construct the distribution of magnetic dipoles in the ferromagnet against the dipole-dipole, "action at a distance" forces. This term differs from the dipole-dipole energy only by the volume integral of a term which depends on local conditions in the magnetic material and may be regarded as an energy density.[5] The first term is either the work done in storing energy in local form (expressible as a volume integral of an energy density) or the work lost in irreversible processes.

The final magnetic work is

$$\delta W = \int \vec{H} \cdot \delta \vec{M} \, dV + \delta \int \frac{H_d^2}{8\pi} \, dV. \tag{2.4}$$

Using two well known theorems from magnetostatics,[17]

$$\int \vec{H}_d \cdot \vec{B}_d \, dV = 0$$

and

$$\int \vec{H}_d \cdot \delta \vec{M} \, dV = \int \vec{M} \cdot \delta \vec{H}_d \, dV,$$

the following useful forms for the magnetic work can be obtained.

$$\delta W = \int \vec{H} \cdot \delta \vec{M} \, dV - \frac{1}{2} \delta \int \vec{H}_d \cdot \vec{M} \, dV \tag{2.5}$$

or

$$\delta W = \int \vec{H}_e \cdot \delta \vec{M} \, dV. \tag{2.6}$$

The latter is the form obtained directly from a consideration of Faraday's law relating the emf to the flux change.[5]

2.2. Thermodynamic Laws

The combined first and second law of thermodynamics states that

$$\delta U \leq T\delta S + \int \vec{H}_e \cdot \delta\vec{M}\, dV$$

in a natural process.[13] For a ferromagnet constrained to $S = S_0$ and $\vec{M} = \vec{M}_0$, this is

$$\delta U \leq 0.$$

The internal energy can only decrease. This law implies that a virtual variation of the energy with respect to internal coordinates must be zero (thermodynamic equilibrium) and that this energy be already as small as possible (thermodynamic stability).

The constraint on the magnetization is difficult to realize experimentally. The controllable parameter is the external magnetic field, $\vec{H}_e$. The usual thermodynamic technique is to perform an appropriate Legendre transformation to an energy function with the controllable parameters as independent variables.[13] The energy function to be used will be

$$E = U - \int \vec{H}_e \cdot \vec{M}\, dV$$

and will be referred to simply as the energy.

$$\delta E = \delta U - \int \vec{M} \cdot \delta\vec{H}_e\, dV - \int \vec{H}_e \cdot \delta\vec{M}\, dV$$

With the combined first and second law, this becomes

$$\delta E \leq T\delta S - \int \vec{M} \cdot \delta\vec{H}_e\, dV.$$

For a ferromagnet constrained to $S = S_0$ and $\vec{H}_e = \vec{H}_{e0}$,

$$\delta E \leq 0,$$