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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 probe may be fixed or removable. The heat leak to the cryogenic liquid may be made negligibly small.

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

The depth of a cryogenic liquid can be measured easily and fairly accurately by using the system described here. This system is a refinement of an ancient technique for finding depths of liquids by using a tubular probe or "dipstick" and a differential-pressure gage. The gage is connected so that its low-pressure side senses the pressure of the vapor space above the liquid, the high-pressure side of the gage is connected to a tubular, open-ended probe which is inserted through the neck opening and which reaches nearly to the bottom of the dewar or cryostat. If, now, the high-pressure probe can be kept full of gas to keep the liquid from intruding into it, the gage will indicate a pressure that is almost entirely due to the hydrostatic head of liquid above the bottom of the probe.

Actually the indicated pressure is the sum of the ρgh of the vapor between the low-pressure probe and the liquid surface, plus the ρgh of the liquid between its surface and the bottom of the high-pressure probe, minus the ρgh of the gas within the high-pressure probe. If, for convenience sake, the gage is given a linear calibration for the liquid density at atmospheric pressure, the accuracy of indication may be significantly affected by the conditions within the dewar itself. At very low levels of liquid, the hydrostatic head of the vapor above the liquid may be greater than the head of the liquid itself, and consequently the gage will indicate much more liquid than is actually present. At pressures greater than atmospheric, the gage indicates less than the actual level, although it gives a more accurate indication of the mass of the liquid, and it is evident that the ρgh of the gas in the high-pressure probe will have little effect on the accuracy of the system if the average temperature of this gas can be kept well above the temperature of the liquid. Obviously the gage can be given a nonlinear calibration and a calibration for pressures other than atmospheric. But in spite of all these qualifications such a system is a handy utilitarian tool for finding liquid levels in dewars and cryostats under normal laboratory conditions.

All the above is dependent on keeping the liquid from intruding into the high-pressure probe, and there have been numerous approaches to this aspect of the problem. Hereward (1951) used polyvinyl chloride sleeving for the high-pressure probe and kept liquid air from entering the probe by inserting therein a 1/16-in.-diam copper wire or a 1/8-in.-diam brass rod which boiled off about 1 cc/sec of gaseous air. His indicating device was a water or oil manometer. Goodwin (1955) measured the level of liquid nitrogen in an ordinary supply dewar by inserting a tube (probably metallic) down the neck of the dewar to act as the high-pressure probe and slowly bleeding into this probe a noncondensable gas. He used a Magnehelic gage* to measure the differential pressure produced. Trujillo and Marino (1964) also used a Magnehelic gage; their high-pressure probe was a 1/8-in-diam stainless-steel tube parallel to and soldered to the dewar eductor tube. A nichrome wire, insulated by means of ceramic tubes, traversed the inner length of the high-pressure probe. In operation, 20 V a.c. was applied to the wire until enough liquid nitrogen had boiled to leave the probe full of vapor.

The high-pressure probe used in the present work was vacuum-jacketed. The vacuum jacket provides thermal insulation to keep the probe warmer than the cryogenic liquid everywhere except at the lower end of the probe where the vacuum jacket ends and the open bottom of the probe is in contact with the liquid. Such a probe works equally well

*Manufactured by F. W. Dwyer Co., Michigan City, Indiana, U.S.A.

in liquid nitrogen, hydrogen, or helium. The thermoacoustic oscillations usually present in an open-ended tube in liquid helium do not occur in a vacuum-jacketed tube, as has been noted by Clement and Gaffney (1955).

We have installed in 150-liter industrial-type liquid-hydrogen dewars high-pressure probes that are 1/8 in. o. d. with a 3/8 in. -o. d. vacuum jacket; both tubes are stainless steel with 0.006-in. wall. For radiation shielding, to prevent excessive heat loss from the probe, several layers of Mylar and aluminum foil are wrapped around the high-pressure probe in the vacuum space, and Teflon plastic spacers are used every 18 inches to maintain annularity of the vacuum jacket and probe. These probes have been made up to five feet long and are easily installed and removed by means of slip-through fittings or locks. One can provide for the difference in thermal contractions of the vacuum jacket and probe and avoid the use of bellows by making a sharp right-angle bend at the top of this dipstick assembly and properly springing the high-pressure probe before the final joint is soldered. A typical probe assembly installed in a dewar is shown in Fig. 1. By adding a low-pressure tap and a Magnehelic gage (the 2000 series) we have a continuous indication of the amount of liquid hydrogen in the dewar at all times. The accuracy is about ±3% of full scale. 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 plumbing must be vacuum-tight to avoid erroneous readings. Obviously the low-pressure tap can be installed as an annulus around the high-pressure probe. Now the entire system becomes a portable, self-contained, sturdy instrument that can be installed on any dewar or cryostat that carries the proper mounting fixture.

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FIGURE LEGEND

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

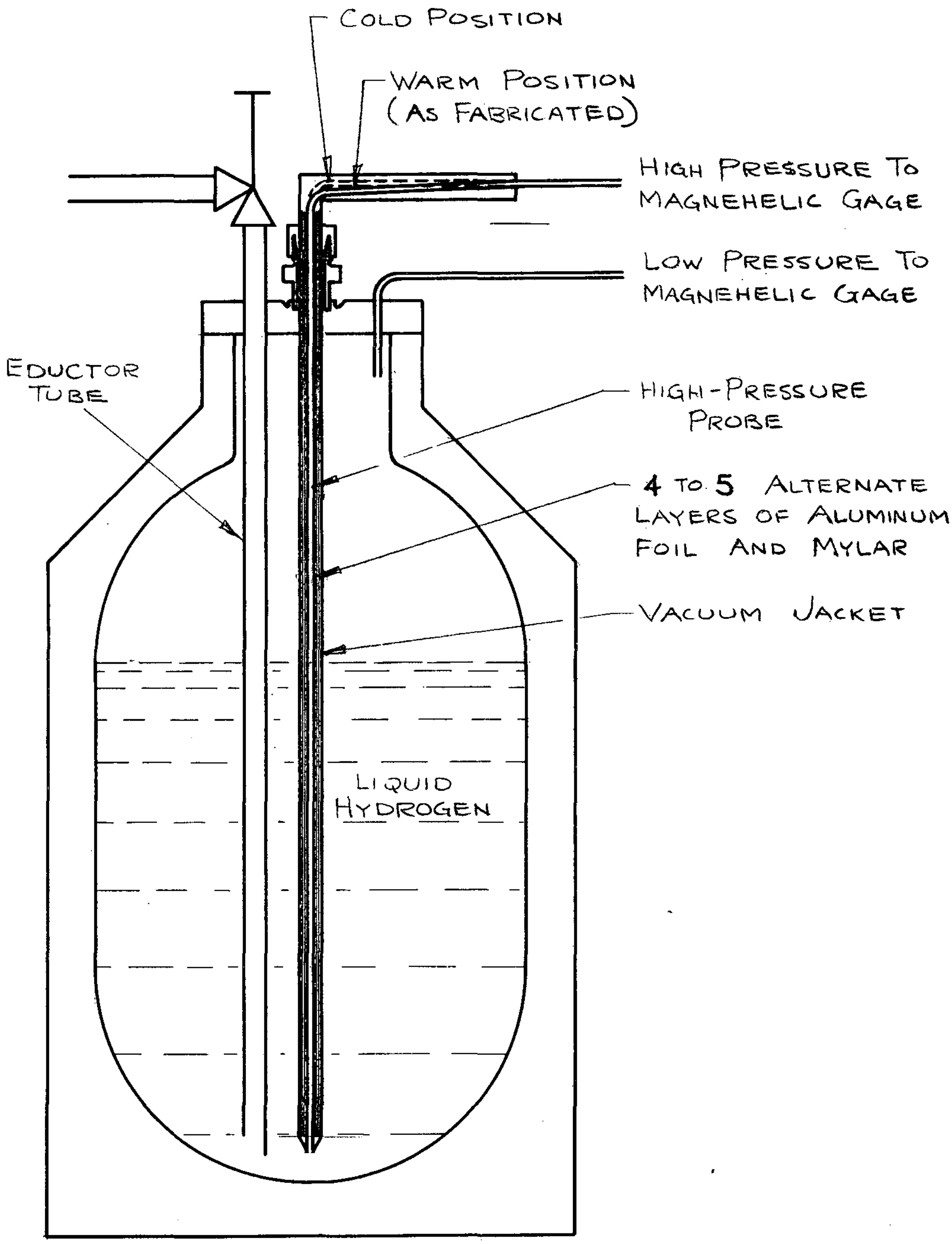

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Fig. 1