CHAPTER II

THERMODYNAMICS OF THE ANISOTROPIC FERROMAGNET

The effect of propagating a one dimensional shock wave through a ferromagnetic material is to create a state of uniform uniaxial strain behind the shock wave. This allows use of the thermodynamics of rigid ferromagnets[5] in this region. This thermodynamic state is maintained by the inertial characteristics of the material and is difficult to obtain by means other than shock wave techniques. It will persist until perturbing waves subject the region to further change. The goal is to predict the magnetic behavior in the shocked region while it is still in a state of uniaxial strain.

The intent of this chapter is to develop consistently the thermodynamics necessary to describe an anisotropic ferromagnet[5] and to obtain the magnetic work term along with the appropriate thermodynamic equilibrium and stability criteria. A complete phenomenological energy expression will be constructed.

This chapter contains nothing that is not already in the literature. It represents a survey, from many sources, for a complete thermodynamic description of the shock induced anisotropy effect. Its content is not necessary for an understanding of the remaining chapters. The various thermodynamic terms and expressions derived in this chapter and used throughout the text have been collected in Appendix I for easy reference.

A thermodynamic approach through an energy expression rather than through direct consideration of the forces involved will be used for several reasons. First, a phenomenological approach relating the forces directly requires a stress hypothesis. Inherent in the stress formulation is a nonuniqueness in that any second rank tensor with zero divergence can be added to the stress tensor without affecting the equations of motion or the boundary conditions. This is usually of little consequence. In magnetic material, however, there is an additional complication to the nonuniqueness. This arises in attempting to separate short range magnetic forces, which will contribute to the stress, from long range magnetic forces, which will contribute to the volume force. A magnetic pole formalism, an Amperian current formalism, or any of several others gives different separation of magnetic stresses and magnetic volume forces.[5] In a thermodynamic consideration, the energy expression is unique and these complicating problems are avoided. Second, when forces are considered directly stability is checked only with difficulty. In thermodynamics stability emerges naturally and simply in the second variation of the energy expression.[13]

2.1. Magnetic Work

The magnetic work done on a magnetic system can be obtained by considering the work done by a source of emf and the related change in magnetic flux through Faraday's law. Alternately, one can obtain the same expression from Maxwell's equations by somewhat more laborious methods. The two are, of course, equivalent. The latter method will be used since this is the point at which most electromagnetic texts prematurely terminate. Also, this method more clearly shows the points at which deviation from complete generality occurs.

The work expression

$$\delta W = \frac{1}{4\pi}\int \vec{H}\cdot\delta\vec{B}\, dV + \frac{1}{4\pi}\int \vec{E}\cdot\delta\vec{D}\, dV + \int \vec{J}\cdot\vec{E}\delta t\, dV \qquad (2.1)$$