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ABSTRACT

A system for measuring depths of cryogenic liquids is described. The indicating device is a commercial differential-pressure gage; the level-sensing probes are of various types, either permanent or removable. The heat leak to the cryogenic liquids may be made negligibly small.

The depth of a cryogenic liquid can be measured easily and fairly accurately by using the system described here. The system consists essentially of a level-sensing probe having a low- and a high-pressure tap (see Fig. 1), and a Magnehelic gage.[1] The latter is a very sensitive differential-pressure gage which has long been used to measure the depths of cryogenic liquids. The idea of using this gage apparently originated at the National Bureau of Standards at Boulder, Colorado about a decade ago. Documentation of the use of this gage has been limited to that of R. L. Goodwin[2] and more recently that of Trujillo and Marino.[3] For all its great sensitivity, this original gage (the 1000 series) has a number of mechanical faults which make its accuracy low and its reliability questionable. The manufacturer has recently done a first-class job of redesigning this gage (the 2000 series). All previous faults are corrected and the gage is now accurate and reliable. The most sensitive model has a full scale range of 7 in. of liquid hydrogen (1/2 in. of water) and a least count of 0.14 in. of liquid hydrogen.

The level-sensing probes used with these gages may be either permanent or removable. The permanent probes are those commonly used to measure a hydrostatic differential pressure, with the low-pressure tap coming from the vapor space above the cryogenic liquid and the high-pressure tap coming from the bottom of the liquid container. This latter tap can be protected from the inevitable debris at the bottom of these vessels either by entering the container through the side wall very close to the bottom, or by entering through the bottom and making a right-angle bend a short distance above the bottom. This high-pressure tap is a thin-walled stainless steel tube (about 1/8 or 3/16 in. o. d.) wound in a spiral or helix with a slight upward cast from the horizontal. The length of tube in this coil minimizes the heat leak; the upward cast insures the presence of a stable boiling interface. The free end of the stainless steel coil is connected to a copper tube of low thermal resistance which is then led out the top flange of the vacuum jacket. The vertical height of the stainless steel coil is of the order of 1/2 or 1 in.; the boiling/condensing interface occurs somewhere in the length of the coil.

The removable probes are of the gas bubbler type. The low-pressure tap again enters through the neck of the vessel and sees the vapor above the cryogenic fluid. The high-pressure tap sees the liquid at the bottom of the container by means of another tube entering through the neck of the vessel. A liquid - vapor interface is kept at the bottom of this tube by continuously or intermittently bleeding in a gas that does not condense at the temperature of the liquid being measured. Liquid-hydrogen levels can be sensed by this probe by slowly injecting helium gas in the high-pressure tap. Although such probes work fairly well, some oscillations are usually present.

A probe that gives transient readings only may be regarded more as a laboratory curiosity than anything else. The high-pressure probe is a thin-walled plastic tube. The lateral thermal resistance of this tube is increased by slipping several additional close-fitting concentric plastic tubes over it (Kel-F electrical spaghetti works well), or by wrapping it continuously with many layers of thin plastic film, such as Mylar. The additional plastic must be sealed to prevent entry of the fluid between the laminations. A hand pump or squeeze bulb of several cc capacity is externally connected to take suction from the low-pressure probe and exhaust into the high-pressure probe. In operation, the bulb is squeezed rapidly until the needle of the Magnehelic gage reads full scale; pumping is stopped, the needle rapidly drops until it indicates the level of the fluid, the needle pauses here for a few seconds and then slowly drifts lower as the injected gas condenses. Such a system works well with liquid nitrogen; with liquid hydrogen the operation is only fair, as the oscillations present necessitate quite a bit of damping.

The ultimate in removable probes is the vacuum-insulated high-pressure probe which generates its own gas. In this version the high-pressure probe is a small thin-walled stainless steel tube which is completely surrounded by an annular vacuum jacket. Such a probe is, of course, easily removable from a dewar by means of slip-through fittings or locks. At Berkeley our 150-liter industrial-type liquid-hydrogen dewars are purchased with neck tubes about 1-1/2 in. i. d. so that these high-pressure probes may be installed parallel to the eductor tube. By adding a low-pressure tap and a Magnehelic gage, we have an accurate and continuous indication of the amount of liquid hydrogen in the dewar at all times.

This probe works equally well in liquid nitrogen, hydrogen, or helium. The high-pressure probe is typically a 1/8-in.-o. d. stainless steel tube with a 0.006-in. wall and the vacuum jacket is a 3/8-in.-o. d. stainless steel tube with a 0.006-in. wall. For radiation shielding, several layers of Mylar and aluminum foil are placed around the high-pressure probe in the vacuum space, and plastic spacers are used about every 18 in. to maintain annularity of the vacuum jacket and probe. They have been made up to 5 ft long. One can avoid the use of bellows by making a sharp right-angle bend at the top of this "dip-stick" assembly and properly springing the high-pressure probe before the final joint is soldered.

Two or more Magnehelic gages can be put in parallel to read from the same probe. As much as 40 ft of 1/8-in.-i. d. tubing has been used to connect the gage and the probe. Because of the high sensitivity of the gage, all connecting systems must be vacuum-tight to avoid erroneous readings.

All differential pressure systems lose accuracy when gaging cryogenic liquids at several atmospheres pressure, and the system described here is no exception. But for continuous reading in general laboratory usage at pressures of from 1/2 to 2 or 3 atmos. the Magnehelic gage is unbeatable for convenience, reliability, and versatility.

FOOTNOTES AND REFERENCES

*This work was done under the auspices of the U. S. Atomic Energy Commission.

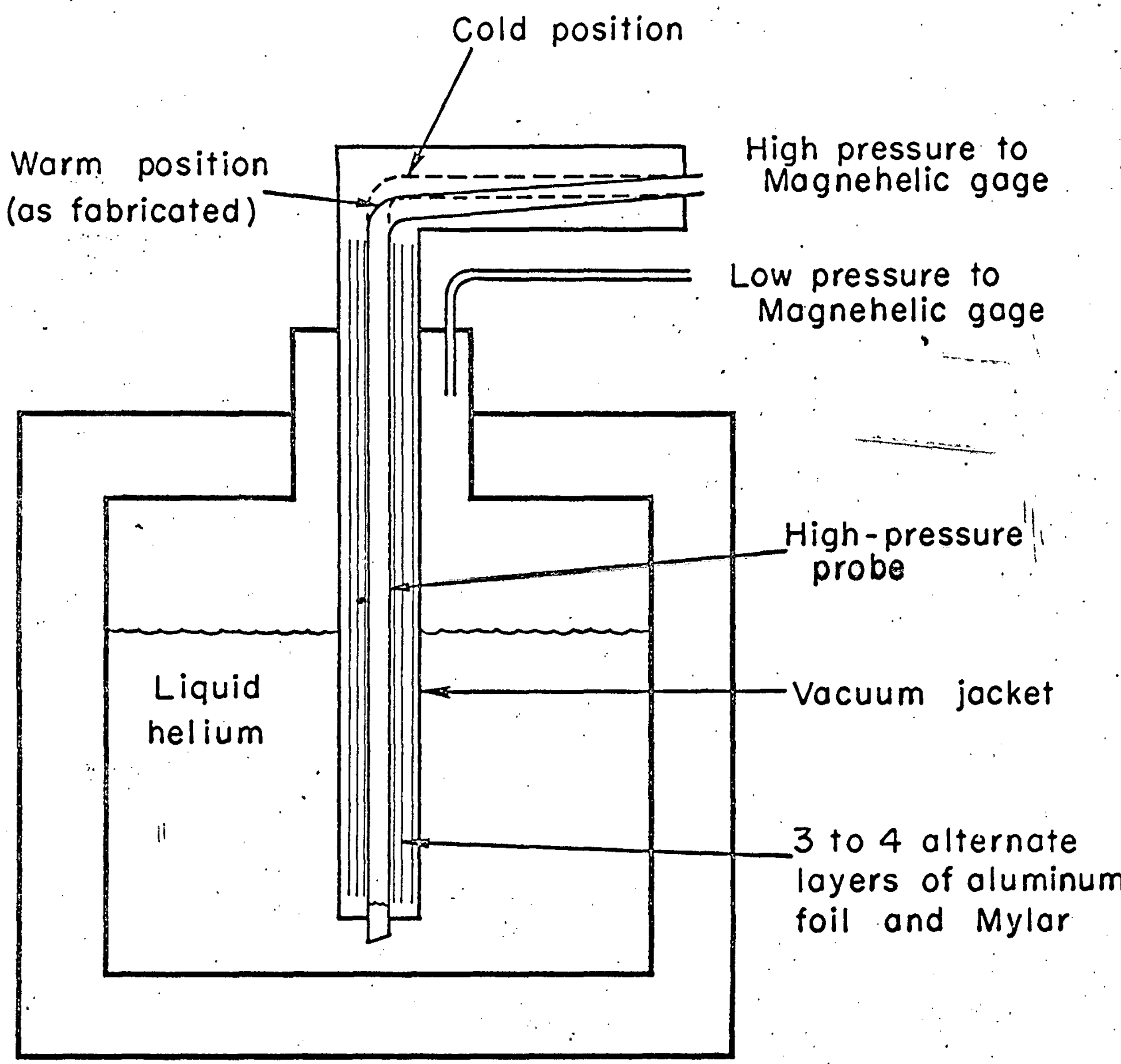
1. Manufactured by F. W. Dwyer Co., Michigan City, Indiana.

2. R. L. Goodwin, Rev. Sci. Instr. 26, 1052 (1955).

3. S. M. Trujillo and L. L. Marino, J. Sci. Instr. 41, 184 (1964).

FIGURE LEGEND

Fig. 1. Vacuum-insulated high-pressure probe for determination of cryogenic-liquid depth.


Cold position
Warm position
(as fabricated)
High pressure to
Magnehelic gage
Low pressure to
Magnehelic gage
High-pressure
probe
Liquid
helium
Vacuum jacket
3 to 4 alternate
layers of aluminum
foil and Mylar

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