HORIZONTAL DILUTION REFRIGERATOR FOR USE IN INTENSE PROTON BEAMS

J.A. Bywater*
Argonne National Laboratory, Argonne, IL 60439

P.R. Cameron and D.G. Crabb
University of Michigan, Ann Arbor, MI 48109

ABSTRACT

A fast loading high-power horizontal dilution refrigerator insert has been built for use in the Michigan Polarized Proton Target (PPT V). This PPT will be used in measurements of spin effects in high $P_\perp$ elastic p-p scattering at the Brookhaven AGS. The cooling power is compared with the existing interchangeable ^{3}He evaporation insert, and with similar dilution refrigerators at CERN and Bonn. The relative merits of these two types of refrigerators in absorbing the heat loads of high intensity beams is discusssed.

INTRODUCTION

The construction of high-power fast-loading[1,2] interchangeable[1] dilution refrigerators has been completed at several laboratories. The emergence of NH_3 as a radiation resistant target material[3,4,5,6] has shifted the limiting factor in beam intensity from target materials to bead cooling. Arguments previously advanced[7,8] suggest that the dilution refrigerator possesses a great advantage in this respect.

EVAPORATION VS. DILUTION

The performance of the three comparable dilution refrigerators (Fig. 1) is quite similar. The maximum cooling power is much less than that of the U of M ^{3}He refrigerator. Also shown is the performance of a hypothetical dilution refrigerator, whose maximum cooling power is equal to that of the ^{3}He refrigerator. It is seen (Fig. 2) that the calculated[7,8] bead temperature (for 1.5 mm dia. beads) is a strong function of heat load for the ^{3}He refrigerator, and surprisingly independent of maximum cooling power in the case of the ^{3}He/^{4}He refrigerator. In transforming the Q_{total} of the lower scale in Fig. 2

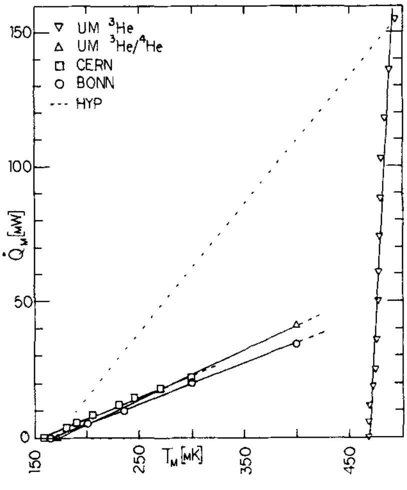

Fig. 1 - Cooling Power

*Present address: Fermi National Laboratory, Batavia, IL to protons per second in Fig. 3 the target mass was taken to be 10g for the $^3He/^4He$ refrigerator and 17g for the ^3He refrigerator, and μwave heating 0.5 mwatt/g to the beads. A Gaussian beam profile is assumed with 95% (2σ) of the beam in the target. Using the calculated T_{beads} of Fig. 2 it is possible to extrapolate a target polarization $P=\tanh(E_{nh}\,\mu B/kT)$. The numerical value of the enhancement factor E_{nh} is found to be 237 by assuming 50% proton polarization in a ^4He evaporation refrigerator with 1.1K bath (and bead) temperature. Conversely, for thermal equilibrium conditions $E_{nh}=1$ and bead temperature may be calculated from the above relation after measuring P (the so-called 'inverse thermal' technique).

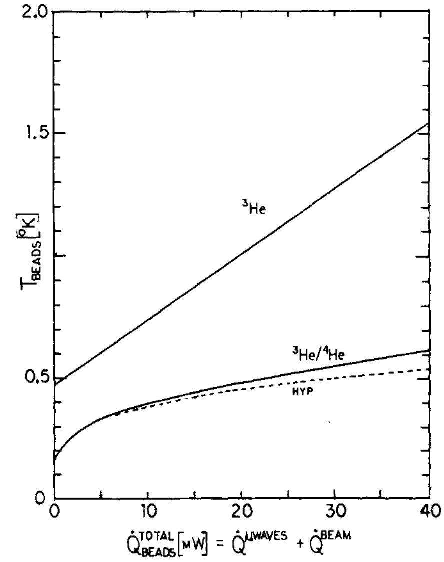

Fig. 2
Bead Temperature vs
Internal Heating

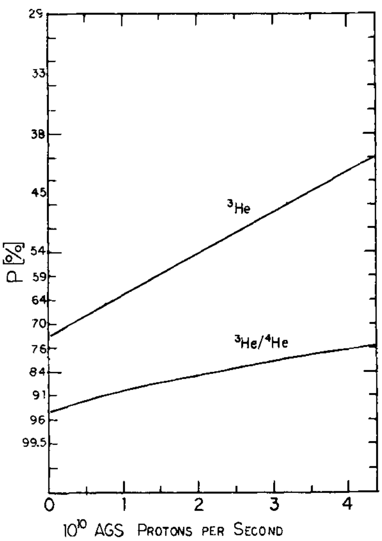

Fig. 3
Target Polarization
vs. Beam Heating

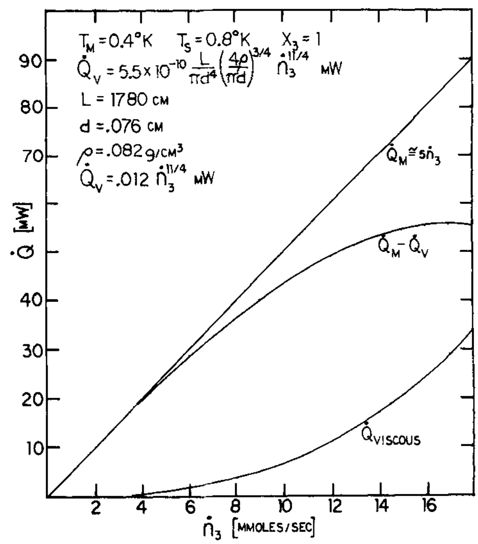

Fig. 4
Viscous Heating in
the Concentrated Stream

CONCLUSION

While it appears that the $^3He/^4He$ refrigerator is much more effective in cooling the beads, a direct measurement of relative bead temperatures has not yet been made. It should be possible to do this incidental to the operation of UM AGS experiment E748 in early 1983.

APPENDIX

The literature abounds with analyses of the operation of dilution refrigerators in the range 0-100 mK. The region 100-800 mK has received much less attention. In particular, viscous heating in the concentrated stream (Fig. 4) can be surprisingly large[9]. These results are calculated for the as-built UM $^3He/^4He$ refrigerator. Most of this heat load falls upon the excess enthalpy of the dilute stream rather than the mixing chamber[10], and the available cooling power is probably only slightly diminished.

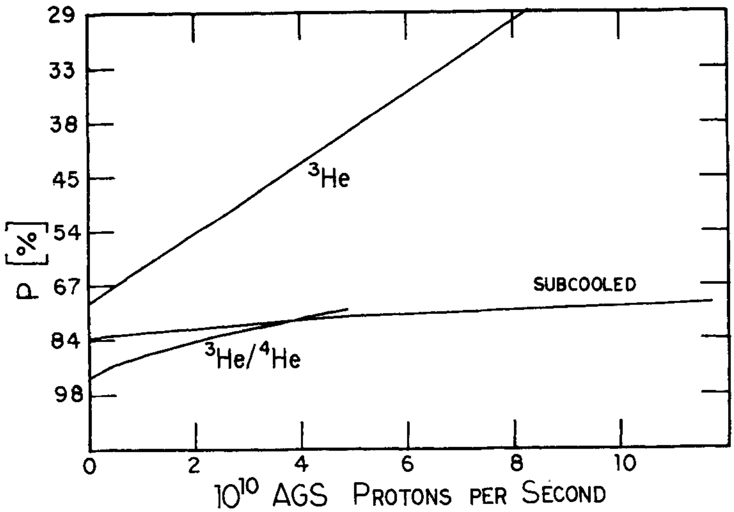

Fig. 5 - Target Polarization vs. Beam Heating

NOTED ADDED IN PROOF

It has been proposed[11] to combine the advantages of the two types of refrigerators in the subcooled ^4He technique. The device described in the Yale-SLAC proposal would use a conventional ^3He evaporation refrigerator and a heat exchanger to cool the ^4He bath.

Figure 5 shows the performance of a device in which the cooling power of the ^3He evaporation refrigerator of Figure 1 has somehow been used to subcool a ^4He bead bath. The beam heating at 10^{11} protons per second corresponds to the 150 mw of cooling power shown in Figure 1.

REFERENCES

1. T.O. Niinikoski and J.-M. Rieubland, Proc. IIR Commission A 1-2, Zurich, 181 (1978).

2. W. Meyer et al., Bonn-HE-82-12 (preprint), May, 1982.
W. Meyer et al., these proceedings.

3. T.O. Niinikoski et al., Phys. Lett. 72A, 141 (1979).

4. M.L. Seely et al., Proc. 5th Int. Symp. on Polarization Phenomena in Nuclear Physics, Sante Fe, (AIP Conf. Proceedings No. 69) P. 933 (1980).
M.L. Seely et al., these proceedings.

5. W. Meyer et al., Proc. 1980 Int. Symp. on High Energy Physics with Polarized Beams and Targets, Lausanne (Birkhauser EXS 38) p. 447 (1981) also Ref. 2) above.

6. D.G. Crabb, these proceedings

7. T.O. Niinikoski, Proc. ICEC 6, Grenoble, 104 (1976).
T.O. Niinikoski, High Energy Physics with Polarized Beams and Targets, Argonne, (AIP Conf. Proc. No. 51) 68, 1978.

8. G.R. Court et al., ibid, p. 15.

9. W. Hoppe, private communication

10. T.O. Niinikoski, private communication

11. V.W. Hughes and K.P. Schuler, SLAC Proposal-Son of E130, September, 1982.