AIP | Review of Scientific Instruments

Compact, magnetic recirculating pump for widerange temperature and pressure operation

H. Mansoorian, E. F. Capps, H. L. Gielen, P. T. Eubank, and K. R. Hall

Citation: Rev. Sci. Instrum. **46**, 1350 (1975); doi: 10.1063/1.1134071

View online: http://dx.doi.org/10.1063/1.1134071

View Table of Contents: http://rsi.aip.org/resource/1/RSINAK/v46/i10

Published by the AIP Publishing LLC.

Compact, magnetic recirculating pump for wide-range temperature and pressure operation*

H. Mansoorian, E. F. Capps, H. L. Gielen, P. T. Eubank, and K. R. Hall

Chemical Engineering Department, Texas A&M University, College Station, Texas 77843

(Received 7 March 1975; in final form, 6 June 1975)

This article presents a design for a simple, inexpensive magnetic recirculating pump. It consists of a piston and cylinder with a separate check valve which can be either normally open or normally closed. The interior offers minimal surface area for adsorption and, with proper dimensioning and material selection, the pump can operate over wide pressure and temperature ranges. A prototype model with cylinder dimensions 22.2 mm o.d.×15.9 mm i.d. ×6.35 cm circulates at 26 $\mathrm{cm}^3/\mathrm{sec}$ (10 cm of H_2O differential pressure). The dimensions of the prototype allow an operable pressure range of $0 \leq P \leq 703$ kg cm^{-2} at room temperature. The temperature range is $100 \leq T \leq 500$ K.

Experiments involving mixtures often require a mechanical device to circulate fluids. The device might make the mixture, speed equilibrium, establish a flow pattern, or cause combinations of these effects. In research applications, the device should withstand extreme environments, present a minimal surface for adsorption, and possess minimal dead volume.

We propose a magnetic pump and present the schematic in Fig. 1. The pump is simply a piston in a cylinder with a check valve. Magnetic coils lift both the pump piston and the check ball. We will describe the specific pump we have already constructed, but the dimensions can be dictated by the application. For our work, we required a small device with maximum capacity. Others have designed recirculating pumps for similar applications.[1–8] While all of these designs have specific merit, our requirements were sufficiently different to dictate a new instrument. We also feel that our design is basically simpler and less expensive to construct.

Our cylinder is a section of standard 304 stainless-steel (paramagnetic) tubing 15.9 mm i.d.×22.4 mm o.d.×6.35 cm. The inside surface has a mirror finish to minimize adsorption and friction. The lower end cap is 304 stainless steel while the upper end cap is 416 stainless steel (ferromagnetic). The piston shell is also 304 stainless steel and has a mirror finish on its outer surface. The clearance between piston and cylinder is 0.127 mm. Four 1.6-mm axial holes are in the top section of the piston shell. The piston core is 416 stainless steel 11.8 mm o.d.×21.1 mm. The core also has a 3.18-mm bore along its centerline. The 3.18-mm hole does not overlap with any of the 1.6-mm holes in the piston shell. The magnetic coil for the pump consists of 800 turns of No. 21BWG copper wire. We included iron cladding around the coil to concentrate the magnetic field.

The check valve is simply a piece of machined 304 stainless steel 15.9 mm o.d.×3.81 cm. The end cap is 304 stainless steel, and the check ball is a 6.35-mm 416 stainless-steel ball bearing. The magnetic coil is 400 turns of No. 21BWG copper wire. Cladding is not necessary for this field.

When deactivated in this configuration, the pump allows communication between the pump inlet and check valve outlet. During operation, activation of the pump coil exerts an upward force on the piston core. When the core contacts the piston shell, all the piston holes are blocked and the piston rises in the cylinder. This action compresses the fluid above the piston and causes suction to pull in fluid below the piston.

While the pump coil is active, the check valve coil remains inactive, and the valve remains open. During the next half-cycle, the pump coil is inactive, and the piston core falls by gravity. This opens the piston holes and allows fluid to flow through the piston. Also during this half-cycle, the valve coil is active lifting the check ball and closing the valve to prevent back flow.

Figure 2 represents a circuit diagram for operating the magnetic pump. A 12-V dc power supply drives the pump, directing the current to each coil alternately through a double throw relay. The relay operates with a rectangular

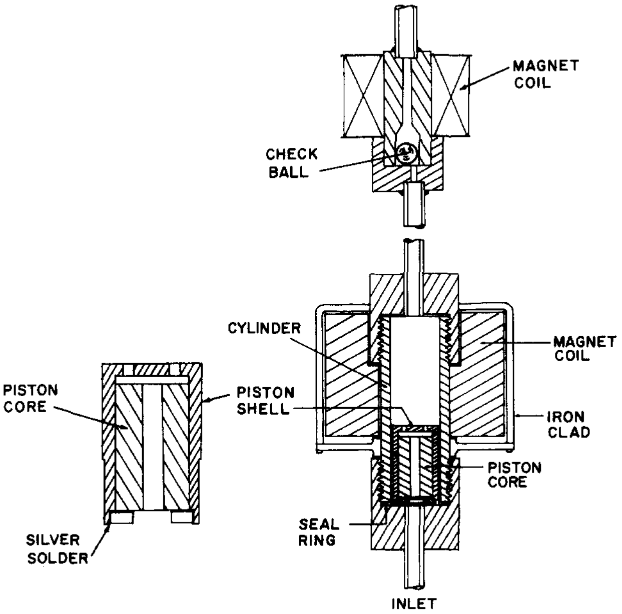

FIG. 1. Schematic for magnetic pump and check valve.

wave generator. Adjusting the frequency and on/off time ratio of the signals controls the circulation rate of the pump.

Figure 3 presents the performance characteristics of the pump. The contours labeled N denote stroke frequency; the efficiency denotes volume pumped per stroke per total cylinder volume. A frequency of 6.5 Hz is the proper operating condition. At this frequency, the piston begins an upward stroke just before striking bottom. This retards wear by eliminating mechanical impact. At the full upward stroke, the ferromagnetic end cap provides an electromagnetic "cushion" to minimize impact, again reducing wear on the pump. The maximum capacity is 26 cm^3/sec (circulating air at room temperature through approximately 700 cm^3 consisting of sample cells, 600 cm^3, and attendant tubing).

Altering the dimensions of the pump can provide a wide range of pressure applications. Attention to thermal compensation will allow a wide range of temperature applications (e.g., same metal for cylinder and piston shell).

We have designed our instrument to allow bidirectional flow when the pump is idle. This is a unique feature of the device and necessary for our immediate application in which we must pull a vacuum through the pump after it has assisted the mixing of two fluids. If the flow-through feature is not desirable for a given application, inverting the check valve will allow the ball to fall into a closed position from gravity. A particular advantage for the latter configuration is that the valve coil becomes unnecessary.

Although our prototype design is for a maximum pressure of 703 kg cm^{-2}, using thicker walled cylinders can increase this limit to almost any desired pressure. For example, increasing the cylinder o.d. to 2.54 cm, while maintaining the other dimensions constant, will increase the maximum pressure to 916 kg cm^{-2}. Attention to thermal compensation allows a wide range of temperature operations. For example, our prototype has an operating temperature range of $100 \leq T \leq 500$ K, and to prevent mechanical freezing the cylinder and piston shell are of same material.

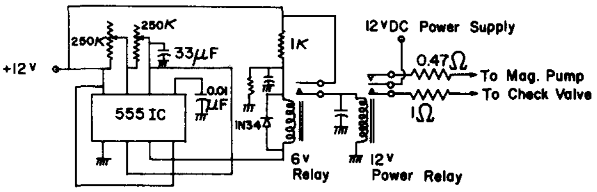

FIG. 2. Circuit diagram for magnetic pump and check valve.

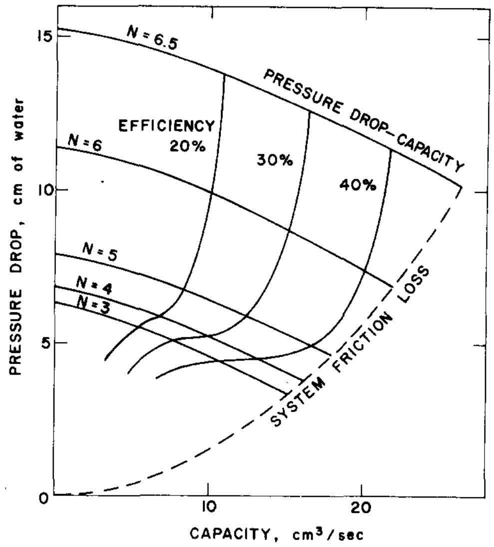

FIG. 3. Performance curve for prototype pump.

---

*We gratefully acknowledge financial support for this project from the following sources: NSF (Grant ENG74-23411, KRH; Grant GK-37087, PTE), American Gas Association (KRH and PTE), and PRF (Grant 7594-AC7, KRH).

[1] H. J. Aroyan, PhD. dissertation (University of Michigan, Ann Arbor, MI, 1949).
[2] F. B. Canfield, J. K. Watson, and A. L. Blancett, Rev. Sci. Instrum. **34**, 1431 (1963).
[3] P. G. Exline and H. J. EnDean, Trans. ASME **70**, 279 (1948).
[4] M. J. Hiza and A. G. Duncan, Rev. Sci. Instrum. **40**, 513 (1969).
[5] W. E. A. Ruska, L. J. Hurt, and R. Kobayashi, Rev. Sci. Instrum. **41**, 144 (1970).
[6] S. R. Smith, Ph.D. dissertation (Ohio State University, Columbus, OH, 1952).
[7] C. J. Sterner, Rev. Sci. Instrum. **31**, 1159 (1960).
[8] W. B. Street and A. L. Erickson, Phys. Earth Planet. Inter. **5**, 357 (1972).