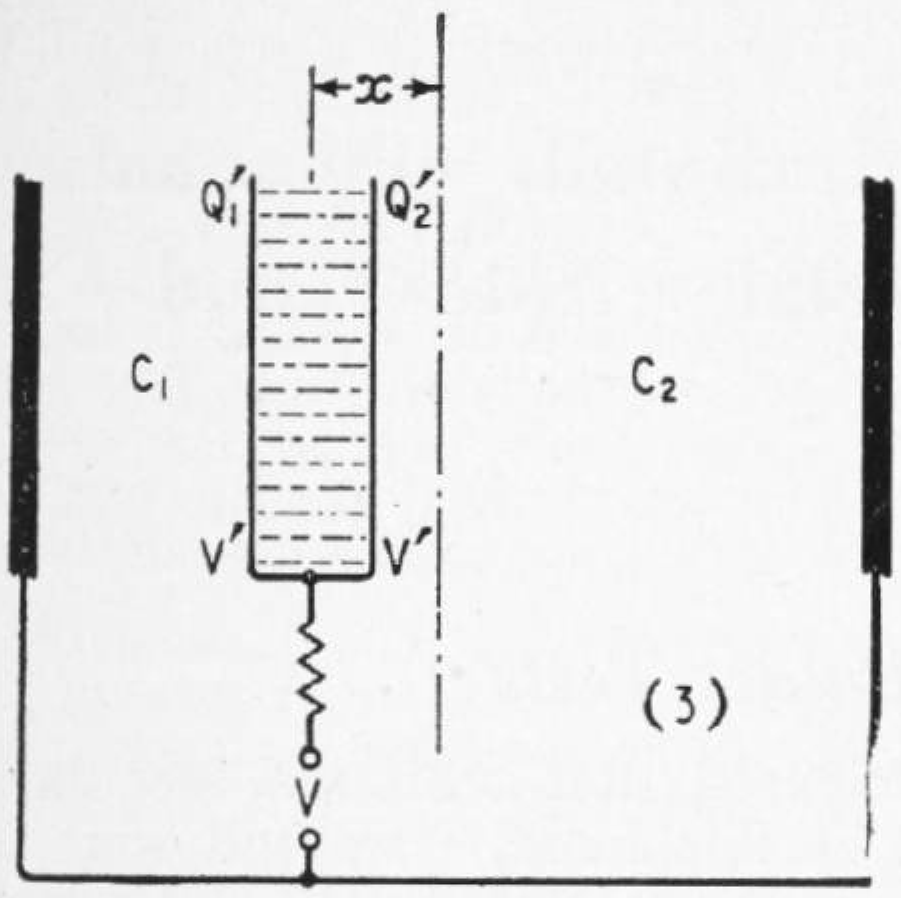



$$\kappa A V'\left(\frac{1}{d-x}+\frac{1}{d+x}\right)=Q'_1+Q'_2=2Q$$

$$V'=\frac{2Q}{\kappa A\left(\frac{1}{d-x}+\frac{1}{d+x}\right)}$$

$$F=\frac{\kappa A}{2}\left(\frac{1}{(d-x)^2}-\frac{1}{(d+x)^2}\right)\frac{4Q^2}{\kappa^2A^2\left(\frac{1}{d-x}+\frac{1}{d+x}\right)^2}$$

$$=\frac{2Q^2x}{\kappa A d}$$

*(3) Conducting diaphragm, displaced and fed through a high resistance (constant total charge)*

is a resultant force on the diaphragm which does not vary linearly with the displacement $x$.

So far we have assumed that the conducting diaphragm is directly connected to the polarizing source and that current can flow to make up the change of Q necessary to satisfy the equation Q=CV when V is kept constant and C is changed. Under these conditions $(Q_1+Q_2)$ will never be less than 2Q.

If a resistance is inserted between the source and the diaphragm it will not affect the conditions (2) if the time constant it forms with $C_1$ and $C_2$ is short compared with a half-cycle of the applied signal; this condition is satisfied by the values which were used for safety resistances in the early electrostatic loudspeakers.

When the series resistance gives a time constant long compared with a half period of the lowest audio frequency the charge on the diaphragm cannot change appreciably from its average value $(Q_1'+Q_2')\approx 2Q$, so when displaced the potential of the diaphragm must fall to a new value V', diagram (3). But, and this is the important point, the charges on each side of the diaphragm will still be dissimilar; and, although we are now working under "constant total charge" conditions there is still a force due to the polarizing voltage when the diaphragm is displaced. This force is linear with displacement, but is not due to the signal and is, therefore, a distortion.

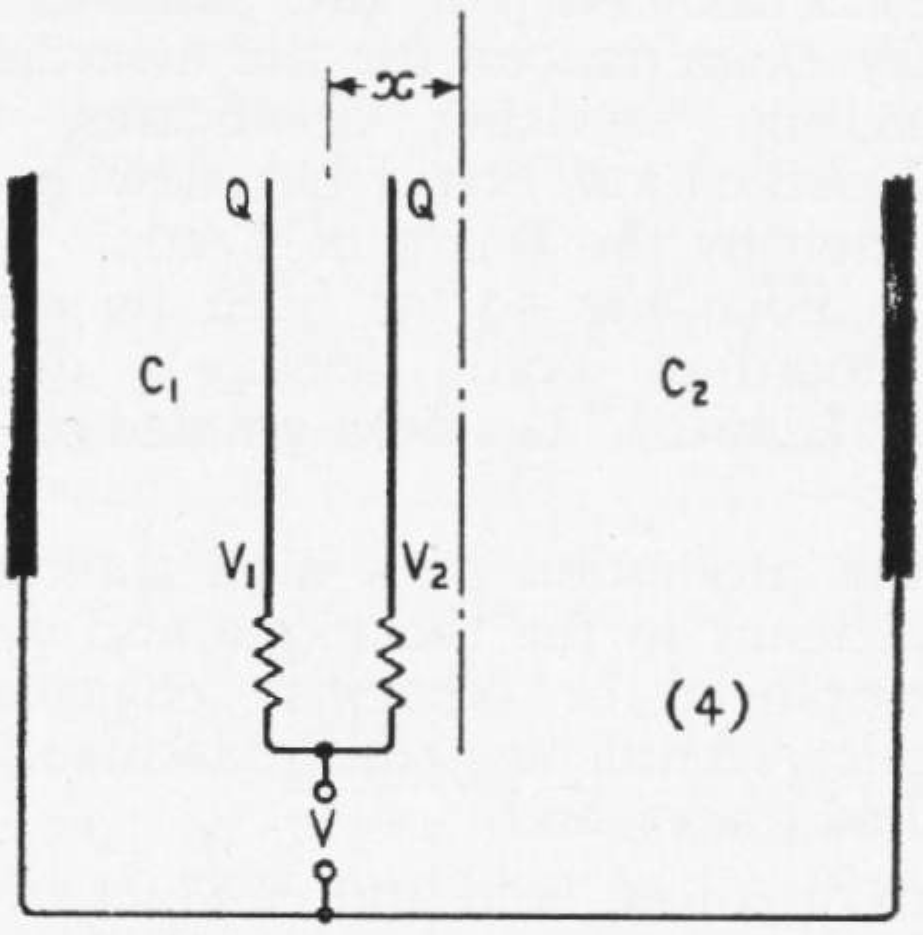
W. T. Cocking has shown[5] that all unwanted forces will disappear only when the two faces of the diaphragm are insulated from one another. Under these conditions, with no possibility of migration of charge as the result of the changes of capacitance, and with separate high resistors feeding each side of the diaphragm, it will be the potentials $V_1$ and $V_2$ which will accommodate themselves to satisfy Q=CV. With voltage varying directly with electrode spacing we now have exact compensation and there will be no force due to the polarizing voltage, irrespective of the position of the diaphragm, (4).

Having disposed of the forces both linear and non-linear arising from the presence of the charge itself, the force due to the establishment of an additional signal field between the two outer fixed plates may be considered separately and unhindered. This is simply the product of the charge and the field strength due to the signal and is independent of the position of the charge in the field.

The object of this note has been to point out that a series resistance will not by itself linearize the electrostatic loudspeaker; the diaphragm must be an insulator so that the migration of the charge between faces is prevented—at least for the duration of a half-cycle of the lowest frequency to be reproduced. If the surfaces of the diaphragm are sprayed to make them conducting, the polarizing voltage must be fed through separate high resistances to each side. A simpler practical approach would seem to be to leave the diaphragm uncoated and rely on the surface resistivity being high, but not as high as the bulk resistivity of the material.

When the electro-mechanical driving force has been linearized there still remain a number of problems for the designer, but they are far less onerous than those associated with the moving-coil drive. The light mass of the electrostatic diaphragm implies much less internally circulating energy in the form of momentum. The load is predominantly that due to the acoustic radiation resistance and the mechanical reactive component is negligible. Good transient response should therefore be easier to achieve, and because the diaphragm is being driven over the whole of its surface, variations due to "break-up" of the vibrating surface—a feature inseparable from coil-driven cone diaphragms at high frequencies—are negligible.

The only remaining problems are how to ensure adequate air loading at very low frequencies and how best to match the capacitive electrical impedance to the amplifier.




$$V_1=\frac{Q(d-x)}{\kappa A}\qquad V_2=\frac{Q(d+x)}{\kappa A}$$

$$F=\frac{\kappa A V_1^2}{2(d-x)^2}-\frac{\kappa A V_2^2}{2(d+x)^2}$$

$$=\frac{Q^2}{2\kappa A}-\frac{Q^2}{2\kappa A}=0$$

*(4) Insulating diaphragm, displaced, with conducting surfaces separately fed through high resistances*