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HELIUM GAS PURITY MONITOR FOR RECOVERY SYSTEMS*

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An inexpensive, direct reading, electro-acoustical system is described which continuously monitors the amount of air present in helium gas being returned to a recovery/re-liquification installation. Contamination as small as 0.1% is easily detectable.

1. INTRODUCTION

A common problem with the use of helium recovery systems is the inadvertent introduction of air into the recovery lines. We have constructed a device which determines gas purity by measuring the speed of sound in the helium-air mixture. This is accomplished by monitoring the frequency of the fundamental plane-wave resonance of the gas in a cylindrical resonator. Similar systems have been proposed[1] and constructed[2,3] to determine the isotopic concentration of ^{3}He-^{4}He gas mixtures. For an ideal gas, the square of the sound speed, $c^2 = \gamma RT/M$, where γ is the ratio of specific heats, R the gas constant, T the absolute temperature and M the mass of a mole of gas. For a mixture of N_a molecules of air and N_h atoms of helium, we define the fractional impurity, $X = N_a/(N_h + N_a)$. The ratio of the resonant frequency of the mixture, f_x, to that of the resonator filled with pure ^{4}He, f_h, is:

$$\frac{f_x}{f_h} = \left[\frac{1 + \gamma' X}{1 + M' X}\right]^{1/2}$$

where $\gamma' = (\gamma_a - \gamma_h)/\gamma_h = -0.158$ and $M' = (M_a - M_h)/M_h = 6.236$. For nearly pure ($X \ll 1$) ^{4}He at room temperature, this corresponds to a sensitivity, $\Delta f_x/f_h = 3.2\ X$. Under the same conditions, changes in gas temperature give $(1/f_h)(\Delta f/\Delta T) = 1.7 \times 10^{-3}/°K$.

2. SOUND CELL

The sound cell is a cylindrical metal cavity with diameter and length equal to 2.54 cm. The ends are closed by simple homemade electret transducers.[4] A small slot (0.16 cm × 1.6 cm) at the cylinder midplane connects the cell with the helium recovery line without appreciably degrading the Q of the fundamental resonant mode (∿100). The calculated diffusion time between the cell and the helium line is about 25 sec. The mixture thermally equilibrates with the cell walls in approximately 1 sec. Changes in cell body temperature are monitored by changes in resistance of a spool containing 37 m of #44 copper wire (∿350Ω) epoxied to the cell body.

The transducers are made by permanently polarizing[5] a 12μ thick sheet of teflon aluminized on one side.[6] A disk of this material is electrostatically held against a sandblasted metal electrode which forms the electrically active element in the transducer. The aluminized side is connected to ground. A few small slits, approximately 1-2 mm in length, are made in the teflon with a razor blade to allow slow pressure changes to equilibrate behind the diaphragm. The use of pre-charged electret material eliminates the need for bias supplies ordinarily present in conventional capacitive transducers.

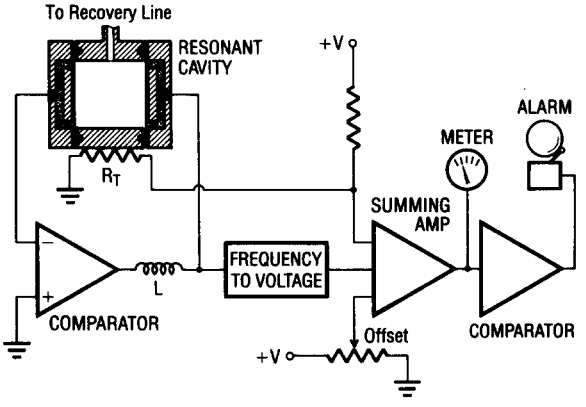

Figure. Block diagram of sound cell and electronics.

3. ELECTRONICS

A block diagram of the electronics[7] is shown in the figure. The cavity, inverting comparator and inductor form a self resonating system. The frequency to voltage converter (a

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tachometer I.C.) produces an analog signal which is summed with the thermometer signal and an offset voltage which is initially set by making the summing amplifier produce zero output when pure helium is in the resonant cavity. The meter's face is calibrated to read air contamination directly and the comparator is biased to activate an alarm when the impurity content exceeds ¼%

4. OPERATION

The self resonant system will track the fundamental plane wave mode up to air concentrations of about 7% before it jumps to a higher mode at which point the summing amplifier goes to a negative value. This causes no confusion because the comparator circuitry is set to maintain the alarm activated under these circumstances.

Four prototype units have been constructed and tested. At this time (March 1981) one unit has been installed in the recovery system and performs as expected. We plan to install these purity monitors at all our recovery stations.

5. ACKNOWLEDGEMENTS

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[7] A complete schematic is available by writing the last author.