We report here an analysis of pumping of blood by means of a non-invasive circulatory-assist device using the principle of Magnetohydrodynamics. This study shows that such a pump would require the application of a slowly moving axial magnetic field of strength of about $10^8$ amp turns/m (approximately $10^6$ oersteds). The results indicate that the temperature rise on account of induced currents is within permissible range.

Introduction. Circulatory-assist devices are required for carrying out cardiac operations. Present mechanical pumping systems for blood if operated for a longer period cause undesirable effects like mechanical trauma, hemolysis and thrombus formation. Therefore, we wish to study whether a non-mechanical type of magnetic blood pump as used in metallurgy for transporting molten metals, could be adapted for pumping blood. It is found from the computational results that such a blood pump is quite feasible.

Principle and Analysis of Magnetic Pumping. If a magnetic field is applied to a moving electrically conducting liquid, it induces electric fields and magnetic fields. The interaction of these fields produces a body force known as Lorentz force which has a tendency to oppose the movement of the liquid. It can be shown that the stationary magnetic field will retard the motion of the
liquid while a suitable moving magnetic field will accelerate the motion. Since blood is an electrically conducting liquid, it should be susceptible to such a control.

To analyse pumping action, we assume a non-viscous-fluid to be flowing in a rectangular channel of depth $d$ and width $w$ as shown in Figure 1. The applied magnetic field is directed to move along the flow. Such a field can be generated by arranging multiphase windings along the length of the channel. The axial magnetic field produced can be expressed mathematically as

$$H_y = H_0 \cos (2\pi f t - ky),$$  \hspace{1cm} (1)

where $H_0$ and $k$ are constants, $f$ and $t$ denote respectively the electrical frequency of alternating current (a.c.) in c/s and time in sec; $k$ is known as propagation constant $= 2\pi /\lambda$, where $\lambda$ is the measure of the wavelength of the applied magnetic field which depends upon the number of phases and their spacing in the winding.

![Figure 1](image)

The equation of motion of an electrically conducting liquid moving with a constant velocity in the presence of magnetic field is

$$\frac{\partial p}{\partial y} = \frac{2\mu_0}{d} \int_0^{a/2} (\mathbf{J} \times \mathbf{H}) \, dx$$  \hspace{1cm} (2)

where $p$, $\mu_0$, $\mathbf{J}$ and $\mathbf{H}$ are pressure, magnetic permeability of blood, current density and magnetic field respectively. The solution of this equation is carried out in Cramer and Pai (1973) by using Maxwell’s equations, Ohm’s law and the boundary conditions prescribed by (1). For the purpose of the present paper, we will not go into details of the mathematical steps involved in the procedure. The final expression for the pressure gradient produced by the pumping action