A Small Transfer and Distribution System for Liquid Nitrogen

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A system for remotely controlled filling of small Dewars with liquid nitrogen from a central storage Dewar vessel is described, consisting of a plunger type pump with an electromechanical driver and electromechanical ball type valves for distribution of liquid nitrogen. The preset nitrogen level in the small Dewars is kept constant by automatic refilling. The delivery is adjustable in steps by frequency change from 2.5 to 25 cm^3/s, and delivery height up to 2 meters is assured.

Keywords: liquid nitrogen, transfer system, solenoid pump, solenoid valve, automatic level control.

1 Introduction

The system was proposed for multiple, remotely controlled selective filling of one of three small Dewars with liquid nitrogen (LN) from a storage Dewar vessel. The liquid nitrogen level in the selected Dewar is to be kept at a preset height by automatic refilling. The liquid nitrogen is transferred by a specially constructed electromechanical pump from a standard non-pressurized storage Dewar. We avoided the solution of LN transfer from the storage Dewar by pressure nitrogen gas provided either by an electric heater situated in the Dewar, by self-pressurization or by dry nitrogen supply from outside. The pump itself, consisting of cylinder, plunger and valves, is immersed in LN above the bottom of the storage Dewar vessel, the electromagnetic driving system being situated outside. The travel of the core in the solenoid of the driving system is transferred to the plunger by a rod. In such a way the Joule heat from the driver, the input power of which is about 10 W, does not contribute to evaporation of liquid nitrogen. The distribution of LN between the three small Dewars is accomplished by a three-way valve with electromechanical actuators.

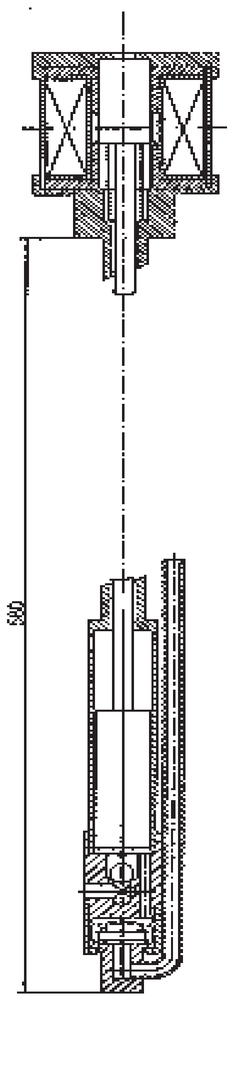

Fig. 1: Pump for liquid nitrogen

2 Electromechanical LN pump

All parts of the pump (Fig. 1) in contact with LN are made from stainless steel. The delivery valve is of a diaphragm type, and the intake valve is of a ball type. The diaphragm of the delivery valve is held in the closed position by a spring, the ball of the intake valve by gravity and hydrostatic pressure of the liquid nitrogen column above it. The intake valve operates successfully even when pressure in the cylinder volume is reduced during suction. Due to the short delivery period, the plunger need not to be provided with a special sealing against the cylinder wall to prevent leakage.

The electromagnetic solenoid type driver of the pump, sketched in Fig. 1, has an axially sliding iron core. The number of windings of the coil is 1400, resistance 15 Ω and inductance 0.5 Hy (when the core is in central position). Without current, the core is held in the extreme upper position by a spring. During the current pulse, the core moves to the central position delivering pumping work. The static characteristic of the system, representing the resultant of magnetic force at coil current value 1.7 A and the resultant of the elastic force of the spring, acting on the core, is represented in Fig. 2 as a function of the plunger position.

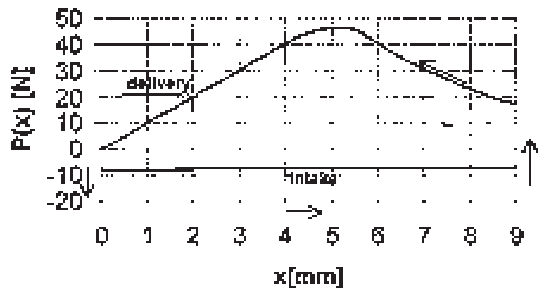

Fig. 2: Force P of the driver unit as function of the plunger position x

This force compensates the inertial forces of the mechanical parts of the system and of the column of the transferred LN in the exhaust tubing during the delivery period and the hydrostatic pressure. The full stroke is maintained up to 10 Hz working frequency of the pump.

The solenoid of the pump driver is excited by rectangular current pulses, peak current 1.7 A, duty cycle adjustable from 0.12 to 0.25 and repetition rate 1 to 10 Hz. The necessary voltage for peak current 1.7 A is 25.5 V, maximum ampere-turns equal to 2380 A. Integrated circuit 555 is used in the pulse current generator, directly switching a Darlington type transistor. The delivery period of the pump corresponds to the peak current, the intake period to zero current in the coil. The return of the plunger during the intake period is assured by the spring in the driver. At 1 cm plunger stroke the suction volume is 2.5 cm^3. The delivery is adjustable in steps by frequency change from 2.5 to 25 cm^3/s, and delivery height up to 2 meters is assured. The use of pulse excitation of the electromagnet with an adjustable duty cycle enables the energy to be concentrated on a short delivery period, thus reducing the mean heat dissipation in the electromagnet coil.

3 Three-way LN valve

The distribution of LN to three Dewars is enabled by a three-way solenoid valve (Fig. 3) consisting of individual

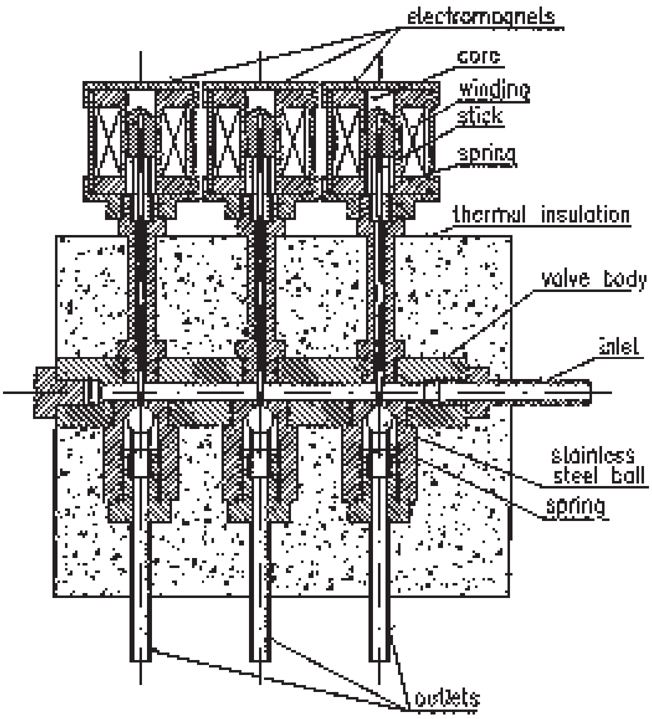

Fig. 3: Three-way valve

ball valves with a common body. Each ball valve is actuated by a solenoid through a rod in contact with the ball of the valve, which is held in the closed position by a spring. Without current in the solenoid coil, its core is held in the extreme upper position by a spring. When the magnet coil is excited, the core shifts towards the central position and only after having reached a certain amount of kinetic energy does it stroke on the rod in contact with the ball. In such a way the ball is set free even if it happens to have been frozen to the seal. The input power of each of the electromagnets is 3.6 W, $z = 2500$, coil resistance 105 Ω, $i = 0.185$ A. The switching circuitry ensures that, when any one of the valves is open, the other two remain closed. As long the valve is open, the LN pump is in action unless the LN level in the corresponding Dewar is already at the preset height.

The levels in the small Dewar flasks are controlled by thermocouple sensors placed at preset heights. When the LN comes into contact with the thermocouple sensor, the current in the pump is interrupted and is renewed when the LN descends. The unwanted cooling of the thermocouple sensor by cold LN vapors during the filling period is compensated by heat supplied to the active part of the sensor by conduction from the warmer parts of the apparatus, keeping the sensor temperature above that of LN.

The common body of the valve is made from teflon to minimize evaporation of liquid nitrogen and at the same time to insulate the valves thermally from the solenoids. For reliable action of the system the air moisture must be prevented from entering the inner parts of the system which are in contact with LN. This is accomplished by rubber gaskets, both in the pumping system and in the distribution valve, situated at places remaining at all times at or near to the room temperature.

The transfer of LN to one of the three Dewars is started by pushing the button switch of the corresponding valve. The starting of the pump is bound to the opening of the valve. The filling and maintenance of the preset LN level in the Dewar is fully automatic.

4 Conclusion

No effects of atmospheric moisture on the function of the distribution valves were observed. In particular, the system did not manifest any tendency to freezing of the nitrogen and clogging the transfer lines or the distribution valves.

References.

[1] Vognar, M., Šimáně, Č. : *Laboratory apparatus for preparation of ^{123}I from ^{124}Xe by photonuclear reaction*. Acta Polytechnica, 5(1996), pp. 49–56

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