre of the outer end of the pistol. This loose tool, of $\frac{5}{8}$ octagon bar steel 6″ or 7″ long, is at outer end shaped to suit its special work, as rivetting, nailing, chipping, caulking, beading, engraving, chasing, stonecutting or planishing. Quite recently an improvement has been made in this all-round useful instrument by increasing its piston stroke to 4", and putting the pistol in a tubular case of cast iron weighing 80 lbs. or more. Its mass absorbs most of the reaction blow which the workman found so distressing to nerve and muscle, but as it requires to be suspended and counterweighted, it is necessarily not as portable, and cannot be used under conditions as confined and awkward as the hammer of shorter stroke and lighter weight. The hose is $\frac{3}{8}$" diameter and the pressure used from 20 to 100 lbs. At the latter hammer delivers 2,000 or more blows per minute, using of free air per minute 15 cubic ft. at 60 lbs., 18 cub. ft. at 75 lbs. and 21 cub. ft. at 90 lbs, it readily does the work of three men; four is claimed and is possible under some awkward conditions. Men on piece work provided with such hammer accept one-third the old piece-work price. Their cost, duty and freight paid, is from $150. to $160. and much of their product is decidedly superior to hand work. This is especially seen in beading over the ends of boiler tubes. Air is used in ordinary vertical smithy hammers, having cylinders 10 in. by 28 in., with what economy is not known, but as no choking exhaust pipe is needed, the exhaust is very free.

RIVETING.

Rivetting tools require little special mention, as any power riveting tool, acting by a single steady squeeze from water or steam, may be worked by air. At most the change is but one of valve or cock, so that all power movements are controlled by one handle, and if desired, the exhaust air may be directed on to the cooling rivet, as in some cases it is on to the point of a drill to keep it cool.

The pneumatic hand-hammer (with its rapid delivery of blows) is well suited for light tank work, that is, for rivets up to $\frac{1}{2}$ in. diameter. The use of this tool—as in hand riveting—requires a holder up. The number of rivets put home per hour, dependent on size, is increased from 50 to 100 per cent. over hand labor. The unpleasant noise it makes is in some quarters an obstacle to its increased use, and as its quickly repeated blow helps to keep up the heat of the rivet, it is probable that this rapid impact hammer will not prove to be as satisfactory on steam joints as it is on tank work, because, in hydraulic riveting, where the dead pressure can be held on the rivet while it is cooling, the amount of caulking required to finish and make a tight dry job is three or four times more than that usually required to make equally good a hand riveted boiler.

HOISTS.

Common shop practice in the home manufacture of air lifts is to use for the cylindrical barrels seemless tubes of iron or brass, smoothed internally by forcing a slug through; for the piston rod cold rolled steel screwed at its lower end into the lifting hook shackle, and for piston head two cast iron disks with one thickness of leather packing between. To secure the satisfactory action of this leather packing a sprung ring of round steel or brass wire cut shorter than the barrel circumference, and bent larger than its diameter, is put inside the turned over edge of the leather packing, and the lower and smaller of the iron disks has cast in it in its outer upper edge a recess to clear and allow for the free play of this sprung wire ring.

The two cast heads or covers, and the barrel which is slightly recessed into them, are held together by through bolts, outside the barrel. So made, of medium length, a 4 in. costs $18 and a 6 in. $28.

Under such conditions of cheap make, the friction of working varies from 3 per cent. in the large sizes to 20 per cent. in the very small, that is 4 in. and under. This compares favorably with epicyclodial and differential hoisting tackle, but lacks, of course, its certainty of sustaining power.

If two cast iron sprung rings are used as packing in a solid piston head the barrel needs boring out from end to end, and if not in fairly continuous use is liable to have the friction increased by rust. In a spring testing machine made by the author, with two cast iron spring rings $\frac{1}{2}$ in. wide by $\frac{3}{8}$ in. thick, working in a 20″ cylinder, new and well lubricated, it took 100 lbs. to start the piston, as indicated by a Salter Balance, and 90 lbs. to keep it moving. In so simple a type of hoist it is a matter of indifference which way the cylinder is set. Given sufficient head room it is suspended vertically from a two-wheeled tandem trolly moving on a single bar runway, so that load, hoist and trolly have horizontal freedom. If head room is wanting it is set horizontally, and the outer end of the piston rod coupled to a chain passing over one or more pulleys, thus changing the direction of the pull, and so used the piston rod on upper surface has been notched so as to form a rack into which a pall falls, thus locking the suspended weight at any height; and when the hoist cylinder is put on to an old hand crane it is often set at an angle, being for convenience of attachment secured to the diagonal strut. A flexible hose of small diameter gives it elastic connection with the shop air-main.

The widest variation in practice is in the controlling valve used, a three-way plugcock being the cheapest to make and the most troublesome to keep tight. Mitre valves or flat valves with recessed elastic seating are more certain. They require a separate spindle (and cotton-packed gland) for each valve, but each pair is movable by one double-ended lever.

Where air enters the barrel of hoist a very small hole or self-closing check valve is desirable, so as to prevent the load running down dangerously fast in case of injury either to the air-main or the supply hose; also it is desirable to have a check or stop on the piston rod so coupled to valve that in case of over-stroke the valve is reversed and air is admitted to the opposite side of piston cushioning it. The same end may be attained by the piston itself striking and opening a supplementary valve, or if the non-working end of barrel is open to the atmosphere by small hole in the side of the barrel, so locating this hole that the piston will block it and the confined air act, first as a cushion and then as a stop. Such a hole sucks in the shop dust and grit, increasing friction and leakage, so that a valve admitting compressed air or exhaust air only, is the better practice.

It is perhaps over the wide surface of a foundry floor and in the midst of its sand, grit and dust, that pneumatic hoists best show their good qualities, and Russel & Co., of Massillon, O., who early appreciated their value two years ago were using 26 cranes of 5 ton capacity, a cupola stock elevator, and many simpler hoists of from 400 to 1,000 lbs. capacity. Under such shop conditions every foot of air exhausted adds to the health and comfort and therefore working capacity of the moulders.

HOSE FOR HOISTS.

In trying to use a portable suspended hoist, and move it under a long length of shop roof, in most cases—even of modern equipment—the flexible air-hose has to be detached, and after the hoisting cylinder has been moved to a new location the air-hose recoupled to the air-main branch. To avoid this delay and inconvenience the C. & N. W. Ry. Co., use a long length of air-hose, equal to half the total length of the runway that carries the hoist, coupling the hose to the air-main at the centre of the length of the runway. Then, at points some 20 feet or more apart, the hose is suspended from a two-inch grooved pulley running freely on a horizontally tight-stretched wire. Each such suspending pulley requires an independent wire, and the wires are arranged so as not to be in the same vertical plane. The result of this ingenious arrangement is that as the hoist moves towards the centre of its runway it crowds or loops the hose, and then when closely massed each suspending pulley runs past its neighbour as the hoist passes the centre, then, extending and straightening the looped up hose, the hoist is free to travel as far to the left hand of the centre (or point of connection to the shop main) as it was originally to the right hand of that point.

Mr. R. Quaylo is so far satisfied with this plan that he has now underway some such arrangement to permit a jib crane, travelling on a single floor rail to propel itself or to hoist at any point in the length of a 500 feet shop.

FORGING.

The most obvious advantage of air ovor water as a transmitter of power is its freedom from frost troubles. It is, however, possible under some conditions to effectively combine the two, not only without frost risk, but with added economy and a much wider range of application, without the machine being so large as to interfere with tho workman's freedom of movement and his ease in handling the material to and from the tool.

This is done by using a pair of tandem differential cylinders, the outer or upper side of the piston of the larger receiving tho full air pressure and delivering that power through the piston rod at higher pressure per square inch to the water contained in the smaller cylinder. A third and independent piston at opposite end of small cylinder is coupled direct through its piston rod to the forging die.

As developed in detail by Mr. J. W. Harkom M. C. S. C. E., at Toronto, the differential cylinders are vertical, the large (air) cylinder being high up—that is, well above the working level of the man—and the smaller cylinder is made longer than its piston travel, and just above ground level opens direct into a third cylinder, set horizontally.

The second and third cylinders are actually one and the same, but in the middle of its length is bent to a right angle, and has a piston at each end-not coupled together, so that the distance between these pistons is variable and the space between them filled with water admitted by valve from the city mains.

The piston rod of the third or horizonal cylinder at its outer end carries the forging die, and the piston has water pressure on one side and air pressure on its relief side, so as to carry the die back after the forging squeeze has been given.

All the fluid used is that contained between the two small pistons, and is a quantity variable at will, and this is the key to the economy in the volume of the air used. The dies being variable in depth, and the forgings in thickness, the position of the third piston should be variable in position, both before and after the forging movement. When the movement for any particular set of forgings is to be small, the maximum quantity of water is forced in by opening a valve coupled to the city water-main, which lifts the large air piston up closer to the top cover of the large cylinder, and thus effectually shortens its possible length of stroke.

If the amount of water (and therefore the distance between the two small pistons) was not definitely adjustable, there would be a large loss of air when a small die were in use—or a shallow forging being made—due to the necessary filling and emptying of the cubic contents of the large cylinder at each stroke. The return (after making a stroke) of all pistons is assisted by compensating balance weights, coupled by chains to the piston rods or tail-rods, and air pressure being always on the relief side of the forging (third) piston the die is withdrawn from the forging as soon as the air is permitted to escape from the top of the large air cylinder. This is controlled by a three-way cock overhead, with two light cords coupled to its double-ended lever, the handles on lower ends of cord just clearing the workmen's head. Opening a single drain-cock at lowest level gets rid of all the water when men leave the shop at night.

COMBINED BORING AND PLANING.

It is an advantage in trying to secure perfect alignment in the boring and planing of large cylinders, pump barrels, etc., that both these operations be done on the one machine table without resetting the work, and this has of late been done by M. C. Bullock Co. of Chicago, * tho

* *American Machinist*, Jan. 2, 1896.

one operation following the other, but with a suitable air motor and flexible hose it should not be difficult to do both operations at once, although the author is not familiar with any portable air motor on the market powerful enough to do the boring in as short a time as the planing usually occupies. It is also possible to do the milling out of the steamports by a second air motor while the boring is being finished, the whole needing but one attendent, as when on piece, work one man regularly attends to three milling machines.

CONCLUSION.

To summarize, air is in practice proving to be a fairly cheap and most convenient transmittor of power, allowing fine sub-division and transportation to remote points with the crowning and unique quality of suffering no appreciable loss when held in storage. For intermittent service it is of great value allowing widely varying speed of tools, dispensing with long lines of shafting and belts, giving free head room, and increasing the shoplight as well as lessening the first cost of roof frames when they have not to carry shafting. The pipes require no coating; they radiate no heat, and therefore can be put in close corners without increasing the fire risk; their direction is readily changed in any plane without risk of pocketing or water-hammer, and leaky joints (we all get them) are not a nuisance or risk. In no case are exhaust pipes required, and in most if not all cases the exhaust adds to the men's comfort.

APPENDIX.

LIST OF PNEUMATIC TOOLS AND MACHINES AT THE TOPEKA WORKSHOPS OF THE A. T. & S. F. Ry. (see *Ry. Review* 25, 4, 96).

1 Riveting machine, of 10 ft. reach, with pneumatic crane.
1 Riveting machine of 6 ft. reach with frame.
1 Combination flange punch and riveter.
2 Truck riveters.
1 Bridge riveter.
1 Frame "
1 Tank "
1 Mudring "
1 Staybolt breaker.
1 Staybolt cutter (nipper).
20 Rotary motors.
4 Brotherhood engines.
1 Grinder.
1 Saw.
6 Hammers (hand).
1 Punch.
1 Angleiron shears.
1 Bolt machine.
3 Hammers in smithy.
1 Large punch and shears.
1 Bulldozer.
1 Rail saw.
1 Rail drill.
2 Rail benders.
1 Stamping machine for tin shop.
1 Bolt shearer.
1 Port miller.
3 Letter presses.
6 Pulling down jacks.
12 Car jacks.
2 Drawbar jacks.
3 Painting machines.
1 Washer maker.
3 Rivet holders.

2 Tube rollers.
8 Pumps.
1 Transfer table.
1 Driving wheel revolver used in setting slide valves.
30 Hoists in shop.
3 Hoists 10 feet lift outside.
1 Device for handling oil.
1 Hose coupling fitter.
1 Tool for tearing down old car roofs.
1 Drop pit.
1 Device for delivering sand.
1 Device for extracting oil from waste, etc.
1 Shunting locomotive (traction engine).
1 Device for securing sheets at flange fire
1 Device for cleaning coah cushions.
3 Paint burners.
1 Whitewashing machine.
1 Device for handling work in brass foundry.
1 Turntable revolver.

Air is also used for testing brakes in shop and yard, cleaning boiler flues, cleaning the shops and engines, and in self-moving dead locomotives from erecting to paint shop.

Although this makes a good show for one set of shops it is far from marking the limit of compressed air as applied in railway service to-day. It is used for moving crossing gates; track interlocked deraders; single semaphores and semapaores interlocked with switches and gates, and this, too, at points 18 miles away from the compressing plant; in timber preserving by injection; in moving capstans and winches for hauling and shunting purposes; in coaling locomotive tenders; in lifting their ashes out; in sifting, lifting and delivering sand to locomotives; in delivering sand to rail; actuating whistle signal; moving the rocking firegrate; opening the firehole door; ringing the bell, and perhaps the best known of all in actuating the continuous automatic brake. Also on other rolling stock for controlling snow-plow wings and aprons; ice flangers and scrapers; doors of dump and drop-bottom cars, and for tilting ballast cars; and inside shops for bending pipes; cleaning pipes from internal scale; testing pipes and their jointing; with gas jets for heating tires and other rings of metal; as a blowpipe for straightening bent wrought iron frames; for spraying fuel into oil furnaces; for belt shifting on countershafts; for machine brakes to stop tools at a definite point; for supplementing the wheel and axle hydraulic press; for axle box and journal press; with sand as sandblast for cutting and scouring; and for scrap shears and scrap tumblers at far end of yard where the noise is least annoying, and where there is ample space for scrap sorting.