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A CRYOSTAT FOR INVESTIGATING SPIN POLARIZED HYDROGEN*

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A low temperature spin polarized hydrogen apparatus is discussed. Fluxes into the hydrogen cell of 10^{14} atoms/sec have been achieved. Hydrogen atom concentrations of 1×10^{16} atoms/cm^3 have been observed in fields of 9 Tesla and at 0.6 K, as determined by strain gauge measurements and calorimetric methods.

Unlike other spin polarized hydrogen apparatuses described in the literature, in which the atomic hydrogen is created in a cryogenic environment [1,2], or brought into the high magnetic field region in an inverted configuration through the bottom of the magnetic solenoid [2,3], the atomic hydrogen is brought into our apparatus from room temperature through the top of the dewar (see Figure 1). We feel that this configuration has a number of significant advantages over other configurations. Locating the R.F. dissociator in the accessible room temperature region makes it convenient to tune and monitor the performance of the hydrogen dissociator for optimum atomic hydrogen yield. The upright configuration in which the hydrogen enters the high field region through the top of the solenoid, as opposed to the more commonly used inverted configuration, is also convenient from the standpoint of using a Toepler pump method for compressing the hydrogen sample [4], or using hydraulic valves to seal off or move volumes of atomic hydrogen gas.

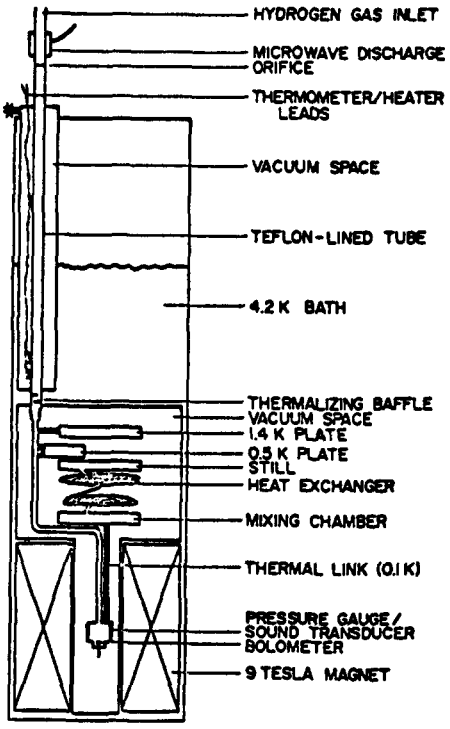

FIGURE 1. Configuration of the Cornell spin aligned hydrogen cryostat. Not drawn to scale.

Perhaps the biggest disadvantage to our configuration is the long path required to bring the hydrogen from room temperature to the sample chamber. For our apparatus the distance from room temperature flange to the exchange gas can flange is 86 cm. The hydrogen is transported from room temperature to the exchange gas can flange through a teflon tube [5] which is inserted in a 1.27 cm i.d. stainless steel tube. The stainless steel tube itself is inserted coaxially in a larger stainless steel tube, the space between the tubes being evacuated. Heaters located on the inner stainless steel tube make it possible to keep the teflon tube at any temperature between 4 K and room temperature. Room temperature measurements done with an X-band E.S.R. spectrometer have demonstrated that atomic hydrogen can be transported through a meter length of teflon tubing without severe loss of atomic hydrogen due to recombination.

The biggest loss of atomic hydrogen in our apparatus appears to be in the 4 K region. Our best performance to date has been obtained with the configuration shown in Figure 2, where the transition from high temperatures to 4 K was made as short as possible by bringing the warm teflon tube into the 4 K baffle region. The transition from the 4 K baffle region to the .6 K ^{3}He pot was also made as short as possible without putting an excessive heat load on the ^{3}He pot due to thermal conduction down the stainless steel tube between the baffle and the ^{3}He pot. All metal surfaces exposed to atomic hydrogen were coated with teflon.

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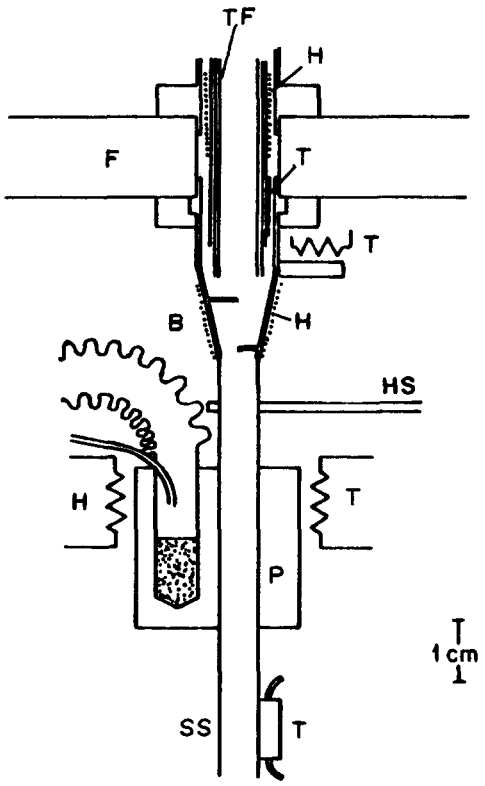

FIGURE 2. Thermalizing baffle region. TF is the teflon tube through which the atomic hydrogen enters the baffle region. F is the 4 K flange. B is the 4 K baffle. T corresponds to thermometer, H corresponds to heater. HS is the heat sink to 1.4 K plate. P is the ^{3}He pot, at .6 K. SS is the .63 cm I.D. stainless steel tube through which the hydrogen passes to the sample cell.

With this configuration we were able to obtain a hydrogen flux of 10^{14} per second into the sample chamber. To trap and stabilize the sample at low temperature we are currently operating with a 5.7 cm bore 9 Tesla superconducting solenoid which, in the sample chamber region, has a homogeneity of one part in 10^5 over a spherical volume with a 1 cm radius. Shim coils are in place which can improve the homogeneity by a factor of 10. This may be important for the magnetic resonance experiments on atomic hydrogen which are presently under development.

The sample chamber itself currently has two capacitance strain gauges for monitoring the gas pressure of atomic hydrogen. The diaphragms of our strain gauges are 1.27 cm in diameter and are made from 6 μm mylar aluminized on one side. The total capacitance of one of our strain gauges is typically 50 pf and has a sensitivity of 7.6 pf/Torr as determined by electrostatic and ^{4}He vapor pressure calibration. The sample chamber also has a pair of bolometers of the type described by Silvera and Walraven [3]. These bolometers are useful for destroying the atomic hydrogen sample and for detecting very small quantities of hydrogen, (less than 10^{14} atoms). Our sample chamber thermometer is a Speer 220 Ω resistor which has been calibrated in the region from .1 K to 1 K against a calibrated germanium thermometer. We have been able to determine hydrogen densities both with the strain gauge and calorimetrically by measuring the amount of heat liberated as a result of the hydrogen recombination during a bolometer heat pulse. Thus we were able to check that the two types of measurements were consistent with each other. The largest hydrogen density we have been able to build up to date is 1×10^{16} atoms cm^{-3}. This density was achieved with the sample chamber temperature near .6 K. Our dilution refrigerator has a bottom temperature of 50 mK. Presently, our refrigerator is able to maintain the sample chamber below .5 K only with unsaturated ^{4}He films, the principal heat leak to the sample chamber resulting from ^{4}He gas fluxing from the ^{3}He pot region to the sample chamber. Efforts are underway to increase the cooling power of our ^{3}He pot by installing a larger pumping line and a diffusion pump. This should significantly reduce the heat load into the sample chamber.

References

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[5] Our supplier of TFE teflon flexible tubing is AIN Plastics Inc., 160 MacQuesten Parkway, South Mount Vernon, NY 10550.