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LIGHT METAL PUMP

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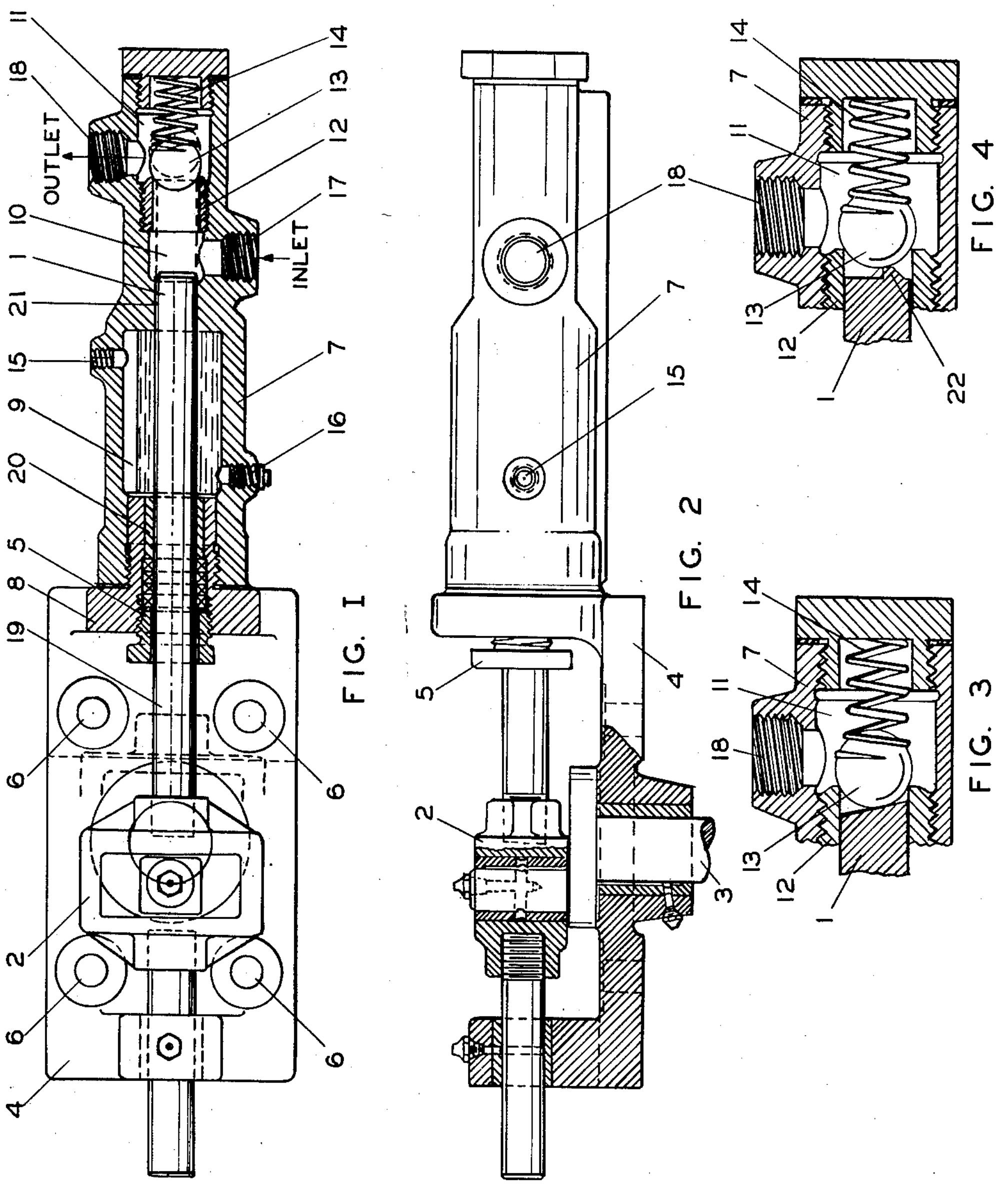

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LIGHT METAL PUMP

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This invention relates to a means for pumping molten metal and more particularly for pumping molten sodium.

This is a continuation-in-part of my copending application for U. S. Letters Patent, Serial No. 78,051, filed February 24, 1949, and now abandoned.

At temperatures of 100° C. and higher, sodium is a low viscosity liquid which readily flows through heated pipe lines and in the pure state generally can be handled like any low viscosity liquid. However, the ordinary methods for pumping liquids have not been adaptable for pumping liquid sodium. The metal is very readily oxidized forming a solid oxide insoluble in the molten metal. Further, it is commonly contaminated with oxide and with calcium which at certain temperatures tends to precipitate out.

Solid impurities such as oxide and calcium in the molten sodium adhere to metal surfaces and eventually build up layers which fill the spaces between moving parts of conventional pumps. For example, a gear pump, used to pump commercial grade molten sodium soon becomes inoperative because of the accumulation of solids between the gear teeth. The pressure of the gear teeth on such solids forms compact layers that cannot be readily removed except by chemical action. Similarly, deposition of such solids building up on a valve seat after a time renders the valve inoperative. Further, the sodium enters the conventional packing gland and there oxidizing causes the packing to fail. The solids, thrown out of suspension by centrifugal force, fill the clearance when centrifugal type pumps are used.

As a consequence of the difficulties noted, ordinary pumping means have not been found suitable for pumping molten sodium. Instead, it has been necessary to place sodum in a reservoir and apply the pressure of an inert gas such as nitrogen to force the sodium out of an opening in the reservoir. However, since solids collect around orifices when undirectional flow is employed, metering is found to be inaccurate. Heretofore the only satisfactory rate measurement has been attained by an intermittent and expensive system of weighing.

Similar problems are encountered in pumping various slurries or mixtures of solids and liquids, for example, aqueous suspensions of inorganic substances. In pumping such materials, the deposition or settling out of solid particles often interferes with satisfactory operations of conventional pumping mechanisms and limits the maximum allowable solids content of slurries that can be pumped.

An object of the present invention is to provide a convenient means for pumping molten light metals such as sodium, potassium and the like. A further object is to provide a pump which does not require an inlet valve. Another object is to provide a pump which will serve to accurately and continuously meter the liquid delivered. A further object is provision of means for pumping aqueous slurries of inorganic substances and other solid-liquid mixtures. Still other objects will be apparent from the following description of the invention.

The appended drawings are sectional and plan views of a pump in accordance with the present invention. Figure 1 is a vertical section of which Figure 2 is a plan view. Figures 3 and 4 are cross-sectional details illustrating modifications of the pump.

An essential and important feature of my invention is to provide in place of the conventional inlet port, fitted with inlet check-valve, an inlet chamber communicating with the cylinder of a reciprocating or plunger type pump. The cylinder is adjacent to and opens on its entire circumference into the chamber, the cross-sectional area of the inlet chamber being larger than that of the cylinder. A reciprocating piston, on its forward stroke, passes from within the inlet chamber and thence enters the cylinder, trapping liquid metal therein. The cylinder, at its outlet end, is provided with a ball check-valve preventing backward flow of liquid. On the reverse stroke the piston is retracted completely from the cylinder into the inlet chamber. As the piston makes a close fit with the cylinder, the reverse stroke of the piston creates a vacuum in the cylinder; and when the piston is withdrawn from the cylinder, the vacuum therein causes liquid in the inlet chamber to suddenly rush into and fill the cylinder.

Satisfactory operation of the pump is evidenced by an audible "water hammer" knock as the liquid suddenly fills the evacuated space. The inrushing column of liquid strikes against the ballcheck and the tension on the latter may be so adjusted that the blow opens the check-valve momentarily, permitting some liquid to pass through the check-valve due to the momentum of the liquid. The forward movement of the piston through the chamber then displaces some of the liquid from the chamber, causing a momentary back-flow in the inlet feed line. When the piston enters the cylinder, the liquid therein is trapped and by the continued forward movement of the piston is forced on through the cylinder. When the piston next is retracted, the cylinder is again filled with liquid as described above.

Another important feature of the invention is that the length of the piston stroke is such that the end of the piston strikes and unseats the ball-check at the end of the forward stroke. Then, as the piston begins its backward stroke, it causes a slight, momentary reverse flow of liquid through the check-valve until the ball is again seated. The reciprocation of the piston is sufficiently rapid that the ball-check is struck with a succession of sharp blows, alternately by the piston and by the column of liquid rushing in to fill the vacuum.

One type of pump, according to the present invention, is illustrated by Figures 1 and 2. Piston **1** is reciprocated by eccentric mechanism **2**, which is actuated by the rotary movement of shaft **3**, in turn rotated by any suitable mechanical means as, for example, a pulley or gears attached to a motor shaft. The eccentric mechanism is mounted on a frame **4**, which may be bolted to any suitable support by bolts fastened through holes **6**. Pump housing **7**, screwed onto boss **8** of frame **4**, is divided into three chambers: oil reservoir **9**, inlet or intake chamber **10**, and outlet or discharge chamber **11**. Hollow pump cylinder **12** extends between chambers **10** and **11**, each of which has a larger cross-sectional area than that of the cylinder, with one end of the cylinder opening into each chamber but penetrating neither. In the preferred form, as shown in the drawing, cylinder **12** is an insert or sleeve screwed in place and preferably made of a hardened steel. A ball check valve is located in chamber **11**, consisting of a steel ball **13**, held in place against the end of cylinder **12** by spring **14**. Oil reservoir **9** is separated from **10** by piston passageway **21** and is provided with ports **15** and **16**, which may be closed by suitable plugs.

Inlet chamber 10 and outlet chamber 11 are provided with suitable inlet and outlet ports 17 and 18, respectively. Suitable pipes connected to the inlet and outlet ports may be provided as desired, a pipe or other conduit being provided to lead molten metal from a source of supply into inlet chamber 10.

The piston rod 19 extends successively through packing gland 5 and bearing sleeve 20 in boss 8 of frame 4, oil reservoir 9, and passageway 21 leading from reservoir 9 into inlet chamber 10. The rod makes a sliding fit with sleeve 20 and passageway 21.

Piston 1 and piston rod 19, as shown in the drawing, comprise a single cylindrical rod, one end of which serves as piston and makes a sliding fit with cylinder 12, the inside diameter of the cylinder being approximately equal to the inside diameter of sleeve 20 and passageway 21. However, if desired, the piston and piston rod may have different diameters.

Eccentric 2 is adapted to reciprocally move piston 1 from a point in chamber 10 near the side thereof opposite cylinder 12, to a point within the cylinder sufficiently far to strike and upseat ball 13, as shown by the dotted lines.

In operation, the inlet port 17 is connected with a reservoir or other suitable source of supply of molten sodium, e. g., by means of a heated pipe line. The liquid entering port 17 preferably is maintained under a slight pressure, e. g., as provided by gravity flow from a reservoir or by means of a low nitrogen pressure on the liquid metal in a supply reservoir. The piston 1 is then actuated reciprocally at a suitable speed, e. g., from 10 to 300 strokes per minute. When piston 1 is in its most retracted position, inlet chamber 10 and cylinder 12 will be filled with the liquid metal. As the piston moves forward through chamber 10 it displaces metal therein, causing a backward surge through the port 17 and through the supply conduit. As the piston, in its forward movement, enters the cylinder 12, it traps the liquid therein and forces it past the check-valve 13 and thence into chamber 11 and out the outlet port 18. Nearing the end of its stroke, the piston strikes and unseats ball 13, which permits a small amount of back-flow past the ball until the latter again becomes seated against the end of cylinder 12. On its reverse stroke, the piston creates a vacuum in cylinder 12; and when the piston is withdrawn from the cylinder, the vacuum causes a sudden inrush of liquid into the cylilnder, so that the inrushing column of liquid strikes ball 13 with an audible knock or click. Simultaneously, there is a corresponding sudden insurge of liquid in the supply line leading into chamber 10. Unless spring 14 is sufficiently strong, the inrushing column of liquid striking the ball will momentarily unseat it and a portion of the liquid thus will flow into chamber 11 on the back stroke of the piston.

The arrangement of parts and the above described action prevents solids occurring in the molten sodium, particularly calcium and oxides, from settling out and building up on both stationary and moving parts. The continual forward and back surges of the liquid keep solid particles dispersed and in suspension. Any solids adhering to the piston are scraped off by the edge of the cylinder as the piston moves forward, and are mixed with the surging liquid metal during succeeding strokes. Rapid liquid flow prevents collection of solids on the seat of the ball-check or such are dislodged by the bouncing motion of the ball 13 caused by the alternate strokes against it by the piston and the "water hammer" effect. Adherence of solids which prevent proper seating of the ball cause it to rotate when struck by the piston, as the latter then strikes it off center. Such rotation causes a different part of the ball surface to be seated against the end of the cylinder, thus correcting improper seating caused by adherence of solids to the ball. Any tendency of the ball to stick in its seat is readily overcome by the power of the forward stroke as the force that may be applied is limited only by the structural strength of the assembly.

In the modifications of my invention, illustrated by Figures 3 and 4 of the drawings, the end of the piston is provided with means for positvely rotating the ball when the latter is struck by the piston. As illustrated by Figure 3, the end of the piston is beveled, so that the surface striking the ball is at an angle of about 75° to 85° with the axis of the piston. In the modification illustrated by Figure 4, the piston is provided with projection 22, which is offset from the axis of the piston. In either case, the ball is struck off center, causing it to rotate, and hence presenting a fresh surface to the end of the cylinder on reseating.

The length of the piston stroke is such that the piston strikes the ball and unseats it a small but definite distance. The distance the ball is removed from its seat depends not only on the length of the piston stroke, but also to some extent on the velocity of the piston when striking the ball, the mass of the ball and the tension on the spring which is adapted to force the ball into its seat. These factors should be so adjusted that the ball is unseated for a distance not less than about 2.5% nor more than about 10% of the inside diameter of the cylinder, preferably 5 to 10% of said diameter. To accomplish this, at a piston reciprocation rate in the range of 10 to 300 strokes per minute, the length of the piston stroke should be such that the piston over travels forward (i. e., moves forward after striking the ball) a distance of about 5 to 10% of the cylinder inside diameter. The tension exerted by the spring arranged to force the ball into its seat generally should be not less than about 50 times the weight of the ball, nor more than about 200 times that value. I generally prefer to operate the piston at 100 to 200 strokes per minute, with a forward overtravel of 6 to 10% of the cylinder inside diameter. Under these conditions I prefer to employ a ball of solid steel and a spring having a tension of 50 to 200 times the weight of the ball.

The preferred tension of the spring will vary, depending on the purpose for which the pump is used. If the pump is used to deliver accurately measured amounts of molten sodium (i. e., the same amount for each stroke of the piston, so that the number of strokes will be an accurate measure of the metal delivered), a strong spring is required, sufficient to overcome the "water hammer" effect of the metal rushing into the cylinder at the end of each back stroke. With a spring of such strength, the forward movement of the ball will not substantially exceed the over travel distance of the piston. The force of the "water hammer" effect depends on known or measurable factors, including the length of the cylinder, the rate at which the cylinder is opened (speed of pump) the viscosity of the liquid, the column height of liquid from the source of supply to the cylinder, the distance between pump and supply, the number and sharpness of pipe bends (resistance to flow) and the specific gravity of the liquid, and may be determined by known methods of calculation.

As an example, a pump constructed according to the appended drawings was used to pump liquid sodium to a reaction vessel and it was desired to utilize the pump to meter the sodium delivered. The pump cylinder was 1.5 inches long by 1.25 inches inside diameter and the ball diameter was 1.5 inches. The piston had a forward over travel of 0.125 inch and was operated at 110 strokes per minute. The spring had a tension of about 15 pounds. Calculations based on the internal volume of the cylinder and rate of piston reciprocation, neglecting the "water hammer" effect, showed the pump to have a maximum capacity of about 400 pounds per hour. Actually, however, the pump delivered about 500 pounds per hour of liquid sodium; and the amount delivered varied with discharge back pressure. The spring then was replaced by another having a tension of 45 to 50 pounds, which was greater than the calculated force of the "water hammer" effect. Thereafter, the pump consistently delivered 400 pounds per hour of molten sodium with an accuracy of ±2% and was successfully used to deliver measured amounts of sodium to the reaction vessel, despite considerable variation in back pressure.

When a relatively weak spring is employed, the "water hammer" effect unseats the ball-check and forces a considerable amount of liquid through the cylinder before the piston begins its forward stroke. This results, as shown by the above example, in an apparent efficiency of more than 100%. This is desirable in those cases where it is not desired to employ the pump to accurately measure the amount delivered.

The oil reservoir **9** is an important feature of my invention, as it protects the packing and packing gland **5** from contact with the liquid metal. As that section of the piston rod reciprocating between the sodium-filled inlet chamber and the oil chamber passes through **21**, the rod surface is wet by a film of oil. This film generally prevents the sodium metal contacting and wetting the rod surface and hence prevents sodium transfer from the inlet chamber to the oil chamber. Should the oil film be broken for any reason, the adhesion of the sodium to the steel may carry a film of sodium into the oil chamber. Any liquid sodium which may escape past the piston or cling to it may fall to the bottom of the oil reservoir. Preferably, the length of oil chamber **9** is greater than the length of the piston stroke, so that that portion of the piston rod entering the inlet chamber **10** will not contact sleeve **20** on the reverse stroke. Hence, any liquid (as sodium) which clings to the piston rod will not be brought into sleeve **20**. This avoids any possibility of transferring sodium into the packing in packing gland **5**. If desired, the oil in oil reservoir **9** may be cooled, to solidify any sodium entering therein. This, however, is not essential; and so long as the amount of sodium in reservoir **9** remains small, it will be kept from contact with the packing gland. If a liquid level gauge, or overflow is placed on the reservoir, e. g., at opening **15**, the amount of sodium entering will be indicated by the oil it displaces. If excessive amounts of sodium enter, it may be removed, e. g., through opening **16**. The amount of sodium entering reservoir **9** will depend on the fit of the piston rod in passageway **21**.

It will be understood that heat must be applied, or conserved by lagging, to maintain the metal in a molten state during its passage through the pump. Any conventional means may be utilized for heating, such as circulation of a hot fluid in a jacket placed around the pump, heating with a flame or by electric heaters fastened to the apparatus. Conduits leading metal to and from the pump may be similarly heated. For pumping sodium a temperature of 100–110° C. is adequate, but higher temperatures, e. g., up to 150° C. may be employed, if desired.

It will be noted that in my invention as shown by the drawings, sodium is forced into a cylinder by the stroke of a piston and the piston passes through an inlet chamber into which the inlet end of the cylinder opens, which chamber has a larger cross-sectional area than that of the cylinder. In the device in Figs. 1 and 2 the inlet chamber is chamber **10** in the pump housing **7**. The movement of the piston through the inlet chamber causes a back surge of the metal from the inlet chamber until the piston enters the cylinder. In the continuing forward stroke of the piston, metal which is trapped within the cylinder is forced forward. Backward movement of the metal into the cylinder is prevented by means of the ball-check valve.

Various other modifications of my invention will be apparent to a skilled mechanic. For example, instead of the simple rod piston shown in the drawings, a piston actuated by a piston rod of smaller or larger diameter may be utilized. The length of cylinder **12** and the stroke of the piston may be varied considerably, provided that on its reverse stroke the piston clears the open end of the cylinder sufficiently to permit metal to rush in and the piston strikes and unseats the ball-check on the forward stroke. It is preferred, however, to employ a piston stroke from about 1.25 to 4 inches, and to operate at 100 to 300 strokes per minute.

The size of the oil reservoir **9** may be varied as desired, provided it is sufficiently large to accommodate whatever metal enters it. Generally it should have a cross-sectional area at least twice that of the piston rod extending through it. Any liquid chemically inert to the molten metal may be used in reservoir **9**, e. g., kerosene, or various hydrocarbon oils. I prefer to use a lubricating oil of the type commonly used in the crankcase of a gasoline motor.

My herein described pump is also useful for pumping and metering a variety of solid-liquid mixtures other than molten metals. For example, I have used my pump successfully to pump a mixture of finely divided zinc cyanide and water containing more than 47% by weight of the solid cyanide. In a plant operation, this slurry had been pumped with a conventional gear pump, modified by cutting recesses between the teeth of the gears. This modification, resulting in a loose fit between the gears, was necessary for continued operation, as otherwise the solid cyanide would become packed into the gears between the teeth and quickly render the pump inoperable. Even with this modification, the gear pump would not handle slurries containing more than about 30% by weight of zinc cyanide; and about once a month accumulated solids packed in the gears necessitated a shut-down to clean the pump. Also, whereas a gear pump of the size and kind employed normally is powered by a 1 H. P. motor, a 10 H. P. motor was required to maintain operation.

To test my pump for handling such slurries, I connected a pump constructed according to Figs. 1 and 2 of the appended drawings with a container, utilizing standard ¾-inch pipes. The outlet pipe was arranged to pump the slurry back into the same container. The pump was operated approximately 8 hours per day over a period of 14 days. The slurry pumped initially contained 26.2% by weight of zinc cyanide; and periodically dry zinc cyanide was added to the slurry. Samples of slurry were taken from the pump discharge line and the solids content determined. At the end of 4 days' operation the slurry contained 45.5% by weight of solids and the pump operated satisfactorily. After standing 16 hours loaded with the 45.5% slurry, the pump was started with no difficulty. The solids content then was increased to 47.1% by further zinc cyanide addition and satisfactory operation continued for 10 days further, with no difficulty in operation on the 10th day. At 47% solids, the mixture had the consistency of stiff putty.

While operating on the 47% mixture, the metering accuracy of the pump was determined by collecting and weighing the effluent discharged over measured time intervals. This showed a metering accuracy of ±0.5%, except for one test which varied 0.84% from the average.

My invention is useful for transporting molten sodium and particularly for feeding it in processes where it is used as a chemical reagent. Thus it may be used to feed sodium at a controlled rate into a reactor for organic chemical manufacture, without exposing the metal or the reaction mixture to the air. It is useful also for forcing molten sodium into baths of molten metals such as steel, copper, or the like, to refine such molten metals. It is useful as a metering device for controlling the feed rates of such molten metals as well as chemical slurries having high solid content. Such slurries heretofore have been difficult to meter continuously, especially at solids concentration of 40% and higher. Such slurries of more than 40% solids content are readily pumped and accurately metered by means of my herein described pump.

I claim:

1. A pump for imparting substantially unidirectional flow to molten sodium and other liquids containing agglomerated solids comprising, in combination: a housing; a reciprocable piston in said housing; means in spaced

relation with said housing to reciprocate the piston; intake and discharge chambers fixed within the housing along the longitudinal axis of the piston, the intake chamber being traversed thereby; separate fluid communication means through the housing into each of said chambers; a cylinder separating the intake and discharge chambers but avoiding penetration into either; a fluid passage of predetermined volume through the cylinder, the fluid passage having an entrance into the intake chamber and an exit into the discharge chamber, each chamber opening directly into the entire circumference of the passage, the piston closing the passage during the forward stroke of its reciprocation and thereby trapping a predetermined quantity of liquid in the passage and at least partially traversing the passage and forcing trapped liquid into the discharge chamber; and a ball check valve opened when the piston closes the passage to deliver to the discharge chamber liquid trapped in the passage but closed on the backward stroke to prevent substantial backflow of the liquid; said valve comprising a ball seated in the exit of the fluid passage on the backward stroke of the piston but unseated on the forward stroke and turning freely when solid particles adhere to and displace the balance of forces thereon, and resilient means biasing the ball against the forces generated by the forward stroke of the piston and positioned to avoid obstructing the fluid communication means from the discharge chamber through the housing and thereby avoid obstructing the flow of agglomerated solids.

2. The invention of claim 1 in which the piston carries means for engaging and positively rotating the ball on its forward stroke.

3. The invention of claim 2 in which the means for engaging and positively rotating the ball is a projection which strikes the ball off center.

4. The invention of claim 2 in which the means for engaging and positively rotating the ball is a bevel which strikes the ball off center.

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