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Research and Development Report

A DIAPHRAGM PUMP FOR LIQUID METAL SERVICE

by

D. E. Westerheide, J. C. Clifford
and George Burnet

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CONTENTS

page

ABSTRACT 5

CENTRIFUGAL PUMPS 6

ELECTROMAGNETIC PUMPS 6

DIAPHRAGM PUMPS 7

PUMP CONSTRUCTION 7

OPERATION OF THE PUMP 12

CONCLUSIONS 14

ACKNOWLEDGMENT 15

REFERENCES 16

IS-464

A DIAPHRAGM PUMP FOR LIQUID METAL SERVICE

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D. E. Westerheide, J. C. Clifford and George Burnet

ABSTRACT

The use of centrifugal and electromagnetic pumps for liquid metals is briefly reviewed. Details are provided on the construction and operation of a two-stage diaphragm pump successfully used for the first time in liquid metal service. From the results of a 5,376 hr test of the pump it was concluded that it is well suited to the pumping of liquid metals at low flow rates where pulsating flow can be tolerated. Operating temperatures and pressures are limited only by the availability of suitable materials of construction.

The use of liquid metals in liquid metal fueled reactors has created the need for suitable pumps not only for the reactor itself, but also for the laboratory scale forced convection loops needed for design and development purposes. Although these small scale loops are usually used to determine corrosion, heat transfer and fluid flow characteristics, they can also be useful in evaluating process equipment such as distillation units for the separation of liquid metals or flowmeters for the measurement of flowrates.

Three types of pumps which are suitable for liquid metal work are centrifugal, electromagnetic and diaphragm. Several good reviews of centrifugal and electromagnetic pumps are available.[1-5, 7, 8, 11, 12]

CENTRIFUGAL PUMPS

Centrifugal pumps for liquid metal service have been developed to a high degree. Several have been operated with sodium, bismuth, sodium-potassium eutectic or lead-bismuth eutectic at temperatures in excess of 800°C and flow rates from 1 to 1200 gallons per min.[1,2,5,8,10] Efficiencies of these pumps vary from 45 - 85%. They are relatively expensive and difficult to maintain because of problems associated with lubrication, seals and corrosion.

ELECTROMAGNETIC PUMPS

Where there are applications for low capacity, high temperature (400-1000°C) pumps, electromagnetic rather than mechanical pumps have been used. Simple construction, the absence of special corrosion problems, ease of control and relatively moderate cost make electromagnetic pumps suitable for both commercial and laboratory scale purposes.

The efficiency of an electromagnetic pump is dependent, among other things, upon the metal being pumped. For example, sodium has better pumping properties than bismuth. This is due to the relatively low values of resistivity, viscosity and density of sodium as compared to bismuth. In one case,[9] the pumping of bismuth decreased the capacity to 25% of that obtained with the sodium-potassium eutectic.

Since electromagnetic pump cells are replaceable, one pump can be used with different liquid metal systems provided compatible cell materials are chosen for each system. For optimum performance the pump cell should be a nonmagnetic material. The most common nonmagnetic steels for high temperature use are the austenitic stainless steels. However, at high temperatures the corrosion resistance of these steels is very poor.

Certain ferritic steels have better corrosion resistance but since they are magnetic their use would result in an additional loss in pump capacity.

DIAPHRAGM PUMPS

In this work a diaphragm-type proportioning pump of the type commonly used in the chemical industries was modified and used to circulate a high temperature liquid metal. The lead-bismuth eutectic was selected as the liquid metal because of its low melting point (125°C), ready availability, well known properties, non-toxic character and potential applications as a heat transfer medium and nuclear fuel carrier.

The diaphragm pump has several advantages over the centrifugal pump. While the operating temperatures of a centrifugal pump are restricted by the upper limit of service of electrical and thermal insulators and lubricants, the diaphragm pump is limited only by the materials used in its construction. The diaphragm pump is also a metering unit due to its displacement characteristic. This same characteristic makes it possible to obtain greater heads than those obtainable from most centrifugal and electromagnetic pumps.

A significant advantage of the diaphragm pump when compared to the electromagnetic pump is its constant efficiency. The efficiency of the diaphragm pump, unlike that of the electromagnetic pump, is not dependent upon the liquid metals being pumped.

PUMP CONSTRUCTION

Figure 1 is a schematic drawing of the two-stage diaphragm pump and ball check valve assembly installed in the test loop. Figures 2 and 3 are photographs of the installation.

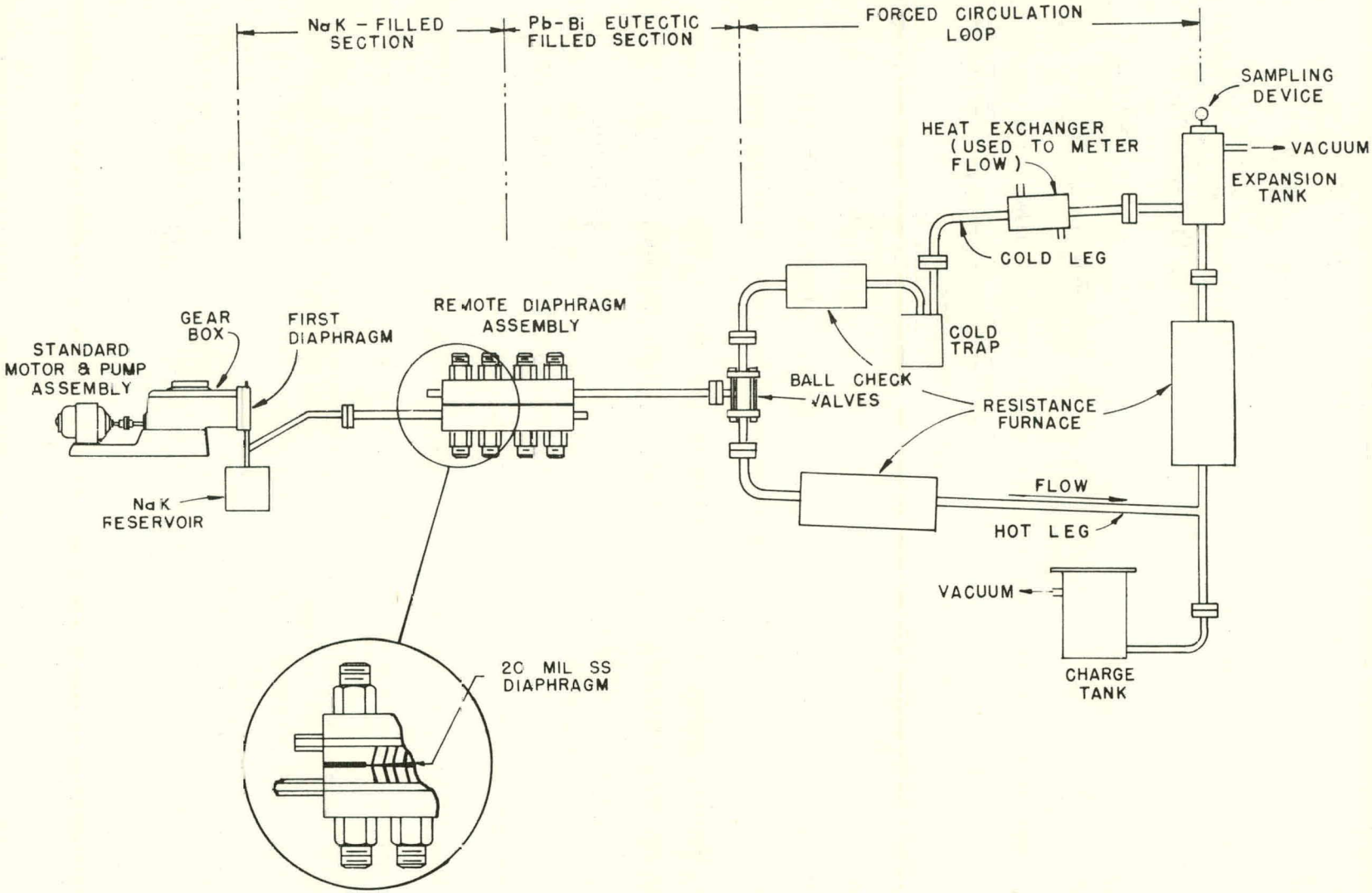

Fig. 1. Schematic assembly drawing of pump, remote diaphragm assembly and loop.

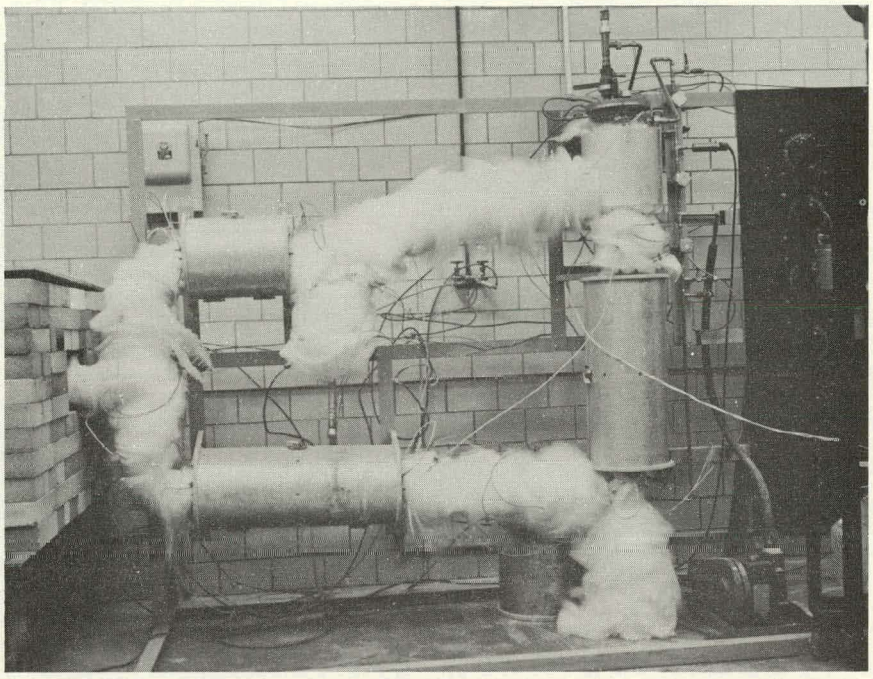

Fig. 2. Liquid metal loop with remote diaphragm assembly in brickwork to left.

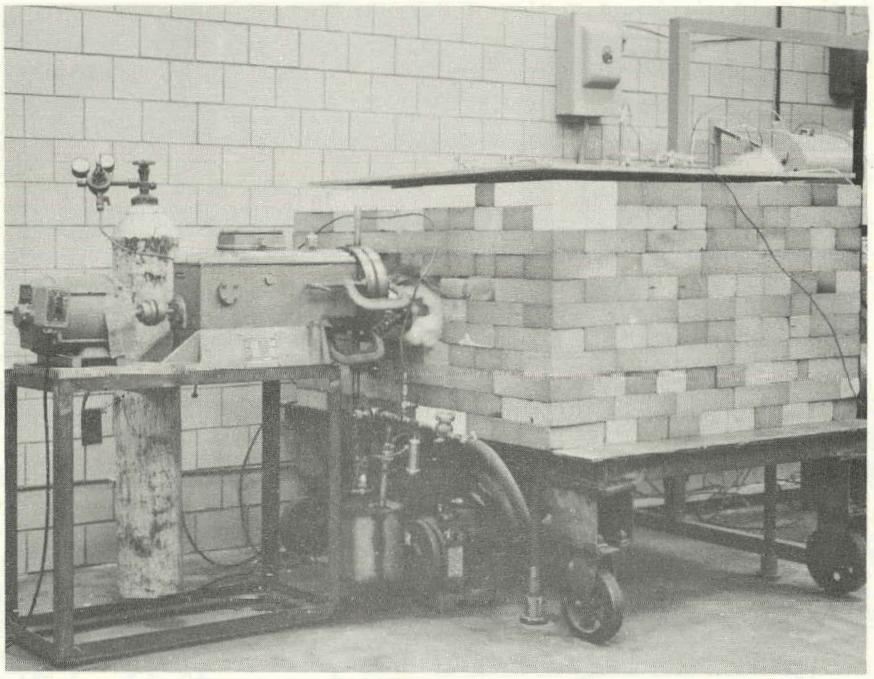

Fig. 3. Standard motor and pump assembly with remote diaphragm assembly to right.

The one-gallon-per-minute pump was manufactured by the Lapp Insulator Company, LeRoy, New York, to meet specifications established by the authors. The pump consists of a standard model CPS-2 Pulsafeeder, normally used as a proportioning pump in the chemical industries and a remote diaphragm assembly capable of high temperature operation. The remote head is positioned horizontally to facilitate piping. The pulse generator operates near room temperature at 58 strokes per min and makes use of a normal hydraulic fluid to transmit the pulse. This liquid fills the gear box, cylinder and that portion of the system up to the first diaphragm. The space on the other side of this diaphragm, as well as that in the lower half of the remote diaphragm assembly and in the tube connecting the two, is filled with the eutectic composition of sodium-potassium (NaK) alloy which contains 78% potassium by weight. The low-temperature diaphragm assembly is of all-welded construction and was manufactured from type 316 stainless steel as was the 20-mil-thick diaphragm.

The upper half of the remote, high-temperature head is filled with the material being pumped; in this case the lead-bismuth eutectic alloy. The outlet from this half of the head is connected to the ball check valve assembly in the loop. The entire remote head is constructed of type 446 stainless steel and the 20-mil-thick diaphragm of type 430. A vacuum-tight seal is maintained between the two halves of the remote head by means of polished, raised bearing surfaces on the face of each half so that the assembly is similar to a pair of raised-face flanges with the diaphragm acting as a gasket.

The remote head is immersed in a heated liquid metal bath for purposes of temperature control. Figure 4 shows the remote head in the bath container. The remote head is connected to the ball check valve assembly and to the pump head by flanges. These flanges are of a special raised face design developed by Clifford and Burnet.[6] Motion of the low-temperature diaphragm in the pump head is transmitted through the sodium-potassium filled connection tube to the high temperature diaphragm, which in conjunction with the check valve assembly causes the pumping action.

It was necessary to install cooling coils on the face of the low-temperature pump head to absorb the heat conducted from the high-temperature remote head. The temperature of the low-temperature head was maintained near room temperature by circulating cooling water through the coils.

OPERATION OF THE PUMP

The system operated continuously for 5376 hr without serious difficulty. On two occasions during operation the cooling water supply was interrupted for several hours which left the low-temperature head without sufficient cooling. This situation was corrected by temporarily reducing the temperature of the loop from 575 to 350°C and reducing the remote head constant temperature bath from 350 to 190°C. This minimized the heat flow due to conduction from the remote head to the pump head. Further cooling of the pump head by forced air convection was achieved by directing two electric floor fans on the head. In both instances the pump continued to operate properly, and was easily brought back to normal operating conditions when the water supply was restored.

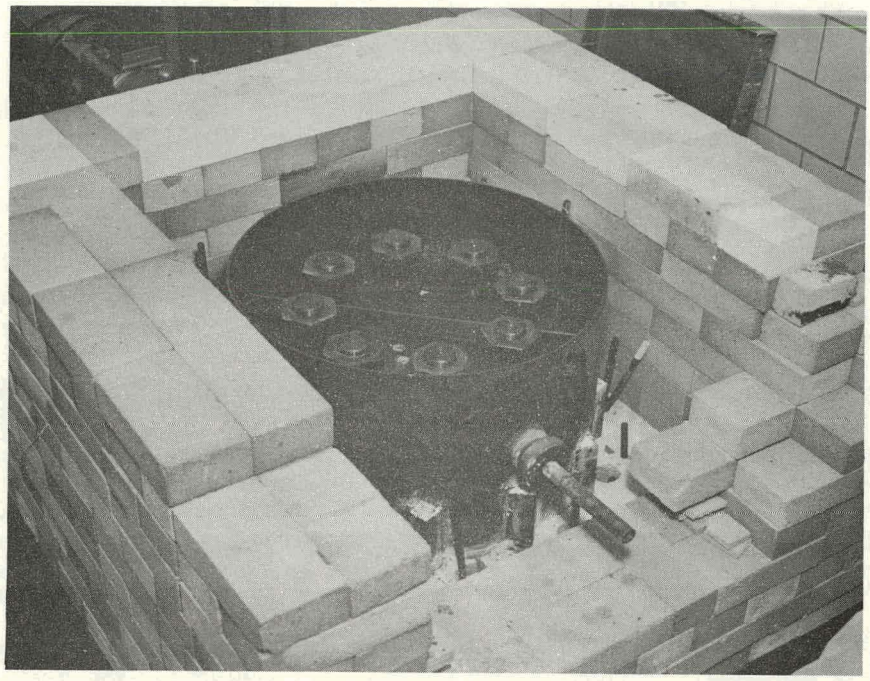

Fig. 4. Remote diaphragm assembly in liquid metal bath container and insulating brickwork.

Except for the above cases the operating conditions were not changed during the run. The expansion tank temperature was held at 575°C and the cold trap at a temperature of 370°C.

Flowrate was determined by calibrating the remote head with water prior to start-up. The flowrates thus determined were checked, once the loop was in operation, by carefully measuring in a small heat exchange section of the loop the heat removed from the eutectic and its temperature drop.

Based on the pump calibration, the flowrate was held at 0.6 gallons per min throughout the test. It was impossible to maintain an accurate check on this figure due to a failure of thermocouples in the heat exchange section used to meter flow. As far as could be determined by the constancy of the temperature profiles of the loop, and excellent condition of the ball check valves after disassembly of the loop, there was no loss in pump capacity during operation. Both the balls and seats showed very little wear and no evidence of corrosion. Scoring of the balls due to repeated seating and unseating was minor. The diaphragm showed no visible signs of wear.

CONCLUSIONS

Experience to date indicates that this type pump is ideally suited to the pumping of lead-bismuth eutectic and probably other liquid metals at low flowrates where pulsating flow can be tolerated. The operating temperature is limited only by the material used in construction of the remote head. Because it is a positive displacement pump, it is also an accurate metering device.

Once the pump is put into operation it needs only routine maintenance provided the proper materials of construction have been selected. This, plus its high degree of reliability, makes remote operation both feasible and simple. Thus the diaphragm pump is ideally suited for use in pumping radioactive materials.

ACKNOWLEDGMENT

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