CAMBRIDGE

Cambridge University Press
0521344565 - An Introduction to Millikelvin Technology
David S. Betts
Table of Contents
More information

Contents

Preface vii

1 Introduction to refrigeration and thermometry 1
1.1 Preamble 1
1.2 Refrigeration 1
1.2.1 Free expansion of a fluid 1
1.2.2 Isentropic expansion or compression of a fluid 2
1.2.3 Isenthalpic expansion of a fluid 5
1.2.4 Adiabatic (isentropic) demagnetisation of a paramagnet 7
1.3 Thermometry 10
1.3.1 The Kelvin scale 10
1.3.2 International practical temperature scales 12

2 Properties of fluid ^{3}He/^{4}He mixtures 14
2.1 Preamble 14
2.2 Phase diagrams 14
2.3 Dilute mixtures 17
2.4 Fermi degeneracy of solute helium-3 17
2.5 Mixtures and the two-fluid model 18
2.6 Osmotic pressure 18
2.7 Vapour pressure 21
2.8 Transport properties 21

3 Dilution refrigeration 24
3.1 Preamble 24
3.2 Evaporation cooling 24
3.3 Layout of components in a dilution refrigerator 25
3.4 Startup 30
3.5 Amount and concentration of mixture 31
3.6 The still 31

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521344565 - An Introduction to Millikelvin Technology
David S. Betts
Table of Contents
More information

3.7 How to obtain the lowest temperatures 34
3.8 Heat exchangers 34
3.9 Heat leaks 41
3.10 Construction of heat exchangers 43
3.11 Alternative methods avoiding the need for exchangers 43

4 The Pomeranchuk refrigerator 46
4.1 Preamble 46
4.2 Properties of melting helium-3 48
4.3 Cooling by solidification 49
4.4 Need to be gentle in compression 52
4.5 Some practical designs 54
4.6 Some more recent designs 57
4.7 Conclusions 59

5 Adiabatic nuclear demagnetisation 60
5.1 Preamble 60
5.2 Basic ideas 61
5.3 Entropy data 62
5.4 Ideal nuclear paramagnet 64
5.5 Reality (non-ideality) 65
5.6 Spin–lattice relaxation 66
5.7 Hyperfine-enhanced Van Vleck paramagnets 69
5.8 Geometry of the refrigerant: plates, wires, or powder? 70
5.9 Apparatuses 73

6 Thermometry 81
6.1 Preamble 81
6.2 The NBS superconducting fixed point device 83
6.3 Vapour pressure of helium-3 84
6.4 Melting pressure of helium-3 85
6.5 Carbon or germanium resistance 87
6.6 Capacitance 89
6.7 Cerous magnesium nitrate (CMN and CLMN) 89
6.8 NMR methods 91
6.9 Gamma-ray anisotropy 94
6.10 Noise thermometry 95
6.11 Conclusion 95

References 96
Index 101

© Cambridge University Press www.cambridge.org