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TITLE: Discharge of a laminar jet of conductive gas into a magnetic field

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TEXT: This is studied by the methods of laminar boundary layers and jet streams. The gas jet is assumed to be discharged from a narrow slit of infinite length and to flow into the same gas kept at a constant pressure. γ, σ and μ are constant. Thermal effects and gas ionization are neglected. The equation of motion

$$\left.\begin{aligned}\bar u\frac{\partial \bar u}{\partial \bar x}+\bar v\frac{\partial \bar u}{\partial \bar y}&=\frac{\nu}{u_0 l}\frac{\partial^2 \bar u}{\partial \bar y^2}-\frac{\sigma\mu^2}{\rho u_0} l H_0^2\,\bar u\,\bar H^2\\ \frac{\partial \bar u}{\partial \bar x}+\frac{\partial \bar v}{\partial \bar y}=0,&\quad \frac{\partial \bar H_x}{\partial \bar x}+\frac{\partial \bar H_y}{\partial \bar y}=0\\ \frac{\partial \bar H_x}{\partial \bar y}&=\frac{d\bar H}{d\bar x}-\sigma\mu u_0 l\,\bar u\,\bar H\end{aligned}\right\}\qquad(3)$$

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of the gas in the reduced variables

$$\bar x=\frac{x}{l},\quad \bar u=\frac{u}{u_0},\quad \bar y=\frac{y}{l},\quad \bar v=\frac{v}{u_0},$$

$$\bar H=\frac{H}{H_0},\quad \bar H_y=\frac{H_y}{H_0},\quad \bar H_x=\frac{H_x}{H_0}:$$

is transformed to the system

$$\frac{\partial \bar\psi}{\partial \bar y}\frac{\partial^2 \bar\psi}{\partial \bar x\,\partial \bar y}-\frac{\partial \bar\psi}{\partial \bar x}\frac{\partial^2 \bar\psi}{\partial \bar y^2}=\frac{1}{\mathrm{Re}}\frac{\partial^3 \bar\psi}{\partial \bar y^3}-\mathrm{N}_0\bar H^3\frac{\partial \bar\psi}{\partial \bar y}\qquad(6),$$

$$\frac{\partial \bar H_x}{\partial \bar y}=\frac{d\bar H}{d\bar x}-\mathrm{Re}_{\text{м}}\,\bar H\,\frac{\partial \bar\psi}{\partial \bar y},\qquad(7)$$

by introducing the dimensionless parameters

$$\mathrm{Re}=\frac{u_0 l}{\nu},\quad \mathrm{Re}_{\text{м}}=\sigma\mu u_0 l,\quad \mathrm{N}_0=\frac{\sigma\mu^2}{\rho u_0} l H_0^2\qquad(4)$$

and the dimensionless stream function $\bar\psi$. This system is solved with the following boundary conditions: (a) on the jet axis ($\bar y = 0$), $\bar v = 0$,
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$\partial\bar{u}/\partial\bar{y} = 0$, $\bar{H}_x = 0$; (b) if $\bar{y}\to\infty$, $\bar{u} = 0$; (c) at a great distance from the slit $\bar{H}_y = \bar{H} = 0$. From this system the principle of linear momentum $\bar{H}^2\bar{x}^{1+q-p} = \frac{ab}{N_0 f(\infty)}\int_0^\infty\left\{f'(\eta)\right\}^2 d\eta =$ const is derived. This equation is possible only if $\bar{H} = x^n$, where $n = (p-q-1)/2$. a, b, p and q are constants. On the condition that $p = 0$, $q = 1$, and $n = -1$ the solutions

$$\bar{u} = \frac{3}{2}\frac{N_0}{\bar{x}}\left(1 - \text{th}^2\frac{\eta}{2}\right) \qquad (17),$$

$$\bar{v} = \frac{3}{2}\sqrt{\frac{N_0}{\text{Re}}}\,\frac{\eta}{\bar{x}}\left(1 - \text{th}^2\frac{\eta}{2}\right) \qquad (18)$$

are obtained for the velocity components,

$$\bar{H}_y = \frac{1}{\bar{x}} - \frac{\eta}{\bar{x}}\,\frac{1}{N_0\text{Re}}\left(\eta + 3\text{Re}_{\text{м}} N_0 \text{th}\frac{\eta}{2}\right), \qquad (22) \text{ and}$$

$$\bar{H}_x = -\frac{1}{\bar{x}}\,\frac{1}{\sqrt{N_0\text{Re}}}\left(\eta + 3\text{Re}_{\text{м}} N_0 \text{th}\frac{\eta}{2}\right) \qquad (23)$$

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for the components of the magnetic field and

$$Q = 2\rho\int_0^\infty u\,dy = 6\mu H_0\sqrt{\rho\nu\sigma}\,. \qquad (19)$$

for the amount of fluid discharged per unit of time. At other values of n the equations of magnetohydrodynamics are not fulfilled.

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