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R. G. PETTS ETAL

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METHOD OF MAINTAINING LEVEL OF CRYOGENIC LIQUIDS

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2 Sheets-Sheet 1

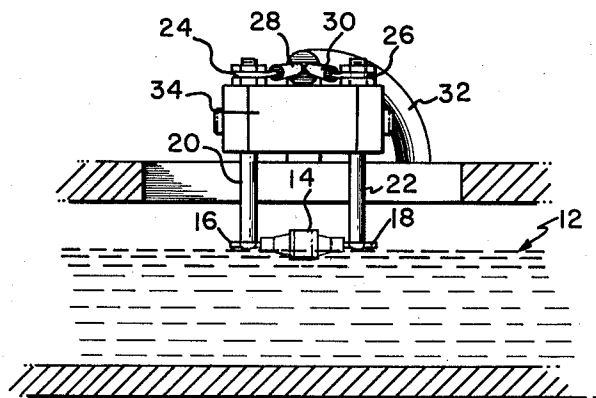


fig-1

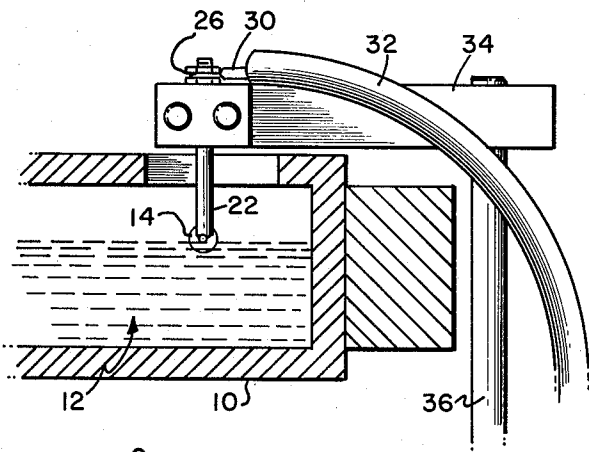


fig-2

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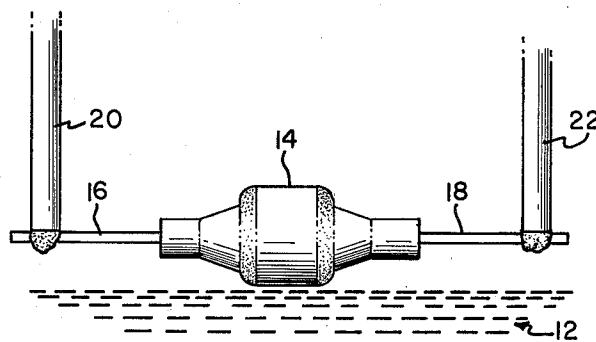


fig-3

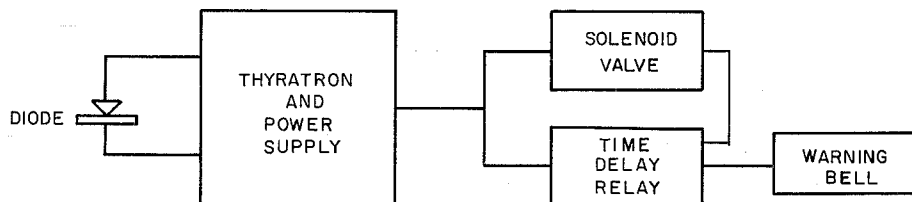


fig-4

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3,097,496 METHOD OF MAINTAINING LEVEL OF CRYOGENIC LIQUIDS

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This invention relates to cryogenic liquids, such as liquid nitrogen for example, and more particularly to an automatic method of maintaining the level of a body thereof in a container or reservoir at a predetermined elevation within very close tolerances.

In the commercial manufacture of photoflash lamps it has been the general practice over the years to evacuate the lamp envelope and then provide it with a filling of combustion-supporting gas at pressures below atmospheric. Structurally, these lamps usually are provided, during the manufacture thereof, with a glass exhaust tube through which the combustion-supporting gas is introduced into the lamp envelope. After this gas filling operation has been completed the exhaust tube is tipped off or closed to thereby provide a hermetically sealed lamp. This exhaust tube tipping or sealing operation is usually performed at ambient temperatures and at atmospheric pressure by the application of heat thereto sufficient to melt the glass exhaust tube. Since the lamp envelope has been provided with a filling of combustion-supporting gas at a pressure below atmospheric, tipping or sealing of the exhaust tube at atmospheric pressure facilitates this operation and presents no substantial engineering problem since the pressure differential causes the molten glass to be drawn inwardly as desired to effect the sealing operation.

In more recent years photoflash lamps provided with a filling of combustion-supporting gas at pressures substantially above atmospheric have been made available commercially. For example, some of these lamps are provided with a filling of combustion-supporting gas at several atmospheres pressure. In these circumstances, the natural advantage of tipping off at atmospheric pressure a device having a gas filling at pressures below atmospheric no longer exists. As a matter of fact the tipping off or sealing operation cannot be performed in the usual manner under these circumstances. Various techniques have been developed to effect the tipping or sealing operation on devices provided with a gas filling at pressures substantially above atmospheric. One of these is the so-called "bell jar" technique in which the exhaust tube to be tipped or sealed is enclosed in a pressurized chamber, the pressure therein being substantially equal to or slightly greater than the pressure within the device and tipping of the exhaust tube is effected in this chamber.

Another technique which has been employed in tipping off or sealing devices having a gas filling at pressures above atmospheric is the refrigeration technique. In accordance therewith, the device, having a gas filling which at normal room temperature is at several atmospheres pressure, is immersed in a liquid refrigerant to effect a cooling thereof to a degree whereby the gas pressure is reduced to below atmospheric and, while in this state, the device is tipped off or sealed by relatively simple conventional sealing techniques, not requiring auxiliary equipment such as a bell jar for example.

In the practical application of the refrigeration technique to the manufacture of high pressure photoflash lamps, means must be provided to effect the refrigeration operation in a manner conducive to high speed lamp manufacturing operations. This may be accomplished by locating an elongated curved trough defining a liquid nitrogen reservoir beneath and in register with a segment of the

turret type exhaust machine on which photoflash lamps are processed. This type of machine, having a plurality of lamp-supporting heads disposed about its periphery, effects the lamp exhausting and gas filling operations. The aforesaid liquid nitrogen reservoir is disposed so that the gas filled lamps depending from the heads of the exhaust machine move through and are immersed in the liquid nitrogen as they are advanced by the indexing of the machine.

During operation of this refrigeration system, depletion of the liquid nitrogen and a lowering of the level thereof in the reservoir occurs. Since the degree of cooling of any given lamp during this operation is a function of the extent to which it is immersed in the liquid refrigerant, any substantial change in the level of the refrigerant will affect the degree of cooling and thus the pressure of the gas filling in the lamp. If the lamp is not cooled enough to bring the pressure down below atmospheric, conventional tipping techniques will be ineffective.

In view of the foregoing, a principal object of this invention is to insure the maintenance of the level of the liquid refrigerant at a substantially uniform predetermined level within very close tolerances.

Another object of this invention is to provide automatic means for attaining the foregoing object.

These and other objects, advantages and features are attained, in accordance with the principles of this invention, by utilizing a semi-conductor diode as a means for indicating the relative level of the liquid refrigerant in the reservoir in which the photoflash lamps are immersed. In air the electrical resistance of a conducting diode, operating from a constant current source, is relatively low and very little voltage is developed across it. However, when the diode is immersed in the liquid nitrogen, the electrical resistance increases and consequently a higher voltage is developed across it. Thus a semiconductor diode is normally immersed in the liquid refrigerant in the reservoir. When the level of the liquid refrigerant drops to an elevation below the diode so that the diode is no longer immersed therein, the resultant changes in electrical characteristics of the diode are utilized by suitable circuitry to effect introduction of more liquid refrigerant into the reservoir to bring back the level thereof to the desired elevation, i.e., with the diode again immersed in the liquid refrigerant.

In the accompanying drawing wherein a specific embodiment of the invention is illustrated, FIGURE 1 is a fragmentary front elevational view partly in section of a liquid refrigerant reservoir showing a semiconductor diode assembly associated therewith, with the diode immersed in the liquid refrigerant.

FIGURE 2 is a fragmentary and elevational view partly in section of the apparatus of FIGURE 1.

FIGURE 3 is a fragmentary detail on an enlarged scale showing the level of the liquid refrigerant dropped to an elevation where it is out of contact with the semiconductor diode.

FIGURE 4 is a schematic block diagram of a circuit arrangement with which the semiconductor diode may be associated to automatically effect the desired maintenance of liquid refrigerant level.

As shown in FIGURES 1 and 2, a reservoir 10 contains a body of liquid refrigerant 12, such as liquid nitrogen for example, and a semiconductor diode 14 having lead-in wires 16 and 18 extending therefrom is disposed in the liquid refrigerant 12. The diode 14 is supported by its lead-in wires 16 and 18 on the lower ends of a pair of electrically conducting rods 20 and 22. The upper ends of these rods 20 and 22 are provided with terminals 24 and 26 to which wires 28 and 30 are connected. The wires 28 and 30 extend through a shielded cable 32 to a suitable power supply. The electrically conducting rods 20 and 22 are insulated from, supported in and depend

from one end of a mounting bracket 34. The other end of the mounting bracket 34 is attached at or near the upper end of a post or standard 36. The bracket 34 is preferably adjustably mounted on the post or standard 36 to thereby provide means for adjusting the relative disposition of the diode 14 with respect to the liquid refrigerant 12. As shown in FIGURES 1 and 2, the diode 14 is disposed in the liquid refrigerant 12. As shown in FIGURE 3, the level of the liquid refrigerant has dropped to a point where the diode is no longer immersed therein.

We have found that in this particular application, a Sylvanian 1N34A point contact semiconductor diode gives particularly good results. However, several other semiconductor diodes were tried and operated satisfactorily for the purpose intended. This diode was connected to a D.C. supply voltage in the conducting directions i.e. positive to anode and negative to cathode and a resistance was placed in series with the diode to limit the current flow to a safe value. This D.C. voltage supply with a series resistance approximates a constant current source. In air the resistance of the diode was relatively low and there was little voltage developed across it. For example, when the diode was disposed just above the level of the liquid nitrogen, the resistance thereof was about 139 ohms, the current through it about 18 milliamperes and the voltage across it about 2.5 volts. As the level of the liquid refrigerant moves farther away from the diode, the voltage and resistance drop and the current rises slightly. On the other hand, when the diode is disposed in the liquid nitrogen, the resistance thereof rises to about 254 ohms, the voltage across it rises to about 4.5 volts and the current through it drops to about 17.7 milliamperes. This voltage is applied to the grid of a Thyatron operating with an A.C. anode supply. The grid bias of this Thyatron is adjusted so that the tube fires at about 3.5 volts and extinguishes at about 2.5 volts. The anode current of this Thyatron operates a relay supplying power to a solenoid valve which controls the flow of liquid nitrogen 12 into the reservoir 10. A thermal time delay relay may be connected in parallel with the solenoid valve to provide a means for indicating that the supply of liquid nitrogen to the reservoir is depleted. The time delay of this relay is selected to be somewhat greater than the normal filling time of the reservoir. Thus if there is a call for replenishment of the liquid nitrogen in the reservoir longer than the time delay, this relay closes and operates a warning bell which alerts an operator and indicates that the supply of liquid nitrogen to the reservoir has become depleted.

In the manufacture of photoflash lamps, high speed equipment is usually employed. For example, in the manufacture of photoflash lamps of the type with which the technique of this invention may be employed, the exhaust machine may process several hundred or more lamps per hour. In these circumstances it will be realized that a reliable liquid refrigerant level control unit must be employed which will respond quickly and accurately to small and frequent changes in the level of the refrigerant in order to preclude damage to, or loss of, substantial numbers of lamps in process due to inadequate cooling thereof.

We have found that the technique of this invention provides a means for maintaining a constant level within a maximum deviation of about one-eighth of an inch.

Although the method of this invention has been described in a specific example in connection with the manufacture of photoflash lamps which are cooled by immersion in liquid nitrogen as a refrigerant, it will be readily appreciated by those skilled in the art that the method may be employed in other circumstances and other cryogenic liquids may be employed without departing from the spirit of this invention.

What we claim is:

1. The method of maintaining the level of a cryogenic liquid in a reservoir at a substantially constant elevation, said method comprising: disposing a semiconductor diode in said liquid at the top surface thereof; connecting said diode in an electrical circuit including control means for regulating the flow of additional cryogenic liquid into said reservoir, said control means being responsive to resistance changes in said diode whereby additional cryogenic liquid is admitted to said reservoir when the level of the cryogenic liquid therein drops to an elevation where the said diode is no longer disposed therein and additional cryogenic liquid is prevented from entering said reservoir when said diode is disposed in said liquid in said reservoir; and electrically connecting a time delay relay and a warning signal to said control means, the time delay of said relay being set to actuate said warning signal when the supply of cryogenic liquid to said reservoir has been depleted.

2. The method of maintaining the level of a cryogenic liquid in a reservoir at a substantially constant elevation, said method comprising: disposing a semiconductor diode in said liquid at the top surface thereof; connecting said diode in an electrical circuit including a Thyatron and a valve for controlling the admission of additional cryogenic liquid to said reservoir, said Thyatron being responsive to resistance changes in said diode due to its disposition in or displacement from contact with said cryogenic liquid in said reservoir and said valve being responsive to the firing and extinguishing of said Thyatron; and electrically connecting a time delay relay and a warning signal to said valve, the time delay of said relay being set to actuate said warning signal when the supply of cryogenic liquid to said reservoir has been depleted.

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