ON FERROMAGNETIC STATES

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Summary

Some regularities in the behaviour of ferromagnetic materials are formulated anew after a criticism of their formulation in Madelung's laws. Moreover a new kind of diagrams to use with the $B$-$H$ diagrams is introduced. As an application the linearization attained in magnetic sound-recording by the addition of a high frequency is explained.

§ 1. Madelung's laws 1) 2). These laws deal with the changes in the $B$-$H$-diagram accompanying certain changes in the state of a ferromagnetic material caused by magnetic processes. A magnetic process is represented by a curve in the $B$-$H$-diagram. A point of such a curve is called a reversal point if it corresponds to an extreme value of the magnetic field in the process, e.g. the point $P$ in fig. 1.

\[ B \]
\[ P \]
\[ 0 \quad H \]

Fig. 1. A magnetic process with a reversal point.

Madelung's first law states that in a $B$-$H$-diagram the curve (PQ in fig. 1) which corresponds to a monotonic variation of the field $H$ is defined by the reversal point ($P$) from which the curve takes its origin. Taken literally this law cannot be correct under all circumstances. It comes into conflict with essential properties of ferro-
magnetism if it is applied in certain cases differing from the case
dealt with by Mandlung. Such a case is found in fig. 2. The figure
shows the largest hysteresis loop obtainable from a certain ferromag-
netic material (such a loop will be called hereafter the limiting loop
of the material). The point A is the point on that loop with the property
that the origin O can be reached by a monotonic decrease of $H$. The
curve corresponding to this magnetic process is ABO. At the end of
the process the field $H$ and the induction $B$ both are zero, though the
material has not come into a really demagnetized state.

![Fig. 2. Two different states corresponding to the origin.](image)

The difference appears clearly from a subsequent magnetization:
the process of increasing $H$ from the demagnetized state is represen-
ted by a part of the normal magnetization curve, the dotted line
OK in fig. 2. For most of the ferromagnetic materials K is situated
well above the point A. The result of an increase of $H$ from the other
state is represented by a curve OCA. Now for the curve OCA the
origin is a reversal point in the sense of Mandlung's laws and so it is for the normal magnetization curve OK, as the demagnetized
state can be reached by a process of rapid commutation of a slowly
vanishing field. Thus, according to Mandlung's first law, the
curves OCA and OK would be defined by the reversal point O only
and therefore show the same shape. This however is not the case.

Mandlung's second and third law suffer from objections of the
same kind. E.g., according to the second law and starting from the
point $Q$ in fig. 1 a decrease of $H$ should be represented by a curve
containing the original reversal point $P$. However, starting from a