United States Patent

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[54] **METHOD AND APPARATUS FOR CONTROLLED PUMPING OF LIQUID MERCURY**
10 Claims, 1 Drawing Fig.

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[51] **Int. Cl.** **G01n 27/42, F17d 1/00**
[50] **Field of Search** ..... 356/181; 324/29, 71, 94; 204/219; 137/2,486.5, 501; 103/1 E, 1 M

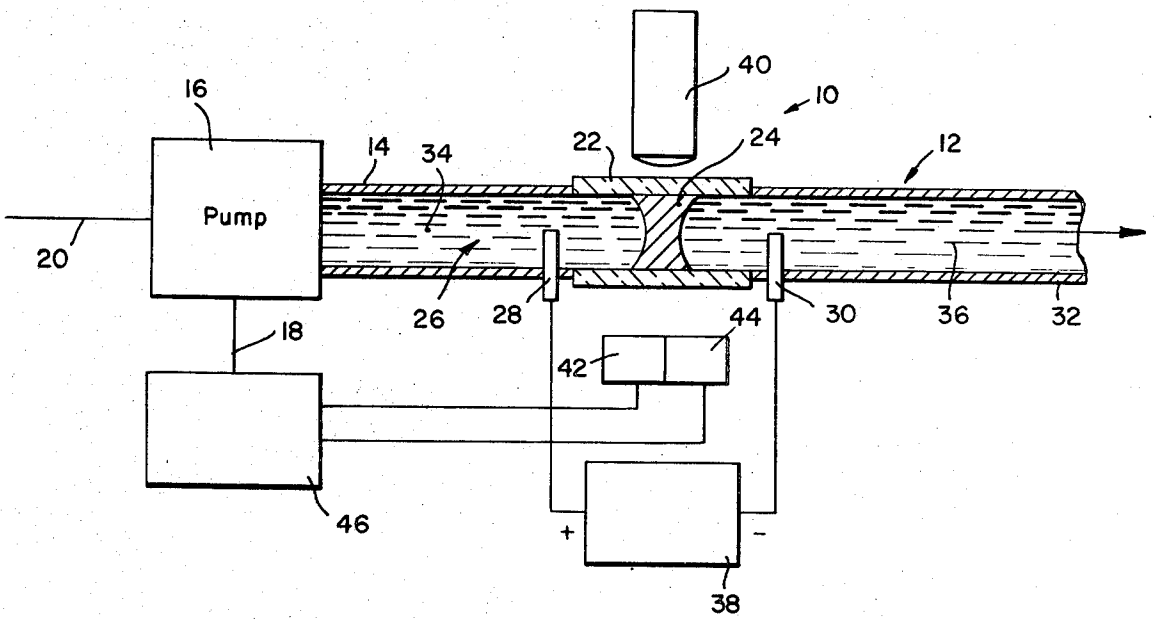
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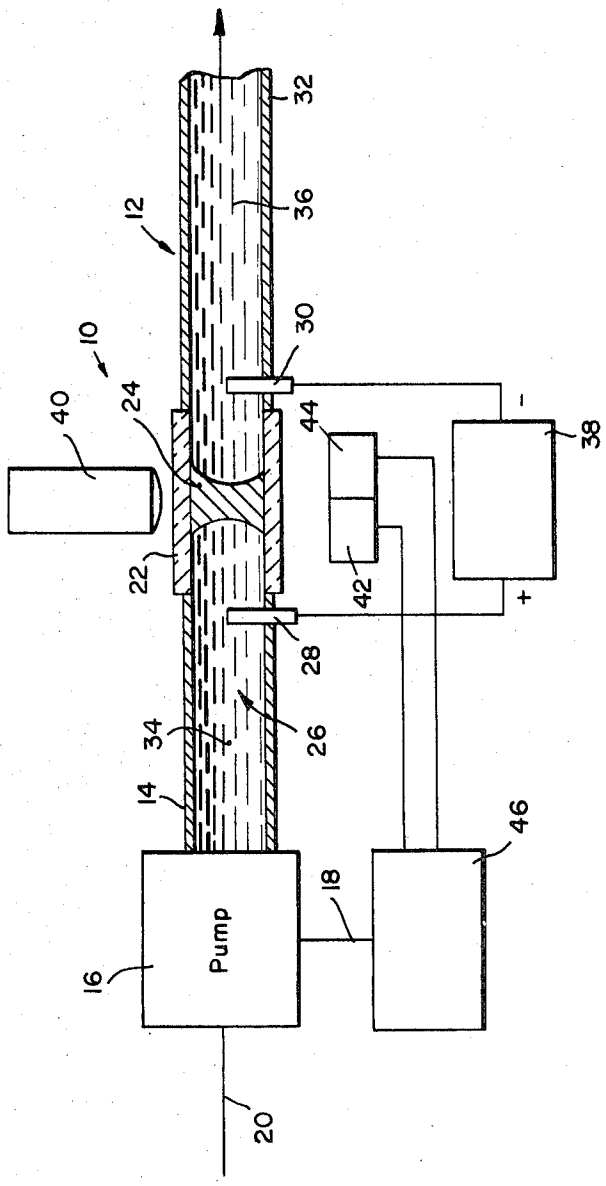
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ABSTRACT: A controllable flow of liquid mercury is discharged into a delivery conduit. First and second electrodes are positioned in the conduit in the liquid mercury therein. The conduit between the electrodes is electrically insulative. A bubble of electrolyte is positioned between the electrodes. An electrolysis current source is connected to the electrodes and regulated in accordance with the amount of mercury desired to be delivered by this delivery conduit. this electrolysis current electrolyzes mercury across the electrolyte from the mercury source toward the discharge end of the delivery conduit. Detection means detect the position of the electrolyte bubble and regulates the controllable flow of liquid mercury to maintain the electrolyte bubble in a substantially fixed position in the delivery conduit. Thus, the amount of mercury delivered out of the delivery conduit is equal to the amount of mercury electrolyzed across the electrolyte.



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METHOD AND APPARATUS FOR CONTROLLED PUMPING OF LIQUID MERCURY

BACKGROUND

This invention is directed to a method and apparatus for the controlled pumping of liquid mercury, particularly at very low rates.

The pumping of liquid is a very old art, and in most cases the advances in the art of pumping have been directed to the pumping of greater quantities of liquid, or the pumping at higher discharge pressures. On the other hand, while there has been some concern about the accurate pumping of small quantities of liquid, little improvement has been accomplished in recent years except through the improved seals in mechanical pumps. Even with the progress that has been made, mechanical pumps or flow control valves have been unable to accomplish proper control when the desired flow rate is very low.

In the pumping of liquid mercury, the metallic character of the liquid pumped has been recognized by Wilfried O. Eckhardt in his Pat. application Ser. No. 687,004 filed Nov. 30, 1967 entitled "Liquid Mercury Flow Control and Measuring System." This prior invention recognizes that the electrolysis of mercury through an electrolyte can deliver liquid mercury at very low flow rates. However, this prior invention is limited by the fact that the maximum delivery pressure is determined by a mercury column and it is not capable of delivering at the higher pressures which are possible with pressurized mercury vessels or mechanical pumps.

SUMMARY

In the summary, this invention is directed to a system wherein a controllable supply of liquid mercury delivers mercury through a delivery conduit and particularly to the control of the controllable supply. The delivery conduit has an electrolyte bubble therein, with the electrolyte being of such nature that mercury can be electrolyzed across the bubble in the direction of mercury delivery. Suitable electrolyzing electrodes and power supply are provided, with the amount of electrolysis current determining the amount of mercury delivered. So long as the electrolyte bubble is maintained in a constant position, the amount of mercury delivered is equal to the amount electrolyzed across the bubble. Electrolyte position detecting means controls the controllable mercury supply to maintain the electrolyte in a fixed position to accomplish this result. Thus, the method and apparatus for controlling the pumping of liquid mercury is especially suited for the delivery of liquid mercury at very low and accurately controlled flow rates.

Accordingly, it is an object of this invention to provide a method and apparatus for controlling the supply of liquid mercury wherein mercury is delivered at low and carefully controlled feed rates. It is another object to provide a method and apparatus in which the liquid mercury can be delivered from its delivery conduit at low and carefully controlled feed rates and at a substantial pressure, should a substantial pressure be required at the discharge point. It is a further object of this invention to provide a delivery system for liquid mercury wherein liquid mercury and liquid electrolyte are in interface relationship so that the mercury can be electrolyzed across the electrolyte. It is still another object of this invention to provide a liquid mercury delivery system wherein the mercury is primarily moved by a source of liquid mercury under pressure having control of the flow of liquid mercury and the control is established without the need for a mercury head so that mercury can be delivered to a discharge point at accurate rates independent of changing in the magnitude or direction of the local gravitational field. Other objects and advantages of this invention will become apparent from the study of the following portion of this specification, the claims and the attached drawings.

DESCRIPTION OF THE DRAWING

The single FIGURE of the drawing shows the liquid mercury delivery conduit in longitudinal section and shows the associated equipment for controlling the flow of liquid mercury through the delivery conduit in schematic form.

DESCRIPTION

The drawing illustrates the apparatus for controlled pumping of liquid mercury, which is generally identified at **10**. Delivery conduit **12** has an input end **14** to which is connected pump **16**. Pump **16** is a pump in the broad sense of the term and includes any device which supplies liquid mercury at suitable pressure and controls its flow. Under these conditions pump **16** can be a pressurized mercury vessel equipped with a controllable metering outlet valve. On the other hand, it can be an electromagnetic pump or a simple mechanical pump with bypass flow control, or the like. In any event, the amount of mercury delivered by pump **16** into the input end **14** of delivery conduit **12** is controlled by the signal in line **18**. Pump power, if required is supplied by line **20**.

Delivery conduit **12** has a control section **22**. Control section **22** contains electrolyte bubble **24**. The control section is electrically insulative along its length, is not wettable by mercury **26** in the delivery conduit, is wetted by electrolyte bubble **24**, and is of such nature that the position of electrolyte bubble **24** is detectable. Glass is a suitable material for control section **22**, especially when optical means is used to detect the position of electrolyte bubble **24**. The control section **22** extends from electrode **28** to electrode **30**. Beyond the control section, delivery conduit **12** has a discharge section **32** which is connected to the point of use of the liquid mercury. Delivery conduit **12** is filled with liquid with a pump column **34** extending between pump **16** and electrolyte bubble **24** and measured column **36** which extends from the electrolyte bubble **24** through the discharge section **32** to the point of mercury use.

Regulatable current supply **38** is connected to electrodes **28** and **30** to cause electrolysis of mercury from pumped column **34** to measured column **36**. The amount of current supplied by the current supply **38** is set in accordance with the desired rate of mercury delivery by the delivery conduit. Faraday's law establishes the linear relationship between the amount of mercury delivered across the electrolyte and the electrolysis current. Thus, with the establishment of a particular electrolysis current, a particular rate of mercury flow across the electrolyte is established. By holding the electrolyte bubble **24** stationary along the length of delivery conduit **12**, the amount of mercury electrolyzed thereacross is delivered out of the discharge section of the conduit.

Any convenient type of electrolyte bubble position detecting means can be used to regulate the amount of mercury delivered by pump **16** into the input end of delivery conduit **12**. Inductive or capacitive means could be used, but optical means is preferred and is illustrated in the FIGURE. Light source **40** directs collimated light through the control section **22** of the delivery conduit and light passing through the fairly transparent electrolyte **24** falls upon sensors **42** and **44** which may be, for instance, EG&G Inc. photodiode bicell SGD–444–2. The varying intensity of light from source **40** passing through electrolyte bubble **24** onto the two sensors **42** and **44** thus detects the position of the electrolyte bubble.

If the bubble moves to the right, as is seen in the FIGURE, the light falling upon sensor **44** increases and that falling upon sensor decreases. Sensors **42** and **44** are connected to pump controller **46** which is in turn connected by line **18** to control the delivery of liquid mercury by pump **16** into the delivery conduit. In the illustrated case, when bubble **24** moves to the right, the output of pump **16** is too great and the signal of more light falling upon sensor **44** decreases pump output. Similarly, if the bubble **24** is farther to the left in the delivery conduit, more light falls on sensor **42** and less on sensor **44** to cause pump controller **46** to increase pump output. The increased

pump output continues until bubble **24** is repositioned so that the amount of light falling upon the sensors **42** and **44** is substantially equal. The system including the sensors, pump controller **46** and the controllability of pump **16** is continuously variable so that electrolyte bubble **24** is maintained closely near the desired fixed position.

A number of different electrolytes can be used to form electrolyte bubble **24**. The electrolyte must be capable of electrolyzing mercury, it must wet the interior surface of control section **22** to prevent a short circuit of mercury along the wall of control section **22**, and in the instance illustrated must be fairly transparent. However, with different position sensors, transparency will not necessarily be required. Furthermore, different electrolytes have different electrolytic capabilities before they break down due to excess current. Thus, the electrolyte may be chosen with the amount of desired mercury flow rate in mind. A suitable electrolyte is mercury iodide in iodide solution. The table below illustrates practical limits on the preferred electrolyte.

Table A

	Preferred
KI	750 grams
HgI	225 grams
H_2O	1000 cc.

The preferred electrolyte listed in the table above is capable of 0.5 amperes per sq. cm. without breakdown. In the specific example of the controlled pumping of liquid mercury, it is assumed that 5×10^{14} amperes of electrolysis current is applied for the period of one hour. This is suitable current for a bore of 0.01 sq. cm. in the control section **22**. The applicable formula is:

$$\text{Mass flow (grams/hr)} = \frac{Q\ (\text{Coulombs} = \text{amp sec})(\text{atomic wt})}{96520\ (\text{valence})}$$

Using the above assumptions and the data for mercury:

$$\text{Mass flow (grams/hr)} = \frac{(5\times10^{-4})\ (3600)\ (200)}{96520(2)} = 0.0018$$

Thus, the delivery rate in the illustrative example is 0.0018 grams per hour of mercury. This rate is independent of tube diameter and dependent only upon the current flow. Current can be decreased to reduce the delivery rate, and can be increased up to the limit of the stability of the electrolyte. Increases in the tube diameter can be made to maintain electrolyte current density at a reasonable level up to the point where the electrolyte can no longer separate the mercury columns. This is a function of the surface activity of the electrolyte with respect to the material of the control section **22** of delivery conduit **12**.

This invention having been described in its preferred embodiment, it is clear that it is susceptible to numerous modifications and embodiments within the ability of those skilled in the art and without the exercise of the inventive faculty. Accordingly, the scope of this invention is defined by the scope of the following claims.

What I claim is:

1. An apparatus for the controlled pumping of liquid mercury, said apparatus comprising:

a source of liquid mercury, a delivery conduit connected to said source of liquid mercury, the improvement comprising:

flow control means connected to said delivery conduit to control the rate of flow of liquid mercury from said source into said delivery conduit;

first and second electrodes positioned within said delivery conduit and spaced along the length of said delivery conduit for passing electrolysis current between said electrodes; and

a sensor positioned adjacent said delivery conduit between said first and second electrodes to sense the position of an electrolyte within said delivery conduit between said electrodes, said sensor being connected to said flow control means so that the rate of mercury flow into said conduit is controlled by said sensing means and said sensing means is controlled by the position of electrolyte within said delivery conduit.

2. The apparatus of claim **1** wherein first and second mercury columns are positioned within said delivery conduit and an electrolyte is positioned between said mercury columns in said delivery conduit, said electrolyte and said mercury columns being in liquid-to-liquid interface engagement.

3. The apparatus of claim **2** wherein said delivery tube is unwettable by said mercury and is wetted by said electrolyte so that said electrolyte maintains said mercury columns electrically separated except through said electrolyte.

4. The apparatus of claim **3** wherein said electrolyte contains mercury ions in electrolyte solution.

5. The apparatus of claim **1** wherein at least a portion of said delivery tube is substantially transparent and first and second columns of liquid mercury in said delivery tube are separated by a substantially transparent mercury plating electrolyte, said electrolyte being positioned between said electrodes.

6. The apparatus of claim **5** wherein said sensor comprises a light source arranged to direct light through said delivery tube and a light sensor positioned to receive light passing from said light source through said delivery tube.

7. The apparatus of claim **6** wherein said light source is a collimated light source and said sensor comprises first and second optical sensors positioned adjacent each other in a direction axial of said tube.

8. A process for the controlled pumping of liquid mercury comprising the steps of:

controllably admitting liquid mercury into a delivery tube so as to substantially fill the delivery tube;

electrolyzing mercury across a mercury electrolyzing electrolyte which is positioned within the tube and separates the mercury column within the tube; and

controlling the position of the electrolyte within the tube by controlling the admission of the liquid mercury into the tube.

9. The process of claim **8** wherein said controlling step comprises:

sensing the position of the electrolyte within the conduit; and

controlling the admission of liquid mercury into the conduit by the sensed position of the electrolyte.

10. The process of claim **9** wherein said sensing step comprises optically sensing the position of the electrolyte along the length of the conduit.