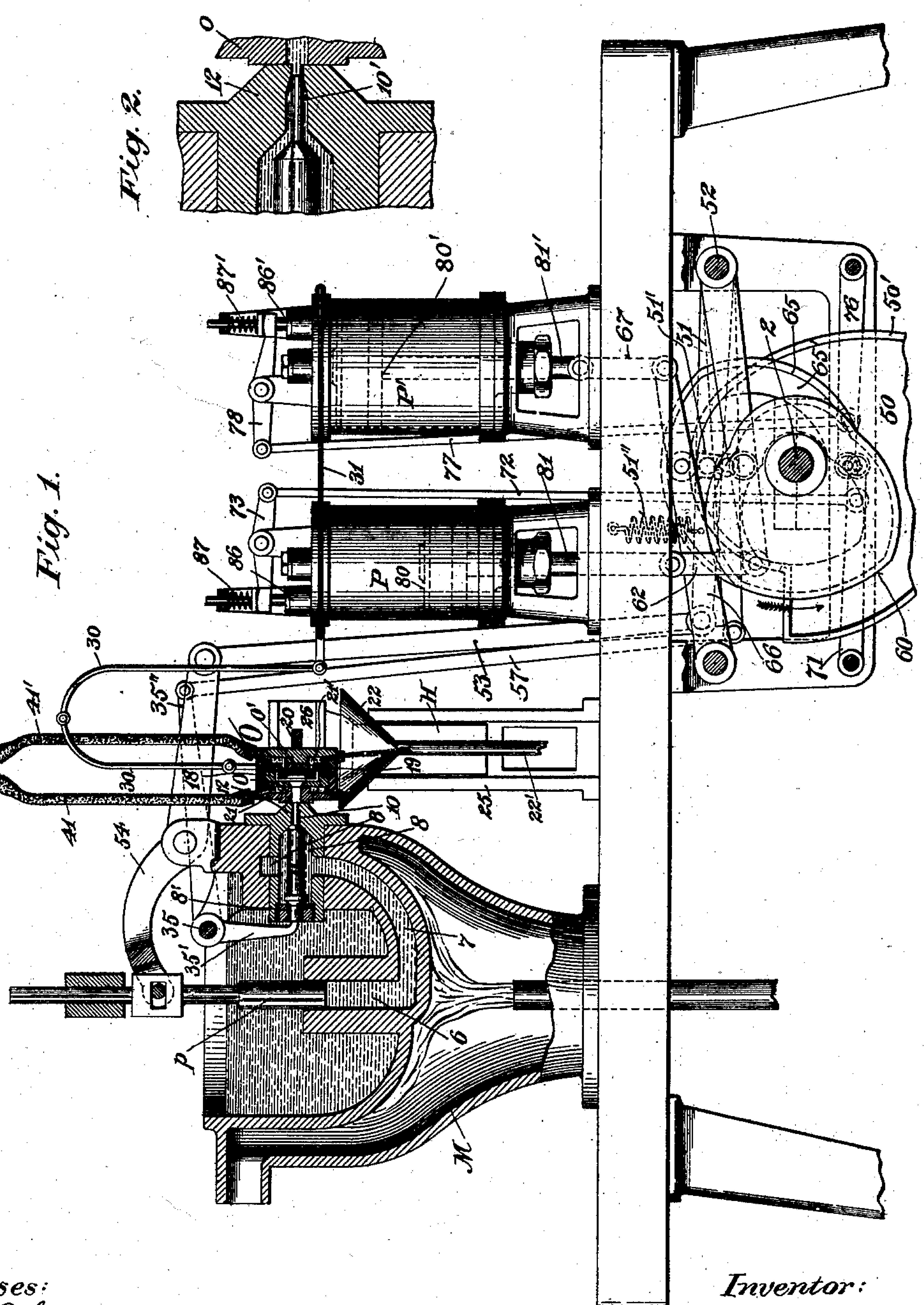
No. 698,593. Patented Apr. 29, 1902.

C. H. VEEDER.

ART OF FORMING CASTINGS.

(Application filed May 21, 1900.)

(No Model.) 2 Sheets—Sheet 1.



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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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(No Model.) 2 Sheets—Sheet 2.

Fig. 3.

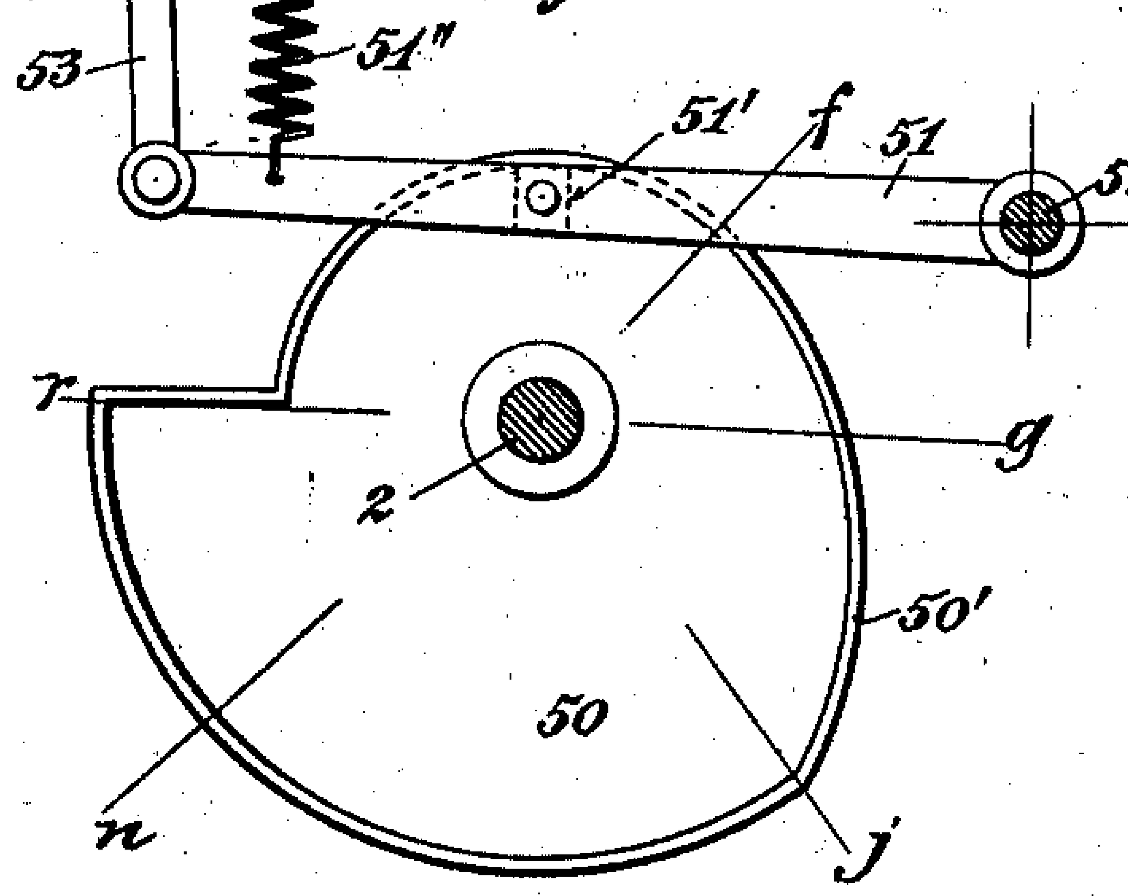


Fig. 4.

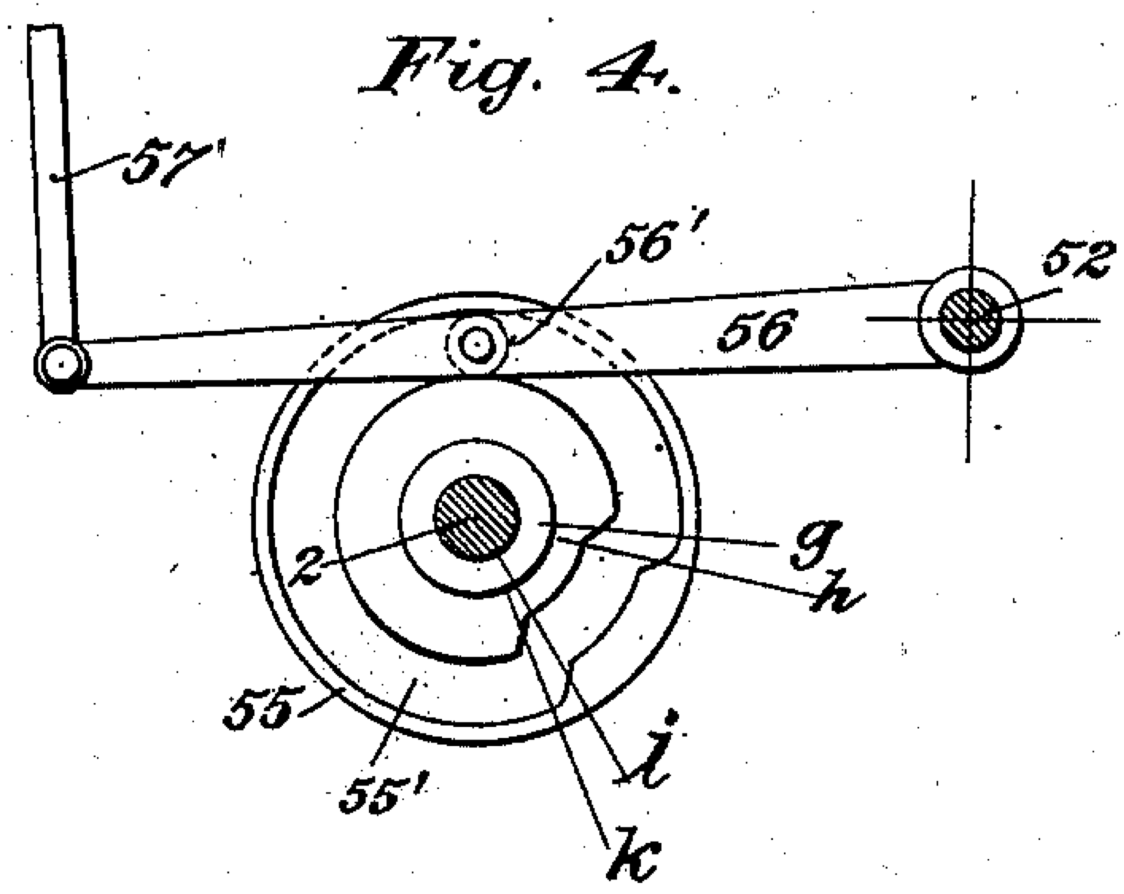


Fig. 5.

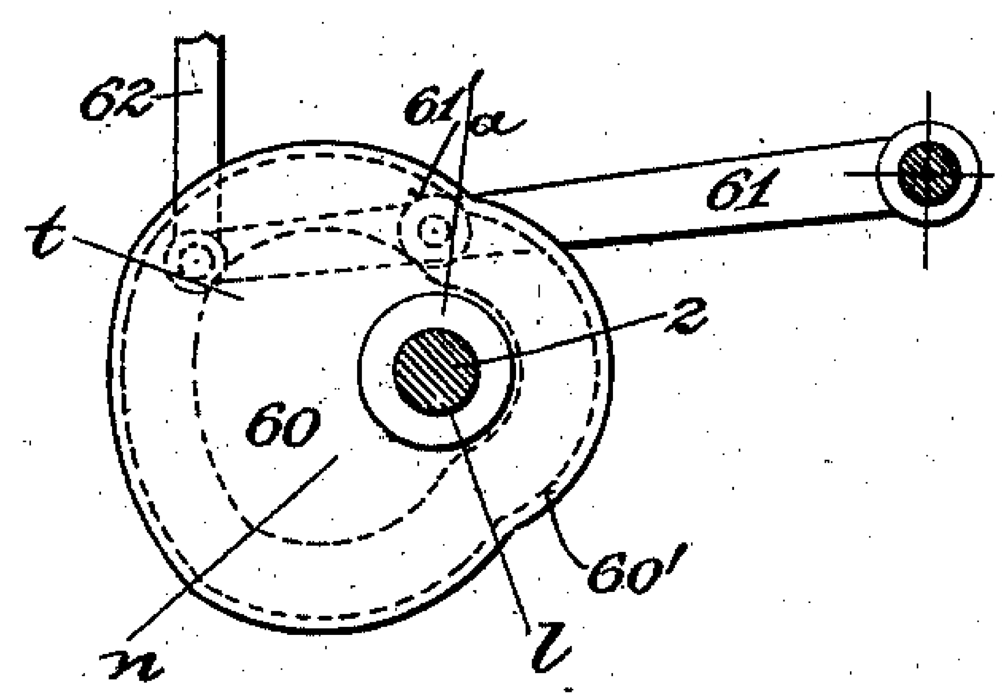


Fig. 6.

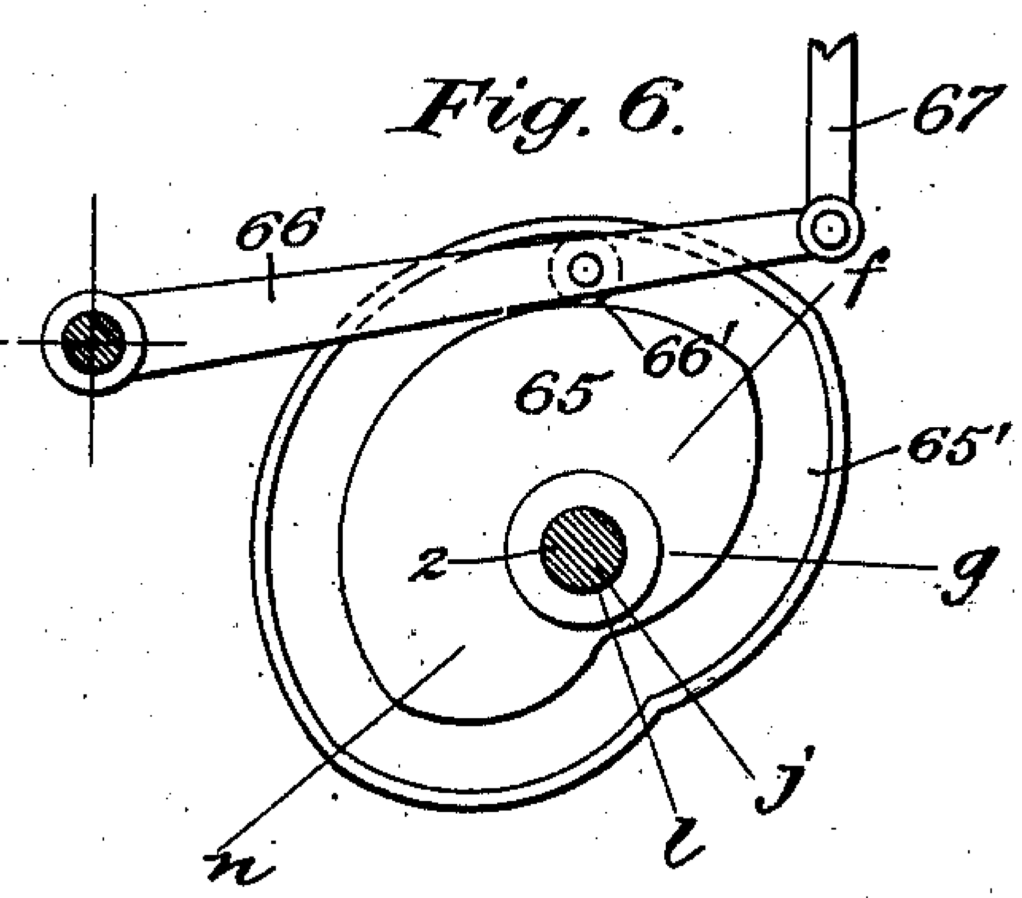


Fig. 7.

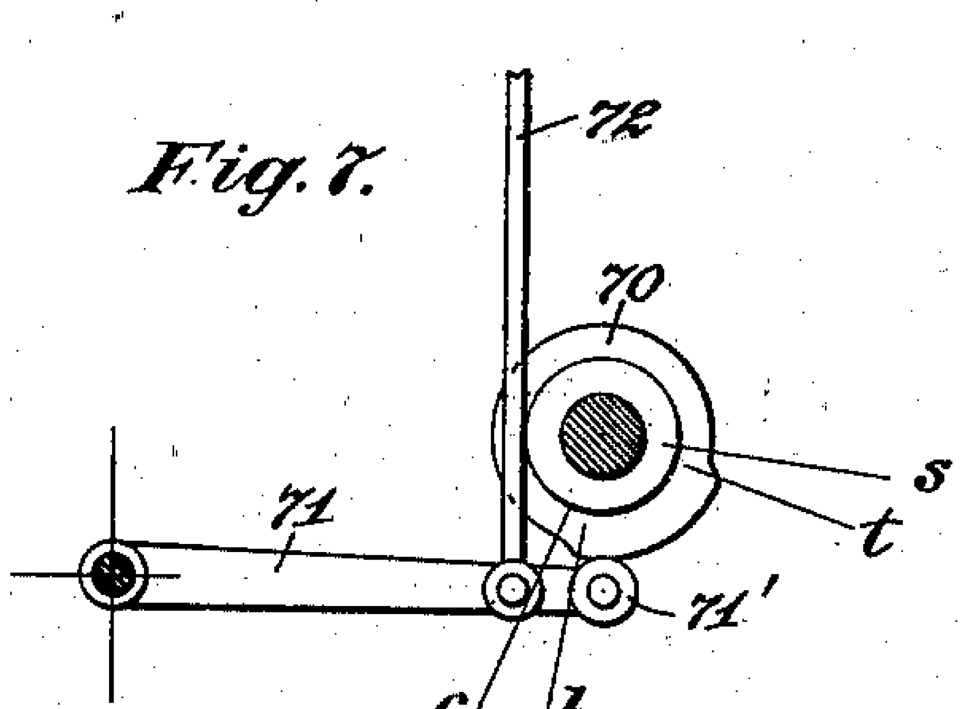
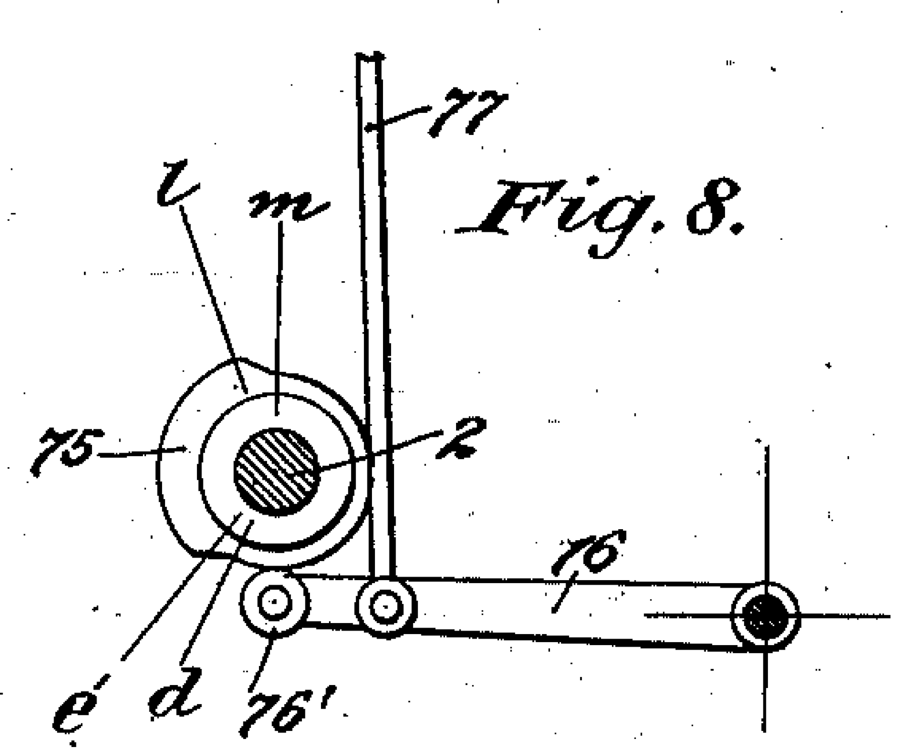


Fig. 8.



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UNITED STATES PATENT OFFICE.

CURTIS H. VEEDER, OF HARTFORD, CONNECTICUT.

ART OF FORMING CASTINGS.

SPECIFICATION forming part of Letters Patent No. 698,593, dated April 29, 1902.

Application filed May 21, 1900. Serial No. 17,331. (No model.)

To all whom it may concern:

Be it known that I, CURTIS H. VEEDER, a citizen of the United States, residing in Hartford, in the county of Hartford and State of Connecticut, have invented certain new and useful Improvements in the Art of Forming Castings, of which the following is a specification.

This invention relates to improvements in the art of forming castings; and it has for its main object the formation of dense homogeneous castings having faces so perfectly formed that the castings will not need to be subjected to the usual operations of planing, turning, &c., but can be used with the bearing-surfaces in the condition in which they come from the mold and under conditions where exceptionally well-finished bearing-surfaces are required in order to permit the proper movements of parts upon one another and can be assembled with other parts even where the most minute projections of a complex casting have to be accurately fitted into correspondingly-minute indentations of a coacting part.

It is well known that in the ordinary methods of forming castings the latter when formed have a more or less open structure, the intermolecular spaces being filled with small bubbles of air and other gases or metallic vapors, while blow-holes of considerable size are of frequent occurrence. These objectionable results have been avoided somewhat by casting metal under pressure in molds that have not been exhausted or by pouring the metal into an open mold located in an exhausted chamber. The former of these methods results in a product more dense and somewhat more homogeneous than when the casting operation is carried out in the ordinary manner—that is, without applying pressure to the molten metal—but the air is still entangled in the molten metal and does not always escape before solidification of the latter begins, and as a result blow-holes are of common occurrence even in castings which are formed under pressure. When the metal is merely poured into a mold located in a vacuum-chamber, of course there are no blow-holes in the casting; but the metal is not condensed and compacted, because it has not been subjected to compression, and, moreover, unless it is the metal will not fill the mold thoroughly and will not reproduce perfectly the fine lines, projections, and indentations of an intricate pattern.

I have found that by producing a vacuum in the mold into which the metal is to be poured and then forcing the molten metal under pressure into the exhausted mold until the latter is completely filled the casting will be free from blow-holes and from bubbles of air and thermochemically-generated gases and metallic vapors and that the metal will be forced into all the spaces and corners of the mold, no matter how small they may be, so as to fill the same completely and form a casting corresponding in contour to the mold, every minute projection or indentation in which will be reproduced perfectly as an indentation or projection in the finished casting, no matter how complex the pattern to be reproduced may be. Moreover, the compressing action exerted upon the metal in the exhausted mold will result in compacting and condensing the metal most thoroughly and in forming a casting having a dense and homogeneous molecular structure throughout and presenting when fractured a finely-crystalline appearance.

The molten metal may be delivered to the mold in many ways, provided that great pressure is exerted against the walls of the mold at the instant the latter is filled; but I prefer to inject the metal after it has been set in motion in substantially the same way that a body of fluid is set in motion in an ordinary hydraulic ram, and when this is done a body of molten metal will be injected into the mold at such a high velocity that when the mold is filled the sudden stoppage of the flow at the moment of complete filling will result in the exertion upon the walls of an exhausted mold of a pressure so great that the metal will be forced into every portion of the mold and will be so throughly compressed, even in the finest spaces and corners of the mold, that the resulting projections and corners of the casting will be as perfectly condensed as the body portion thereof and the condensation of the metal will be so complete that the casting will not withdraw from the walls of the mold in solidifying, and hence there will be substantially no shrinkage for which to make allowance.

In order that the structure of a casting may be very finely crystalline, it is desirable to cool the molten metal as rapidly as it is possible to do so without weakening the resultant casting, and when the crystallization of the metal is checked by hastening the solidification thereof the tendency of the molten metal to form large crystals in cooling will be avoided. It is especially desirable to accomplish this result when the metal employed to form the casting is one which tends to crystallize quickly and form large crystals, as is the case, for example, with the metal antimony, which is one of the metals that will be used most frequently in forming castings by means of my improved process. When this metal especially is present, it is desirable to hasten the crystallization or else large crystals will form and the resultant product will not be perfectly homogeneous throughout.

Another feature of my process which I deem of importance is the subjection of the molten metal to additional compression after the metal has been forcibly injected into the mold and has filled the latter, the principal object of this additional step in the process being to compress the metal into a smaller space, and thus form a casting more condensed and having more metal within a given space than a casting which has not been subjected to this additional compressing action.

All of the various operations hereinbefore described and certain modifications thereof which will hereinafter be referred to, being in their nature elemental actions, may be performed without the aid of mechanism; but as it is desirable in practice to carry out each sequence of operations with the utmost precision I prefer to employ mechanism for more readily performing the several steps of the operation, and hence I have shown a mechanism suitable for this purpose, this mechanism being illustrated in the drawings accompanying this specification and forming part of the present application, and in which—

Figure 1 is a sectional side elevation of a casting-machine suitable for the purpose of practicing my improved process. Fig. 2 is an enlarged sectional detail illustrating the manner in which the metal is subjected to final compression after it has been forced into the mold; and Figs. 3 to 8, inclusive, are details illustrating certain cam movements, which will be hereinafter more particularly described.

Similar characters designate like parts in all the figures of the drawings.

In practicing my improved process there are many ways of exerting pressure upon the molten metal and upon the walls of the mold at the moment of complete filling and also many ways of exhausting a mold into which molten metal is to be delivered. I have found that all of the fine channels and sharp corners of a mold may be most perfectly filled when molten metal is forced thereinto in a solid column under high velocity and an exceedingly high pressure developed and immediately exerted directly against the walls of the mold. Ordinarily the metal will be set in motion before communication with the mold is established, and after said metal has begun to move under the influence of its own velocity, which may be developed in any suitable way, pressure will be applied to increase the force with which the metal will be injected into the mold, and at the proper time, which may be at the moment when the molten metal is moving with maximum velocity, communication with the mold may be established and every other outlet-opening closed practically simultaneously in order to prevent any loss of pressure.

For the purpose of injecting metal into a mold, such as O, in the manner just described I may make use of a melting-pot, such as M, having a well 6, communicating, by means of a passage 7, with a valve-chamber, such as 8, in which will be placed a valve, such as *v*, so constructed and operating in such a manner as to control two openings, such as 10 and 8′, respectively, at different points in the valve-chamber. Normally this valve will close the passage 10, and at such time of course the passage 8′ will be open and molten metal may flow from the main portion of the melting-pot into the valve-chamber; but these openings should be so located with respect to each other and to the cut-off faces of the valve that the passage 10 may be opened and that at 8′ closed practically simultaneously by a very slight movement of the valve. The valve *v* may be either freely movable within the valve-chamber to close the passage 8′ when pressure is exerted on the valve by the molten metal or else it may be held positively in the position shown in Fig. 1 by some suitable part, such as the rock-arm 35′, after there has been developed in the chamber 8 a pressure sufficient to shift the valve to close said passage 8′. Ordinarily pressure will be exerted upon the walls of the valve-chamber and upon the valve *v*, located therein, through the passage 7 and the well 6, in which latter a plunger, such as *p*, may work and may be operated in any suitable manner. When this plunger is forced down, the metal in the well 6, the passage 7, and the valve-chamber 8 will of course receive and transmit the pressure of the plunger, and as the passage 8′ is the only one then open a portion of the body of metal in said valve-chamber will seek an outlet through said passage 8′. Hence the pressure of the plunger will set up a circulation of the metal through the well 6, the passage 7, the valve-chamber 8, and the opening 8′ into the main body of metal in the melting-pot, and thus kinetic energy or *vis viva* of the molten metal will be developed. As the velocity of the circulating metal increases, the kinetic energy thereof, and hence the pressure exerted upon the walls of the valve-chamber and upon the valve v located therein, will also increase. If the valve v be mounted so as to be freely movable at this time to close the opening 8′, said valve will be shifted to the left, as seen in Fig. 1, as soon as the pressure in the valve-chamber is sufficient to overcome the inertia of the valve, the hydrostatic pressure of the main body of metal on the left-hand end of the valve, and the suction at the right-hand end of said valve if the mold be in its proper position at this time and is being or has been exhausted, as should be the case. These three forces tending to hold the valve v in position to keep the passage 10 closed will be sufficient to prevent the closure of the passage 8′ for an appreciable period of time, and during this period the metal will begin to circulate in the manner just described; but if no means other than these forces be utilized to hold the valve in its closed position the pressure in the valve-chamber will be sufficient to open the valve before the moving body of metal will have developed its maximum kinetic energy under the influence of the pressure that may be exerted by the plunger p. Hence if the valve be operated in this manner it will open very soon after the plunger begins to descend.

Now the force with which the molten metal is injected into the mold is dependent upon several factors, one of the most important of which is the velocity developed by the metal before the passage 8′ is closed. If the maximum velocity of this column of metal be developed, it will be evident that the energy exhibited by the stream which enters the mold will be very much greater than is the case when only a portion of such velocity is developed. Hence when it is desired to exert the maximum pressure upon the walls of the mold at the moment of complete filling of the same in order to force the metal most perfectly into every channel and corner of the mold-space the downward movement of the plunger p may be continued for a longer period of time than is required to develop within the chamber 8 a pressure sufficient to overcome the inertia of the valve, the hydrostatic pressure, and the suction of the exhausted mold-space. When the descent of the plunger is continued for the proper period of time, the maximum velocity of the molten metal will be developed, in the construction shown, and also the maximum ratio of the pressure upon the walls of the valve-chamber to the pressure upon the walls of the opening 8′, owing to the fact that as the metal is set in motion and continues to move with increased velocity through an outlet of smaller area than the inlet at which pressure is applied, this gradually-increasing velocity being due to the gradually-decreasing resistance opposed by the mass of metal in the body of the melting-pot to the efflux of metal through the opening 8′ after the inertia of that portion of the mass adjacent to said opening has been overcome and the adjacent molten metal gradually set in motion, the resistance of the metal in the valve-chamber to the force applied thereto by the plunger steadily increases, and hence the ratio of the pressures just referred to, and here also the kinetic energy developed, increases as the pressure of the plunger continues to be applied, this increase continuing until a maximum constant ratio is reached and a maximum constant velocity of flow through 8′. If this descent of the plunger be continued until the pressure in the valve-chamber and the velocity of the stream flowing through 8′ are very much greater than are required to shift the valve and close the passage 8′, it will be evident that this increase in the force that serves to shift the valve will be due chiefly to the increased velocity of the circulating metal as compared with the velocity of the same when the valve is shifted at the moment that the pressure in the valve-chamber becomes sufficient to accomplish this result.

Whether the velocity developed in the molten metal be just sufficient or be very much greater than is necessary to shift the valve the valve when shifted should move rapidly in order that the whole force of the moving body of metal may be transferred instantaneously from the opening 8′ to the opening 10 without appreciable loss and exerted upon the body of metal in the valve-chamber to project a solid column of metal violently into the mold O and into every corner thereof. The whole body of metal entering the mold is thus projected with tremendous force against a solid and immovable body, and as the velocity of the metal developed before the shifting of the valve and the additional or continued pressure of the plunger p are both exerted upon the moving column of metal to carry and force the same forward into the mold the resultant great final pressure exerted upon the walls of the mold at the moment the mold completely fills and the flow stops will drive or ram the metal into every corner of the mold and also condense the metal, and this final great pressure is only exerted against the walls of the mold when there is no air or gas present to cushion the blow and prevent the sudden stoppage of the flow. It should be understood, however, that it will not be necessary in all cases to develop the maximum velocity of the metal in the well 6, the passage 7, and the chamber 8 before closing the passage 8′, but that in many instances it will be sufficient to develop the velocity of the metal only to a point where there will be force sufficient to shift the valve. When the maximum velocity is developed, the rock-arm 35′ may be held up against the valve to keep the same closed until the column of metal is circulating with maximum speed, when said rock-arm should be withdrawn from the valve quickly in order that it may not retard the movement of the latter.

The step in my improved process which has just been described and which consists in forcing the metal under pressure into the mold is an important one; but if it were the only one relied upon the castings resulting from that operation alone would in nearly all cases be imperfect, for the reason that they would contain more or less occluded air and generated gases and metallic vapors in the intermolecular spaces and in the pockets or blow-holes of the completed casting. The exertion of pressure upon the molten metal to force the latter into the mold is not, however, the only means relied upon to form close-grained and perfect castings, for in nearly every case it will be found necessary to produce a vacuum within the mold in order to obtain the best results, and this is done in the present case. Hence if the molten metal be forced in the proper manner into an exhausted mold as there will be little or no air in the mold-space there will be little or none occluded by the metal of the casting. In order to produce the most perfect results, however, I deem it desirable to do something more than exhaust the mold, as the molten metal injected into the mold will almost always contain some air occluded thereby and more or less thermo-chemically-generated gases and metallic vapors, and these should all be eliminated from the metal in the mold-space before the casting cools. Obviously if the mold be merely exhausted and no vent be provided for the escape of these generated gases and vapors the latter will remain in the casting after the cooling of the latter, and the finished casting will be more open in structure and less homogeneous than when formed entirely of molten metal from which all other bodies have been removed. These gases and vapors can be removed most perfectly by applying suction to that body of metal which on cooling forms the finished casting, and in order to accomplish such removal not only will the metal be forced into the mold at one point in the mold-space and suction maintained at another point therein during the filling of the mold, but this suction should be maintained substantially constant throughout the filling of the mold in order that all of the foreign elements—viz., the residual atmosphere of the mold-space, the air which is occluded by the molten metal, the gases generated in the latter, and the metallic vapors—may be drawn from the molten metal, preferably into an evacuated space in which the suction is maintained substantially constant in order that the high degree of vacuum produced in the mold-space and in the evacuated space into which the atmosphere of the mold is exhausted may be maintained and the reduction of the degree of vacuum which would occur if the air, generated gases, and metallic vapors accumulated, owing to the removal of the suction, prevented. Of course the suction so produced and maintained at a different point in the mold-space from that at which the molten metal enters serves by reducing the resistance opposed to the column of metal injected into the mold to facilitate the entrance of the metal into every corner of the mold, and the effective pressure on the metal entering the mold-space is greater than it would be if any material resistance, even that of a highly-attenuated residual atmosphere such as that described, were opposed to such pressure.

In the present case I have shown a simple form of mold, such as O, having two mold-sections, such as *o* and *o'*, each of which may comprise two or more parts. In this case the mold-sections fit tightly together and are mounted on a carrier, such as H, in such a manner that the mold may be moved up and down in front of the discharge-opening 10 and also toward and from the latter and yet be held closed and pressed firmly against the face of the discharge-nozzle 12, as by means of a key or wedge, such as 20, when a casting is to be formed. In this case the carrier H is mounted so as to move up and down in a vertical guide, such as 25, and has a horizontal guide 26, in which the mold-sections are supported for horizontal movement. The mold-space will preferably be formed in a pair of plates or dies, such as 18 and 19, fitted tightly in the mold-sections *o* and *o'*, but removable therefrom. The mold-space formed between these sections when the mold is closed will preferably communicate, by means of fine channels, such as shown herein, with means for exhausting the mold-space, and these passages should of course be small enough to enable their walls to chill the metal before it flows very far, and thus prevent clogging of the connections through which the mold-space is exhausted. Here jointed tubes or pipes, such as 30, connected in such a manner as to permit the necessary vertical and horizontal movements of the mold, communicate with a pair of air-pumps, such as P and P'. These pumps have a pair of valves, such as 86 and 86', controlling communication between the mold-space and the pump-cylinders. In this construction the port of the valve 86 communicates directly with the piping 30, while that of the valve 86' may communicate with such piping through another tube, as 31.

The pump P should be so operated as to withdraw substantially all of the air from the mold-space before the passage 10 is opened to deliver metal into the mold, and the valve 86 should shut off communication between the cylinder of the pump P and the mold-space before communication is made with the cylinder of the pump P'. It will be evident that when the mold-space is exhausted in this manner the major portion of the atmosphere of a relatively small mold-space will be exhausted into a relatively great evacuated space and that thereafter the residual atmosphere of the mold (with such air, generated gases, and metallic vapors as may be present in the molten metal) will be exhausted into a second relatively great evacuated space, and an extremely high vacuum will be produced. The molten metal will be delivered into the mold, however, before the piston in the pump P′ reaches the limit of its exhaust-stroke, and hence a substantially constant suction on the metal entering the mold will be maintained by the plunger of the pump P′ through the pump-cylinder, the pipe 31, the piping 30, and the mold-passages leading to the mold-space, while communication between the pump P and such mold is shut off, and not only will all of the gases and vapors present be drawn out of the mold-space and into the cylinder of the pump P′, but the increase in the effective pressure on the molten metal entering the mold, which increase is due to the decreased resistance opposed by the almost perfect vacuum in the mold-space, will increase the condensing effect upon the metal as the latter is rammed against the walls of the mold and into all the corners of the mold-space.

As soon as the molten stream strikes the walls of the metallic dies or plates 18 and 19, between which the mold-space is formed, the molten metal will begin to chill, and this chilling action is intended to be hastened and the crystallization of the metal correspondingly checked by subjecting the mold to the action of a cooling medium, a stream or streams of cold water being preferably circulated continuously in contact with the dies or plates 18 and 19. Here water is taken from a suitable supply-pipe, such as 40, and is delivered through the branches of a **Y** in some suitable manner, as by a pair of tubes 41 and 41′, to channels in the mold-sections *o* and *o′*. Here the mold-sections have projecting nipples to receive the ends of the tubes 41 and 41′, and these nipples have passages therein communicating in this case with annular passages 21 and 21′ in the mold-sections, these passages in turn communicating with corresponding outlet-openings through which the water after circulating in contact with the dies 18 and 19 may be carried off, as by a funnel 22, having a waste-pipe 22′, leading therefrom. The flow of water through the supply-pipe 40 may be controlled by a valve, such as 42. It will be evident that as a stream of cold water will be constantly circulated in contact with each of the mold-sections the mold will be kept cool, and the molten metal delivered thereinto will be chilled and solidified very quickly after entering the mold-space. It will therefore be practically impossible for the metal in cooling to form large crystals, and the resultant solid casting will have a very close grain, and, moreover, the fine crystalline structure thereof will be uniform throughout.

In order to force the particles of the casting into the most intimate relation with one another, and thereby secure a casting of maximum density, I may also exert upon the metal in the mold after the latter has been filled and either during cooling or after the metal has subsantially completely solidified a compressing force separate and distinct from that which is used to force the metal into the mold and into the corners thereof. This additional compressing force may be applied at any time after partial cooling and before the metal after solidifying has become cold, and when applied while the casting is hot and yet has completely solidified will result in forging the casting into shape and converting the product from one having only the characteristics of cast metal into a casting having an extremely close grain and a structure less crystalline in character, the metal displaying in structure and characteristics the qualities possessed by wrought metal. This compressing force may be exerted in any suitable manner; but I prefer to make use of the valve *v* for this purpose. Here this valve has a cylindrical forward end which when the valve is completely closed—that is, when the forward or outer end thereof is in the plane of the meeting faces of the mold O and the nipple 12—will fill the outer cylindrical portion of the passage 10, but will not fill the tapering portion 10′ of such passage during the early stages of the closing movement of this valve. Hence it will be evident that when the valve begins to move to shut off the flow of molten metal into the mold it will not close communication between the valve-chamber and the mold-space until it reaches the forward end of the tapered portion 10′ of the passage 10, and that when it does reach this point the small body of metal in the cylindrical portion of the opening 10 will be forced forward bodily and will be added to the metal in the completely-filled mold-space, the result being that the metal in the mold will be condensed into a smaller bulk, owing to the addition thereto of this small body of metal in the forward cylindrical portion of the passage 10, the metal so forced into the mold-space by this additional compressing action being sufficient to effect the condensation of the largest quantity of metal into the smallest possible bulk and the consequent prevention of shrinkage of the casting.

The pumps P and P′ (including the valves 86 and 86′) and the valve *v*, as well as the supply of water to cool the mold, may be controlled by hand; but I prefer to actuate the valve *v*, the pump-pistons, and the valves 86 and 86′ mechanically—as, for example, from a shaft 2 by cams and springs in the manner shown herein. In this case the plunger *p* is operated from the shaft 2 by means of a cam, such as 50, having a single cam-rim projecting therefrom, on the inside of which rim an antifriction-roll, such as 51′, may travel, this roll in the present case being carried by a lever 51, pivoted at 52 to a fixed point and having its free end pivoted in turn to a connecting-rod, such as 53, the upper end of which is secured to a lever 54, pivoted between its ends on the upper side of the melting-pot and connected in turn at its free end to the plunger p. A spring, such as 51″, may be employed to force the plunger down at the proper time, while the cam-rim 50′ will serve to raise the plunger.

The valve v may be operated by a cam 55, secured to the shaft 2, and having a cam-groove 55′, in which may travel an antifriction-roll 56′, secured to a lever 56, pivoted at one end at a fixed point 52 on the framework and at its other end to a connecting-rod 57, secured at its upper end to the long arm 35″ of an angle-lever of which the rock-arm 35′ may form the short arm, this angle-lever being secured to a rock-shaft, such as 35. The cam-groove 55′ is so shaped as to permit a quick movement of the valve v in either direction.

The piston 80 of the pump P will be operated by a cam, such as 60, also secured to the shaft 2 and having a cam-groove 60′, in which may travel an antifriction-roll 61′, secured to a lever 61, also pivoted at one end at a fixed point on the framework and pivoted at its other end to a link 62, connected to the lower end of the piston-rod 81. In a substantially similar manner the piston 80′ of the pump P′ may be controlled in its movements by a cam 65, having a cam-groove 65′, in which may work an antifriction-roll 66′, carried by a lever 66, pivoted at one end at a fixed point on the frame and at its other end to a link 67, connected to the piston-rod 81′.

The valve 86 may be operated from the shaft 2 by means of a cam, such as 70, which may coact with an antifriction-roll 71′, carried by a lever 71, pivoted at one end to a fixed support and pivoted between its ends to a connecting-rod, such as 72, the upper end of which is pivoted in turn to a lever 73, supported on the pump P, and preferably forked at its end to engage an enlarged portion or projection on the stem of the valve 86, a suitable spring, such as 87, normally tending to hold said valve closed. The valve 86′ may be operated in substantially the same manner from the shaft 2 by means of a cam, such as 75, coacting with an antifriction-roll 76′ on a lever 76, pivoted at a fixed point on the framework, and also having pivoted thereto between its ends a connecting-rod 77, the upper end of which is pivoted to a lever 78 on the pump P′, this lever operating the valve 86′ in substantially the same way that the lever 73 operates the valve 86, and a spring 87′ normally tending to hold the valve 86′ closed.

It being understood that the valve v is closed and that the mold is in a position to receive molten metal to form a casting, the shaft 2 may be rotated either by hand or power in the direction of the arrow, as seen in Fig. 1, whereupon the piston 80, which is not quite at a limit of its downward stroke, will be carried to its lowermost position by the cam 60, this position being indicated by the line a, Fig. 5, and immediately thereafter the valve 86, which during the descent of the plunger 80 is open in order to permit the partial exhaustion of the mold-space through the connections to the cylinder of the pump P, will be closed by the movement of the cam 70 from b to c, Fig. 7, and communication between the cylinder and said pump and the mold-space will thus be shut off completely, leaving in the mold-space only the residual atmosphere to be exhausted by the second pump P′. Immediately after the valve 86 is closed by the cam 70 the valve 86′ is opened by the cam 75 moving from d to e, Fig. 8, and communication is established between the cylinder of the pump P′ and the mold-space. The cylinder of the pump P′ is preferably larger than that of the pump P, and the residual atmosphere of the mold-space may be exhausted into a space having the same cubic measure as the cylinder-space of the pump P before the piston 80′ is at the limit of its downward movement, and the remainder of the descent of the piston 80′ may be utilized to maintain a constant suction upon the mold-space while the molten metal is being delivered thereinto. In the construction shown the cam 65 moves from the position shown at f, Fig. 6, and begins to draw down the piston 80′, and at the same time (see line f, Fig. 3) the spring 51″ begins to raise the lever 51 and force down the plunger p. When the piston 80′ has accomplished about two-thirds of its downward stroke (see line g, Fig. 6) and the plunger p about one-half of its movement in the same direction (see line g, Fig. 3) and the metal in the well 6, the passage 7, and the chamber 8 has developed the desired velocity, the cam 55 moves from position g to position h (see Fig. 4) and through its connections withdraws the rock-arm 35′ quickly from the valve v and the pressure in the valve-chamber immediately shifts said valve, thus closing the passage 8′ and opening that at 10. The plunger p and the piston 80′ will continue to descend, the former exerting its pressure upon the molten metal to force the metal into the mold at one point and the latter maintaining a constant suction upon the mold-space at another point throughout the filling of the mold, the downward movement of the latter during this period being in this case about one-third of its stroke and the plunger reaching the limit of this movement somewhat in advance of the piston, as shown by lines j and l. (See Figs. 3 and 6.) About this time the cam 55 on the completion of the filling of the mold shifts the valve v again suddenly (see lines i and k, Fig. 4) and closes the opening 10, thus cutting off the supply to the filled mold and at the same time compressing the small body of metal in the cylindrical portion of the passage 10 into the mold-space. After the valve v has closed the cams 60 and 65 move from the position shown at l and begin to raise the pistons 80 and 80′ and at the same time the valve 86′ is closed by its cam 75 (see lines l and m, Fig. 8) for shutting off communication between the cylinder of the pump P′ and the mold-space.

During the ascent of these pistons or before they begin to descend again the mold should be lowered, withdrawn from the discharge-nozzle 12, opened, and the casting removed, after which the mold may be raised again, advanced to its working position, and closed ready for another operation. Of course the supply of water may be turned off and on again, if desired, after the formation of each casting and before making another one by properly manipulating the valve 42. After the mold is in its working position again and the pistons are at the limit of their upward movements (see line *n*, Figs. 5 and 6) the cam-rim 50′ (see line *n*, Fig. 3) may begin to raise the plunger *p*, and after the latter has reached the limit of its upward movement (see line *r*, Fig. 3) the cam 70 (see lines *s* and *t*, Fig. 7) may operate to open the valve 86 again, whereupon the cam 60 will begin to carry down the plunger 80 (see line *t*, Fig. 5) to effect the partial exhaustion of the air from the mold-space and from the communicating passages in the piping, and when this plunger 80 reaches the position shown in Fig. 1 the parts will be in position to go through a new cycle of operations.

Having described my invention, I claim—

1. That improvement in the art of making a casting which consists in projecting the molten metal into and against the walls of the mold by a ram-like action produced by first setting in motion a body of molten metal in a direction other than into the mold, and afterward, subsequent to the establishment of such flow, instantly diverting the direction of flow of the entire body of moving metal into the mold, whereby the kinetic energy of the entire mass of moving metal becomes effective to increase the impact of the entering metal.

2. That improvement in the art of making a casting, which consists in first exhausting the mold and in then projecting the molten metal into and against the walls of the exhausted mold by a ram-like action produced by first setting in motion a body of molten metal in a direction other than into the mold, and then, subsequent to the establishment of such flow, instantly diverting the direction of flow of the entire body of moving metal into the mold, whereby the kinetic energy of the entire mass of moving metal becomes effective to increase the impact of the entering metal.

3. That improvement in the art of making a casting which consists in projecting the molten metal into and against the walls of the mold by a ram-like action produced by maintaining a closing pressure upon the valve which controls the ejection of the molten metal and during this time establishing a movement in a body thereof in a direction other than into the mold, and afterward, subsequent to the establishment of such flow, suddenly releasing the pressure on the valve, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold, and in continuing the application of the force by which such movement in the body of metal is accomplished during the open position of the valve.

4. That improvement in the art of making a casting which consists in projecting the molten metal into and against the walls of the mold by a ram-like action produced by maintaining a closing pressure upon the valve which controls the ejection of the molten metal and during this time establishing a movement in a body thereof in a direction other than into the mold, and afterward, subsequent to the establishment of such flow, suddenly releasing the pressure on the valve, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold, and in continuing the application of the force by which such movement in the body of metal is accomplished, during the open position of the valve, and in cooling the casting during the setting of the metal.

5. That improvement in the art of making a casting which consists in projecting the molten metal into and against the walls of the mold by a ram-like action produced by maintaining a closing pressure upon the valve which controls the ejection of the molten metal and during this time establishing a movement in a body thereof in a direction other than into the mold, and afterward, subsequent to the establishment of such flow, suddenly releasing the pressure on the valve, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold, and in continuing the application of the force by which such movement in the body of metal is accomplished, during the open position of the valve, and also continuing the pressure on the casting and cooling the same during the setting of the metal.

6. That improvement in the art of making a casting which consists in operating the pistons of air-pumps communicating with the mold and opening the valve in the passage-way leading from one pump to the mold, in then closing this valve and opening the valve in the passage-way leading from another air-pump to the mold, in projecting the molten metal into and against the walls of the exhausted mold by a ram-like action produced by first setting in motion a body of molten metal in a direction other than into the mold, and maintaining a pressure during this operation on the valve controlling the injection of molten metal, and finally, after said second-mentioned valve in the passage-way leading to the second pump has been opened, suddenly releasing the pressure on said metal-controlling valve, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold.

7. That improvement in the art of making a

casting, which consists in first exhausting the mold, in then projecting the molten metal into and against the walls of the exhausted mold by a ram-like action produced by first setting in motion a body of molten metal in a direction other than into the mold, and after the mold is exhausted and such flow inaugurated, instantly diverting the direction of flow of the entire body of moving metal into the mold, and in cooling the casting during the setting of the metal.

8. That improvement in the art of making a casting which consists in operating the pistons of air-pumps communicating with the mold and opening the valve in the passage-way leading from one pump to the mold, and then closing this valve and opening the valve in the passage-way leading from another air-pump to the mold and in projecting the molten metal into and against the walls of the exhausted mold by a ram-like action produced by first setting in motion a body of molten metal in a direction other than into the mold and during this operation maintaining a pressure on the valve controlling the injection of molten metal and then suddenly releasing the pressure on said metal-controlling valve after the second-mentioned valve in the passage-way leading to the second pump has been opened, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold and in continuing the application of the force which sets said body of molten metal in motion after said metal-controlling valve has been opened.

9. That improvement in the art of making a casting which consists in operating the pistons of air-pumps communicating with the mold and opening the valve in the passage-way leading from one pump to the mold, in then closing this valve and opening the valve in the passage-way leading from another air-pump in the mold, in setting in motion a body of molten metal in a direction other than into the mold, in maintaining a pressure on the valve controlling the injection of molten metal during this operation, in suddenly releasing the pressure on said metal-controlling valve after the second-mentioned valve in the passage-way leading to the second pump has been opened, thereby permitting the instantaneous diversion of the direction of flow of the entire body of moving metal into the mold, and in continuing a pressure on the casting during the setting of the metal.

10. That improvement in the art of making a casting, which consists in first exhausting the mold, in then projecting the molten metal into and against the walls of the exhausted mold by a ram-like action produced by establishing a movement in a body of molten metal in a direction other than into the mold, and then, after the mold is exhausted and such flow is inaugurated, instantly diverting the direction of flow of the entire body of moving metal into the mold, and in cooling the casting and maintaining a pressure thereon during the setting of the metal.

CURTIS H. VEEDER.

Witnesses:
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HENRY BISSELL.