The experiment is shown schematically in Fig. 7. If the magnetic field strength is B, and ℓ is the length of the foil perpendicular to both B and to the mass velocity, u, Faraday's law of induction reduces to:

$$\mathcal{E} = -(\partial/\partial t) \int B \cdot dA = B\ell u$$

where $\mathcal{E}$ is the emf. If we insert typical values into this expression we find

$$\mathcal{E} = 500 \text{ gauss} \times 1 \text{ cm} \times 10^5 \text{ cm/sec} = 0.5 \text{ volt.}$$

A field strength of this magnitude is readily attainable and yields an easily measurable signal at mass velocities of interest.

It is perhaps surprising, in view of the simplicity of the method, that it has not been more widely used. It cannot be used, of course, on conducting samples because eddy currents induced into the sample would distort the magnetic field.

One might suspect that the polarization field induced into an insulator, by virtue of the dielectric constant of the insulator, would distort the electric field in the wire or the magnetic field itself and influence the measurement. Detailed examination of these effects, however, shows them to be negligible.[34]

Ainsworth and Sullivan state that the method is useful up to about 30 kbar. However, it is not clear why such a limitation need be imposed; Dremin reports measurements up to about 400 kbar in glass.

When used with guns or explosives precautions must, of course, be taken to prevent the motion of the projectile or explosive gases from distorting the magnetic field.

The precision reported by Dremin is approximately 3%. As with manganin gauges thin foils are desirable to achieve high time resolution.

3. Sapphire Gauges

Some recent work has been devoted to developing sapphire as a transducer.[35] It is used in similar fashion to the quartz gauge, but depends for its operation on the change in capacitance due to the change in dielectric constant and to the reduced electrode separation resulting from shock compression.

The current developed by the gauge is a function of the mass velocity of the impacted surface; the relation is linear at low velocities and is expressed as:

$$i(t) = (VAU/\ell^2)\,[\gamma + (\varepsilon_i/U)]\,u(t), \qquad 0 < t < \ell/U$$

In this expression i(t) is the observed current, V is the initial applied voltage (of the order of 2 kilovolts), A is area of the disc, ℓ is the thickness of the disc, U the shock velocity, ε_i and γ are the unstressed permittivity and the rate of change of permittivity with mass velocity.

At higher impact velocities the relation becomes nonlinear, but can be readily expressed in terms of measurable constants of the material.

Sapphire in the 60° orientation seems to be usable at impact stresses up to 100 kbar in the sapphire. Because its shock impedance is relatively high it provides a reasonably good impedance-match to heavier metals, such as iron. The principal disadvantage is the short recording time available from reasonable crystal thicknesses, caused by the high shock speed. This time is typically 0.25 μsec.

Other materials, such as ruby and Z-cut quartz have also been examined as possible gauges of this type.[35] The lower yield stress of ruby, however, limits its usefulness to stresses below about 40 kbar. Z-cut quartz is not suitable at present because it exhibits internal conduction and noise.