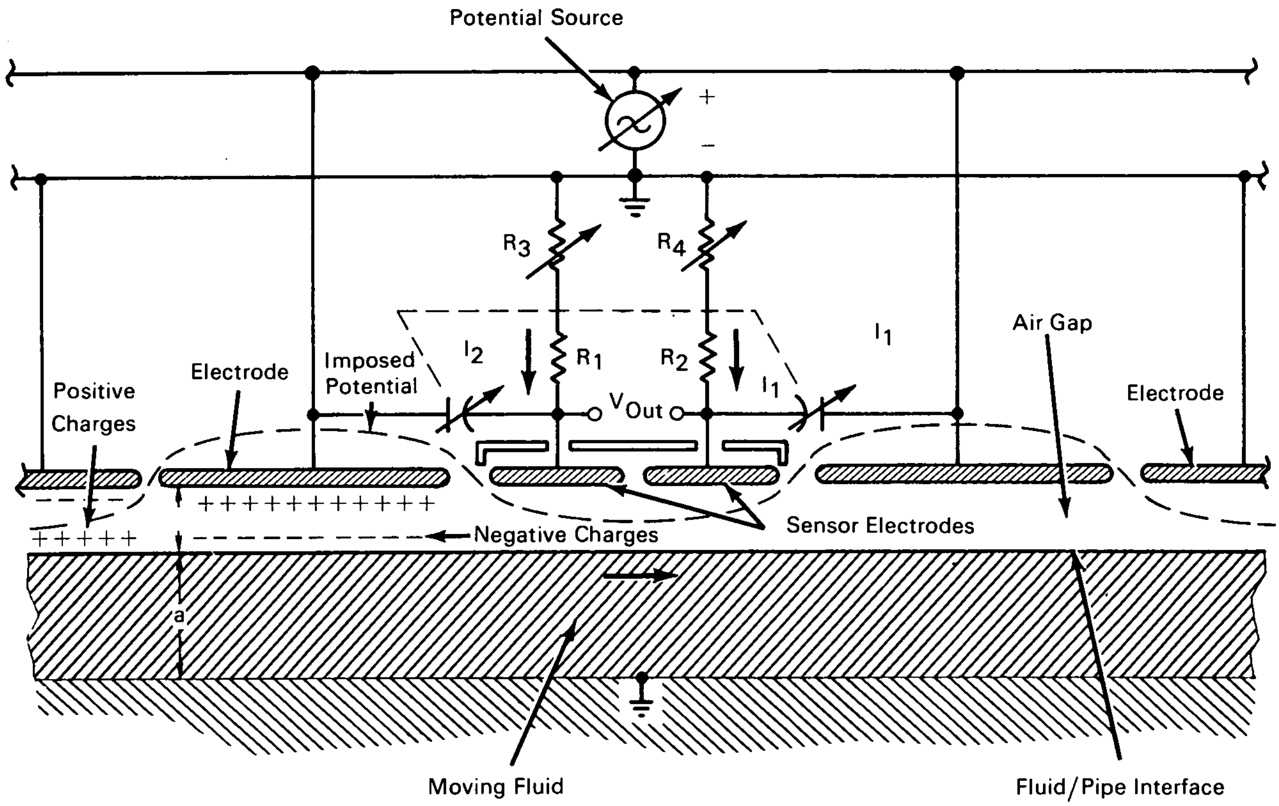
NASA TECH BRIEF

Electrodynamic Induction Flowmeter



A device has been invented that determines velocity and electrical conductivity of a moving fluid of high electrical resistance by imposing a transverse electroquasistatic field on the fluid. Position changes of charge accumulations induced within the fluid by the field are sensed by relative movement between fluid and sensor.

The device, shown schematically in the figure, is comprised of a number of electrodes (mechanically isolated from the material by an air gap) which impose on the fluid an electro-quasistatic field having an effective component orthogonal to the direction of movement of the fluid. The electric potential imposed on the electrodes induces an electric charge on the electrode surfaces. This, in turn, induces charges of opposite polarity in the adjacent fluid; the degree is determined directly by the strength of the electric potential and at a rate inversely proportional to the electric relaxation time constant of the fluid. The electrodes are connected across a variable-frequency source of ac elec-

(continued overleaf)

tric potential so that at any particular time, adjacent electrodes contain charges of opposite polarity. With the fluid stationary, the surface charges induced on the electrode surfaces and the respective induced charges at the fluid/pipe interface are in spatial phase with the imposed potential represented by the imposed potential curve. However, if the fluid is moving, the charges are shifted in spatial phase. This is true because the charges require a finite time (on the order of the relaxation time ϵ/σ) to accumulate or disperse at the interface. With the interface close to the electrodes, the charges there form a significant part of the images for charges on the electrodes. Thus, the fluid when in motion creates a shift in the spatial phase of the electrode charge distribution.

As shown, each electrode forms one-half wavelength for electric potential distribution along the direction of fluid flow. A pair of sensor electrodes together forms one-half wavelength, the imposed potential on the pair being substantially the same as the potential on one set of electrodes at any particular instant of time. However, whereas on any particular set of electrodes the charge distribution serves no particular purpose, in the sensing electrode pair a potential difference V_{out} occurs between the pair across resistors R_1, R_2, R_3, and R_4, connected serially across the electrode pair. Resistor pairs R_2-R_4 and R_1-R_3 are also connected between the potential source and the respective sensing electrodes. Because the potential drop across the resistances R_1-R_3 and R_2-R_4 is very small, the sensor electrodes can be considered to be at the same potential as the output of the source, which is shown at ground potential, as far as the imposed potential is concerned. The currents shown at i_1 and i_2 account for the time rate of change of the charge accumulation on the sensor electrodes. Then, the voltage V_{out} is zero because then the charge distribution is in spatial phase with the potential distribution and $i_1 = i_2$. However, with movement of the fluid, as in the direction of the arrow, there is an imbalance of the charges on the pair of sensor electrodes and V_{out} is proportional to the magnitude of the imbalance. It is possible under certain conditions, therefore, to measure the velocity of the fluid by properly calibrating the voltmeter in terms of appropriate linear dimensions of fluid movement per unit of time, irrespective of the frequency of the potential from the source, within predetermined limits.

The source of ac electric potential is connected as shown to introduce different values of electric potential to the adjacent electrodes. Thus, one set of electrodes at the particular instant depicted in the figure is at a positive potential; whereas the adjacent electrodes lying between each other pair of electrodes, are at a negative potential, thereby creating alternate regions of positive and negative electric potential along the flow direction. The output of the potential source varies in time so that the regions adjacent to alternate electrodes vary from positive potential values to negative potential values, thereby creating the standing potential wave, represented by the dotted sinusoid in the figure, along the flow direction. The voltmeter connected to measure the value V_{out} will be a measure of velocity of the fluid and can be calibrated. In this mode of operation, the meter will require calibration where the velocities of fluids of different conductivities are to be measured.

Notes:

1. This flowmeter could be used to measure the velocity and electrical conductivity of a variety of colloidal solutions in industry. An example would be the slurry in coal mining operations.
2. No additional documentation is available.

Patent status:

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to the Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139

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