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A MECHANICALLY CONTROLLED CRYOSTAT

DONNER LABORATORY

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MECHANICALLY CONTROLLED CRYOSTAT*

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This note describes a low cost device for controlling a wide range of low temperatures using a cryogenic liquid as a refrigerant. A vapor pressure thermometer provides the error signal to meter the flow of the refrigerant into a heat exchanger to maintain an object at a constant temperature. The heat may be transferred between the heat exchanger, the test object, and the thermometer by conduction in a solid or by convection in a gas or a liquid. The system can quickly respond to fluctuating heavy heat loads.

In our specific example shown in Fig. 1 the system was constructed for the purpose of liquifying xenon (-105°C at 3.8 psig)[(3)] in a test chamber inside a Freon-11 bath (freezing point -111°C).[1] Another useful liquid for the purpose of heat transfer in the bath is a mixture of 70% commercial-grade n-hexane and 30% cyclohexane (melting point ≃-105°C). Liquid nitrogen is stored in a standard "chicken-feeder" type dewar and is gravity fed into the heat exchanger cup via a control valve. The heat exchanger is submerged in the liquid bath where the test object is located. The temperature of the bath is sensed by a vapor pressure thermometer that contains, when cold, a partially liquified gas. The vapor pressure developed in the sensor causes the bellows to move and actuates the control valve through a linkage. The valve movement is proportional to the difference between the measured temperature and desired temperature. To prevent bubbling back through the control valve, the boil-off gas released in the heat exchanger cup is vented through holes in the vent tube. The vent holes are located inside the liquid nitrogen dewar for the following purpose: upon initial cool down, violent boiling takes place at the hot walls of the heat exchanger, expelling a mixture of liquid and gas through the vent holes. The liquid portion is then captured in the upper dewar.

Figure 2 shows the vapor pressure vs temperature relationships for various common gases that may be used in the vapor pressure thermometer. For a given gas the temperature can be controlled over a span of ~ 30°C by adjusting the pressure that opens the valve. The slope of the vapor pressure curves is typically 0.7 psig/°K which is sufficient, in practice, to provide enough force for control within a fraction of a degree. The ball valve opening is set by adjusting the force of the spring or the length of the pull rod (Fig. 1).

The liquid nitrogen dewar was a standard "chicken-feeder" type of 7-liter capacity[2]. The valve was assembled from a dia. 12mm brass ball drilled and brazed to the 7mm diam., 34 cm long stainless vent tube. The seat of the ball, at the tip of the "chicken-feeder" dewar, was ground by another identical ball and an abrasive compound. The expansion bellows were made from 38mm diam. brass bellows brazed to plugs at both ends. The vapor pressure thermometer was made of 3.1mm diam. stainless tube brazed to a 4.7mm diam., 5 cm long copper tube. For our purpose it was charged with 25 psig of xenon via a valve (not shown). The cup was constructed of a double walled vacuum jacket and a copper bottom. For most applications a vacuum jacket may not be necessary and a simple thin wall cup may suffice. The surface area of the heat exchanger was increased by brazing copper fins to the bottom of the cup.

A test was conducted in a glass dewar containing 3 liters of Freon-11. It took approximately two hours to cool the bath at a constant rate of 1.2°C/min, from room temperature to -105°C (168°K). This corresponds to ~80 watts of cooling capacity. The nearly constant rate of cooling indicates that, in this case, the rate was not limited by heat transfer but rather by the flow of nitrogen through the system. The temperature was controlled to better than $\pm 1°C$.

Acknowledgments

I wish to thank Tony Vuletich and Joe Savignano for suggestions and construction, and Steve Derenzo for helpful discussions.

Footnote and References

* Work performed under the U.S. Energy Research and Development Administration and the National Institutes of Health.

1. Haim Zaklad, Stephen E. Derenzo, Thomas F. Budinger. Liquid xenon multiwire proportional chambers for nuclear medicine applications. Proc. First World Congress of Nuclear Medicine, Tokyo, Japan, Sept. 1974.
2. Minnesota Valley Engineering, Inc., New Plague, Minnesota.
3. 1 psi = 0.068 atm.

Figure Captions

Fig. 1. Schematic diagram of mechanically controlled cryostat.

Fig. 2. Vapor pressure curves vs temperature for various substances, for a range of working pressure, 6 to 60 psia.

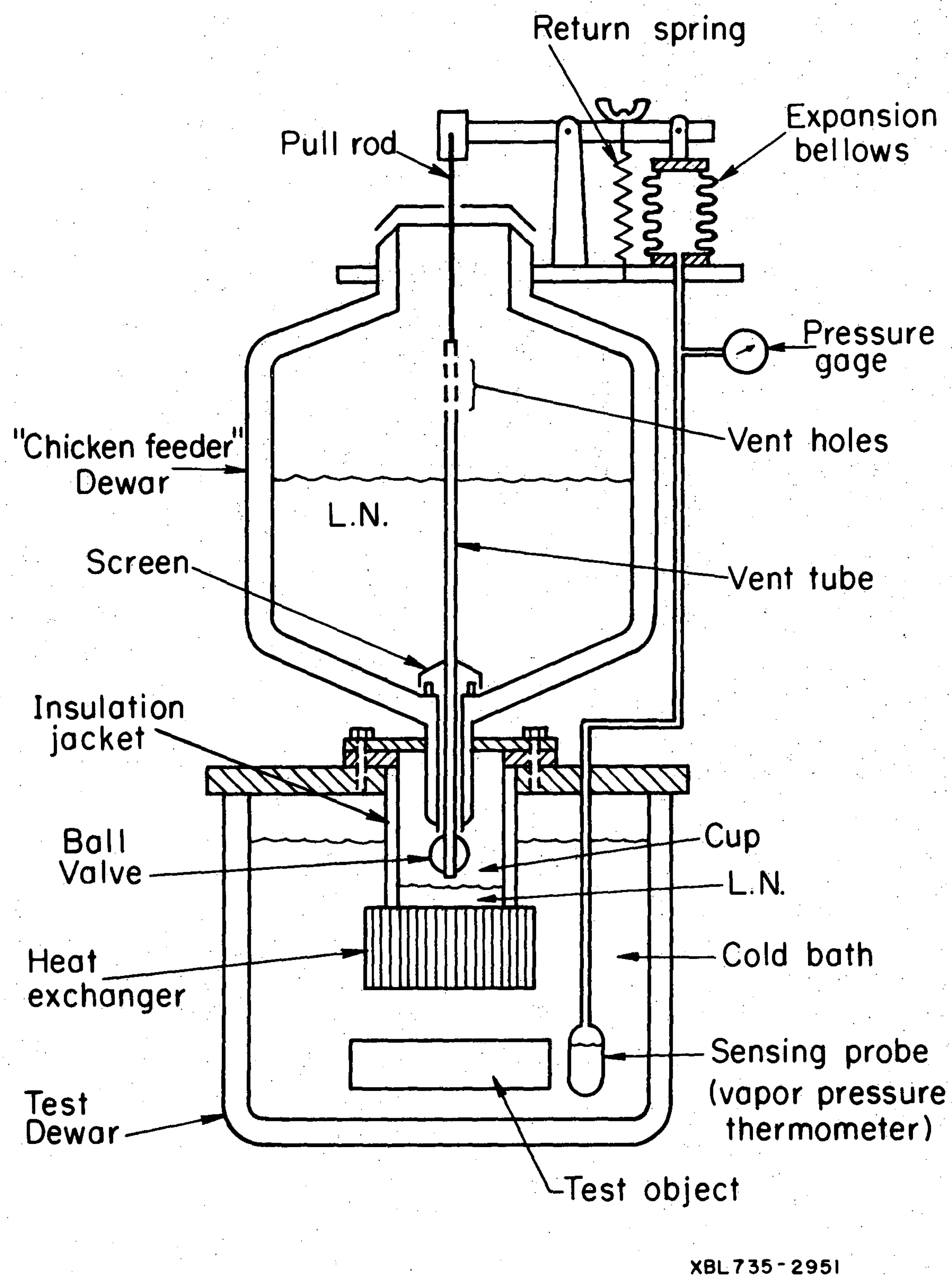
Return spring
Pull rod
Expansion bellows
Pressure gage
Vent holes
"Chicken feeder" Dewar
L.N.
Screen
Vent tube
Insulation jacket
Ball Valve
Cup
L.N.
Heat exchanger
Cold bath
Sensing probe (vapor pressure thermometer)
Test Dewar
Test object
XBL735-2951

Fig. 1

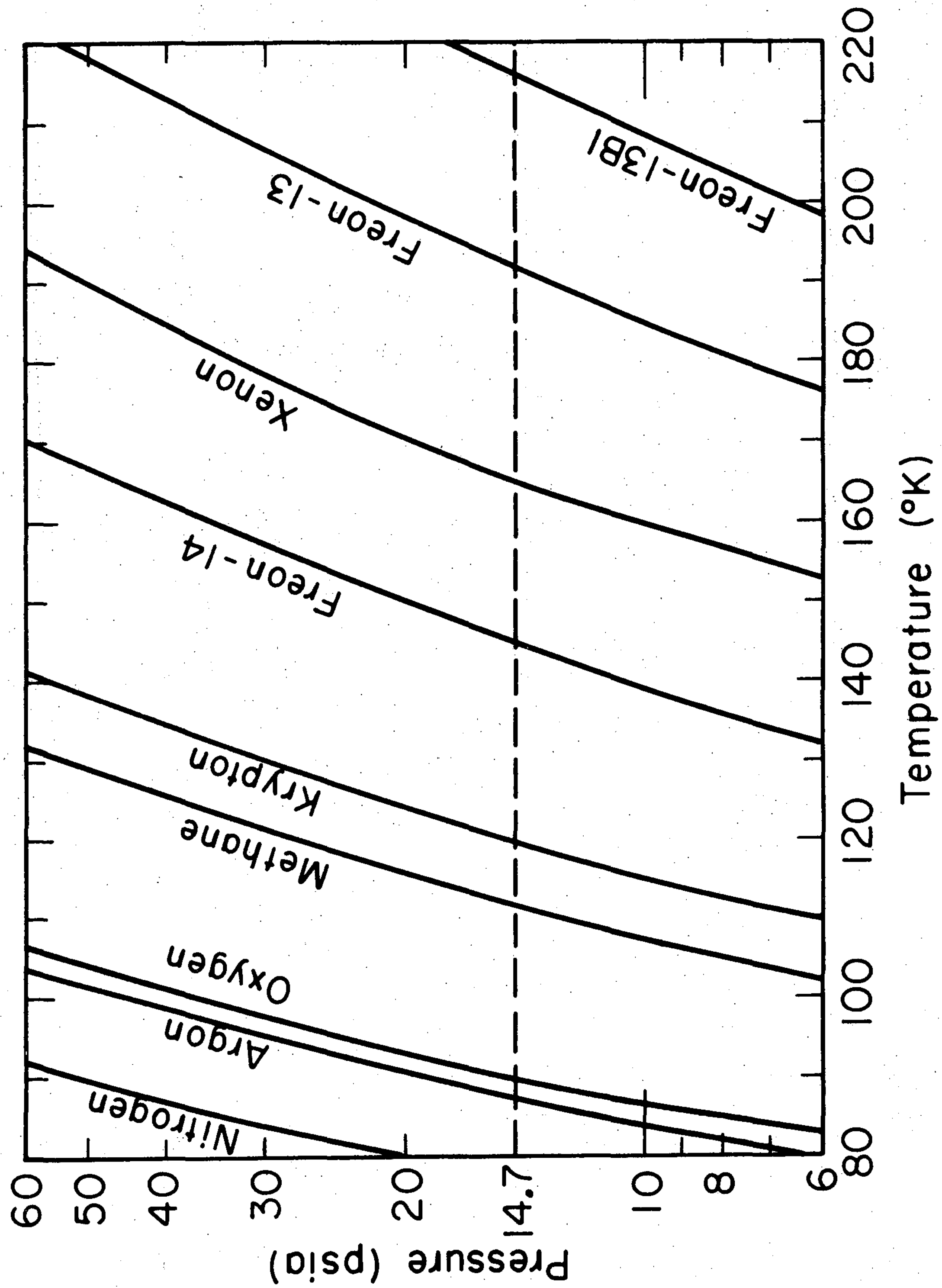

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Fig. 2

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