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# WORTHINGTON ROTATIVE DRY VACUUM PUMP

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## HENRY R. WORTHINGTON

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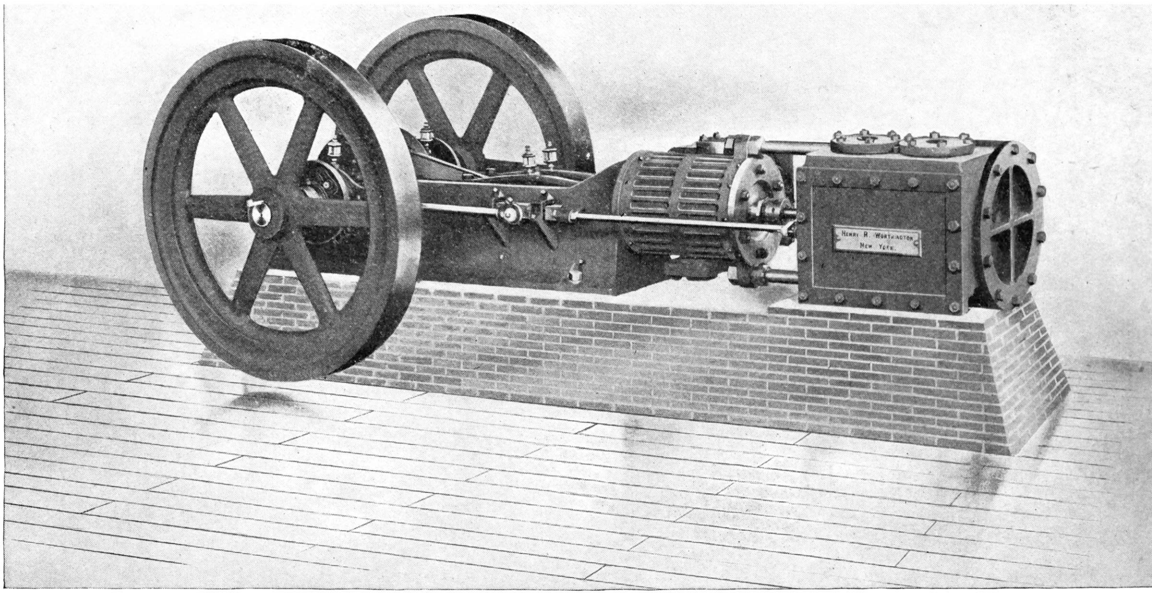


Worthington Rotative Dry Vacuum Pump. Size 9 x 16 x 12.

## WORTHINGTON ROTATIVE DRY VACUUM PUMP.

THIS new form of Dry Vacuum Pump has been designed and constructed to meet the requirements of services that call for the pumping of comparatively large quantities of air under high degrees of vacuum, such as are met with in sugar refineries in connection with vacuum pans; preserving processes in the sealing of jars by the removal of air under the covers; and in central condensing systems where high efficiency is of first importance.

As will be seen by the cut the machine is very substantial, compact and simple. It consists of one steam and one vacuum piston upon the same rod, the fly-wheels being of such weight as to enable operation at a very low speed if desired. As no water is used in the vacuum cylinder which is cooled by means of jackets, and as the air valve is positively controlled by an eccentric on the engine shaft, the maximum speed is only limited by that of the steam engine itself. As a fair running maximum 100 revolutions per minute has been adopted, although in special cases it can be safely exceeded, and each machine is fitted with a speed governor in addition to the throttle valve, which prevents the machine from exceeding the speed of 100 revolutions per minute. Lower speeds, to suit each case, are easily obtained by adjustment of the throttle valve, or, if a constant rate is desired, by setting the governor for that speed.

Another very satisfactory arrangement is to place two machines side by side on the same crank shaft, with the cranks 90 degrees apart.

Omitting the use of water in the interior of the vacuum cylinder eliminates the difficulty of removing it at the end of the stroke, and allows a speed of rotation that does not make the duplex or double-crank form necessary or even desirable. In rotative wet and dry vacuum pumps that have been previously offered by manufacturers, and which employ voluntary suction and delivery valves, and use water to cool the cylinders and to seal the valves from leakage, it has been necessary to run at a speed so low that the admitted water could be discharged without damage to the cylinder heads and other parts. In order to accomplish this, low speed duplex, or, rather, double forms have been used, in which the cranks are set at quarters, and one side helps the other over the center at the end of the stroke when the latter is doing its greatest work, and is meeting the resistance of the water and delivering it through the force valves against atmospheric pressure. In other words, with water in the cylinder and with voluntary valves it is necessary that the speed of rotation be low, and it is also necessary that the machines be double in order that the rotation may be slow and not stop on centers.

As the air pumped by vacuum pumps of this class is usually free from entrained water there is no reason why a dry vacuum pump cannot be viewed purely as a gas pump, and, in determining the speeds through the ports and valves, be considered from a gas standpoint rather than from a liquid standpoint. It will be understood that with a machine on this service, the advantages obtained by pumps with duplex valve motion in the handling of water do not apply to the double-crank forms, and the single form is in many respects preferable, notably on account of the reduced number of parts and consequent less wear and tear. On the score of economy in steam consumption the single form is in the lead because of the earlier cut-off that can be used in the steam cylinder, due to the higher rotative speed. The machine being described has a point of cut-off that can be varied from one-fourth to one-third of the stroke, according to the steam pressure maintained upon the boilers, while with a double machine of the ordinary type the cut-off must be at least at one-half the stroke in order to derive the full power of one cylinder to help the other over the center at the time when the latter is doing its greatest work.

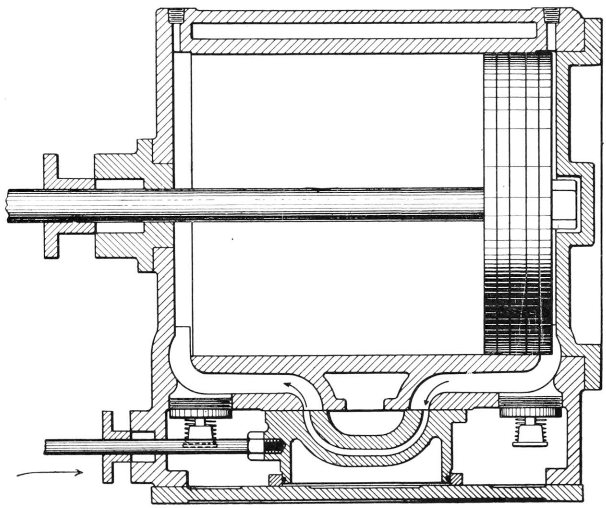

FIG. 1. SECTIONAL PLAN OF VACUUM CYLINDER. PISTON AT END OF STROKE.

Fig. 1 gives a section of the vacuum cylinder and the positively moved air valve. The valve, while it is large in order to make the use of large ports possible, is partially balanced by means of a piston and ring bearing against the valve chest cover, so that the pressure of the valve against the seat is reduced to a minimum. The delivery valves are of the voluntary form and easily accessible by removal of the steam chest cover. The ports are very liberal in size, and designed to give the least reasonable friction to the flow of the air at the high tension under which it passes through the ports to the cylinder. The suction valve, being positively moved, opens to its fullest extent at the proper time and offers no obstruction to the flow of air into the cylinder, there being no valves to lift nor springs to be acted upon. It might be thought that the large ports would be detrimental to the efficient action of the machine, and this would be the case if it were not for the method we have adopted of eliminating the influence of clearance space by means of the equalizing port that can be seen in the body of the valve, the function of which is to connect the opposite ends of the cylinder with each other when the piston is at the end of each stroke. The result of this connection is to remove the air from the clearance space in front of the piston into the large vacuous space at the back of the piston, the pressures being equalized and reduced to nearly that of the vacuum to be maintained in the suction pipe, so that when the piston begins to make the return stroke, instead of the clearance space being filled with air, which would expand and prevent the immediate production of a full vacuum, work at once commences and practically perfect efficiency is obtained.

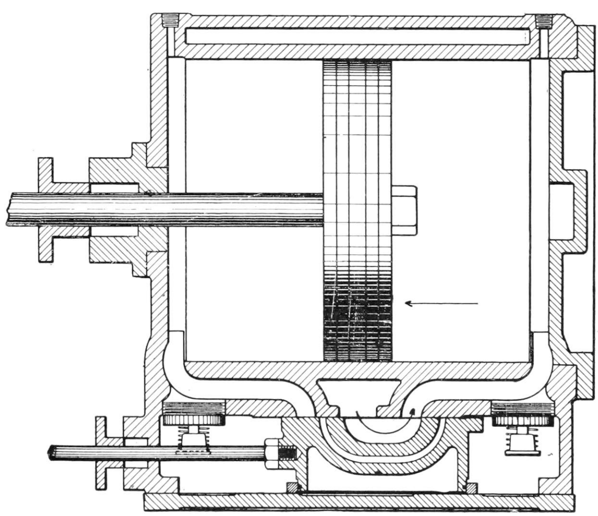

FIG. 2. SECTIONAL PLAN OF VACUUM CYLINDER. PISTON AT MID-STROKE.

Fig. 1 shows the piston at one end of the stroke and the slide valve as traveling from left to right and at mid-position, with the spaces at each end of the piston connected together by the equalizing port.

To explain the operation, we will say that the piston during the stroke just finished has produced a vacuum of 26 inches, or 2 pounds absolute pressure, and that the clearance space at each end of the cylinder is .05 of the piston displacement. The space in front of the piston is filled with air at atmospheric pressure, or 15 pounds absolute, the voluntary valve having closed as the piston came to rest. The slide valve now moves, and the two sides of the piston and the two clearance spaces are connected and we have an equalization of the pressure. 15 pounds $\times$ .05 added to 2 pounds $\times$ 1.05 $=$ 2.85. If we divide 2.85 by the sum of all the spaces, or, 1.10, we have 2.6 pounds absolute, or 24.8 inches of vacuum as the resulting average. This having been effected, the slide valve travels to the extreme right, shuts off the equalizing port and connects that which was the front of the piston with the suction pipe. The piston at the same time begins the return stroke with a vacuum of 24.8 inches in the clearance space, and when it reaches mid-stroke we have the position shown in Fig. 2. The indicator card produced

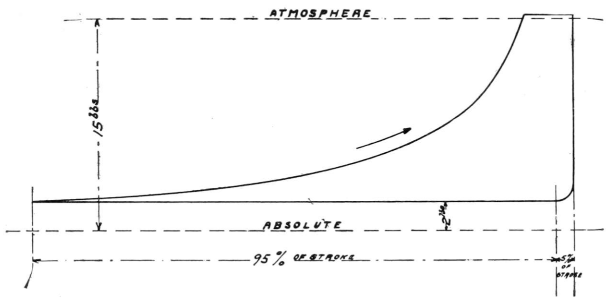


FIG. 3. INDICATOR CARD OF VACUUM CYLINDER, WORTHINGTON ROTATIVE DRY VACUUM PUMP.

would be like that of Fig. 3, and the suction-pipe pressure would be reached at an exceedingly early point of the stroke.

Contrast this action with that of an ordinary vacuum pump with voluntary valves, and assume, for the sake of comparison, a similar amount of clearance space. When the piston begins its return stroke, both the suction and delivery valves being closed, the air in the clearance space at atmospheric pressure expands behind the piston, and the suction valve remains closed until expansion has reduced the pressure below that of the suction pipe before the pump begins to do any effective work. If a vacuum of 26 inches, or 2 pounds absolute pressure, be maintained in the suction pipe, then $15 \div 2 = 7.5$. This means that 7.5 times the clearance space must be provided to give sufficient room to expand the air and reduce the pressure to 2 pounds, and as the clearance space itself is included in this volume, it will be seen that (7.5 minus 1) 6.5 is the number of times the volume displaced by the piston must exceed the clearance space before the suction pressure will be reached; .05 clearance $\times$ 6.5 = .325, or 32½ per cent., so we see that one-third of the stroke will have to be traveled before air can flow from the suction pipe and effective action take place, thus giving an efficiency of 67½ per cent.

Fig. 4 illustrates graphically what occurs in this instance. With higher ranges of vacuum the "Worthington Rotative" Pump shows still more favor-

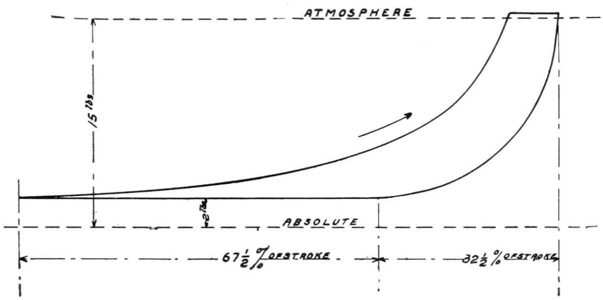


FIG. 4. INDICATOR CARD OF VACUUM CYLINDER, ORDINARY PUMP WITH VOLUNTARY VALVES.

ably, and 28 inches, and even 29 inches, of vacuum are obtainable, if conditions of temperature and amounts of air to be pumped are within the range of possibility. A comparison with the standard form of dry vacuum pump that has been generally considered as a model of excellence will give an idea of the relative capacity of the two machines. A double machine, having two vacuum cylinders 16 inches in diameter, and a stroke of 9 inches, is considered to be doing its best work at about 40 revolutions per minute. This is equivalent to one cylinder at 80 revolutions per minute, or 120 feet piston travel, with, say, 65 per cent efficiency. The Worthington Rotative Pump of 12-inch stroke will travel 200 feet, and the 18-inch stroke 300 feet per minute, so that our 9 x 16 x 12, with a single vacuum cylinder, will displace 60 per cent. more than the two cylinders of the double machine. Taking the efficiency into consideration, $\frac{200 \times 95}{120 \times 65} = 2.4$; that is, a Worthington Rotative Dry Vacuum Pump, with a single cylinder is 2.4 times as effective as the old style machine with two cylinder, each of the same size as the Worthington, and using voluntary valves and water to seal them.

Cool water is required in the jackets of the vacuum cylinder to protect the oil used to lubricate the piston and cylinders from the heat due to the compression of air from two pounds absolute pressure to fifteen pounds, or atmospheric pressure. The quantity used, however, is small compared with that employed when it is injected into the cylinder, and used to fill the abnormally large clearance spaces and to seal the valves of the double-crank vacuum pump above referred to. If the water is of normal temperature, not over one-quarter of the amount usually used will be necessary. Water injected into the cylinder is detrimental for two reasons other than that of retarding the rotative speed; first, it destroys good oil lubrication of the moving parts, and second, the water often carries dirt and other suspended material, that, in the absence of good oil lubrication, rapidly cuts and grooves the cylinder and piston rings. Being assured of proper lubrication, we employ metals of greatest durability. The cylinders are of close-grained cast iron. The side valves and seats, as well as the piston rings, are of the same material, while the seats and guards of the voluntary discharge valves are of composition. The high efficiency and capacity for handling air allows us to omit water-sealed stuffing boxes and avoid the objections to which they are open.

These machines are built in a great variety of sizes. Special selections will be made for any particular service. Details and drawings may be had of any of our branch offices.

March 1, 1900. HENRY R. WORTHINGTON.