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On the Vector Model of Nonadiabatic Transition in Nuclear Magnetic Resonance

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Résumé. — On a présenté les résultats de l'expérience sur le modèle vectoriel de la transition non adiabatique, qui confirment la validité de ce modèle et rendent possible l'application de résonance nucléaire dans des liquides en mouvement pour l'étude des problèmes hydrodynamiques.

The examination of the nuclear magnetic resonance in flowing liquid allows to confirm in a quite simple manner the vector model of the nonadiabatic transition. When the change of the direction of the magnetic field occurs in a time considerably shorter than the period of the Larmor precession of the magnetic moment situated in this field, then the magnetic moment does not follow the change of the field and preserves its initial direction in space. Our experiment was similar to that of Purcell and Pound [1] on the negative temperature of spins. However, in our case of liquid, the concept of the negative temperature cannot be introduce because the both relaxation times T_1 and T_2 are nearly equal and the reversed population of states disappears before the thermodynamical equilibrium, even in local regions within the spin system, is attained. Purcell and Pound employed a sudden change of the magnetic field direction by 180°, which caused the magnetization vector take an antiparallel orientation to the field intensity. We could change the direction of the magnetic field by different angles.

In our experiment the observations of the nonadiabatic passage were made for tap water, which relaxation time $T_1 \approx 1.5$ sec. The water flowed at the average velocity of 120 cm/sec through the spiral tube, 350 cm long, between the electromagnet pole faces and therefore remained in the field of the electromagnet sufficiently long to attain nearly full stationary magnetization M_0. As it is shown on Fig. 1 before entering the resonance detecting coil, the water flowed outside the electromagnet gap into the region of the scattered magnetic field. In this region, where the intensity of the stattered field, measured by means of a fluxmeter, was $H' = 65$ gauss, the tube formed a loop on which an auxiliary coil was wound.

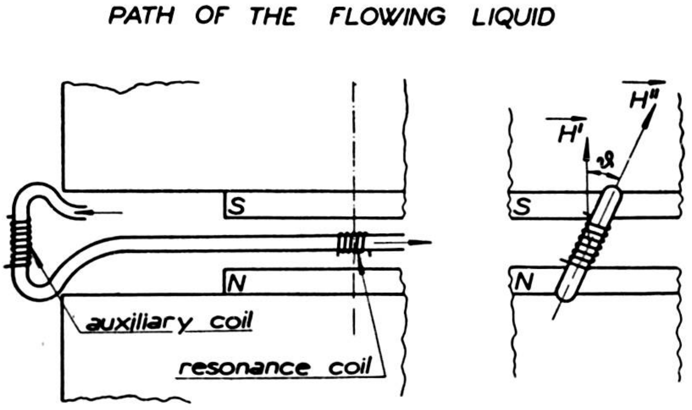

Fig. 1.

By discharging the battery of condensers through the auxiliary coil a new magnetic field was suddenly created, which amplitude H'' depended on the suitable choose of the series resistance. The angle θ between H' and H'' could be changed by rotating the loop. As the field H'' was set in a fraction of a microsecond the transition was nonadiabatic one. All other transitions i.e. the decay of H'' and the entry of water into the strong field of the electromagnet took place sufficiently slowly to fulfil the condition of adiabatic passages.

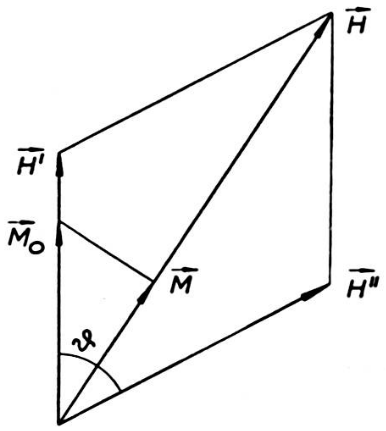

Fig. 2.

From the vector diagram on figure 2 the value of the magnetization component M in the direction of the resultant magnetic field $\vec{H} = \vec{H'} + \vec{H''}$ can be calculated

$$M = M_0 \frac{1 + s \cos \theta}{\sqrt{s^2 + 2 s \cos \theta + 1}} \tag{1}$$

where $s = H''/H'$.

The theoretical dependence of the ratio M/M_0 from the angle for different parameters s used in the experiment are shown on figure 3.

The amplitudes of resonance lines in flowing water were registered on a photographic paper tape of mirror oscillograph using the 50 c.p.s. modulation of the magnetic field. After the battery of condensers was discharged and the water with the changed magnetization passed through the resonance coil, the change of the amplitude of resonance lines was observed. For $H'' > H'$ and for sufficiently large angles θ the lines were reversed. The maximal effect on each record depends on the ratio M/M_0 and on the degree, to which the tube in the region of the resonance coil is filled by water with

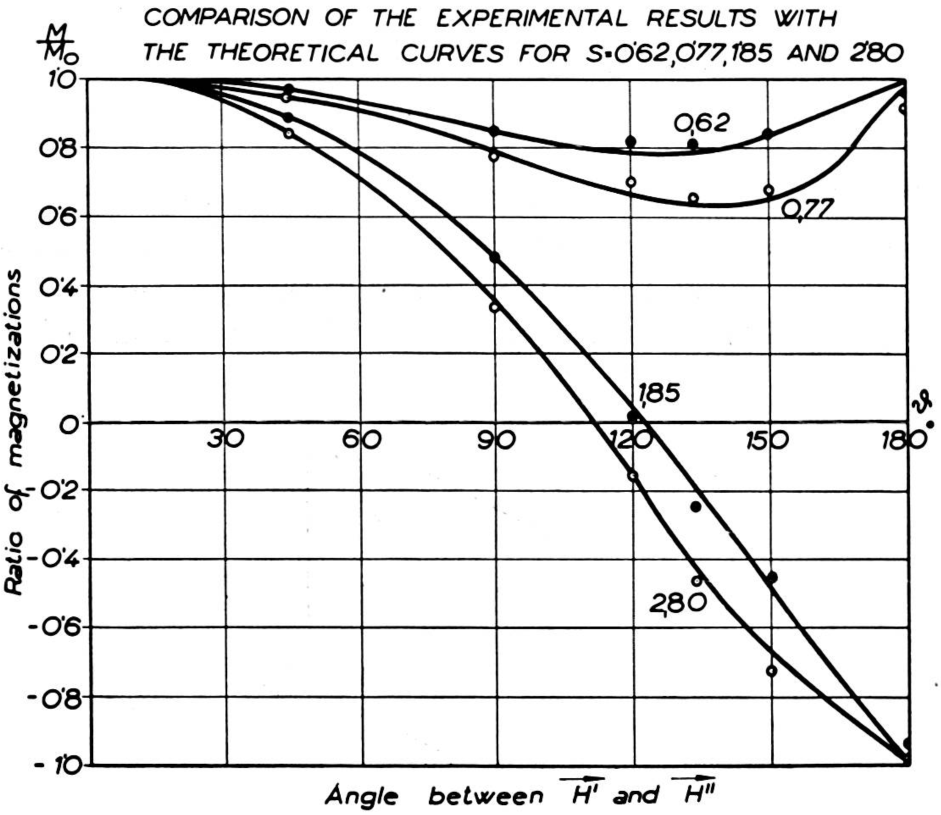

Fig. 3.

changed magnetization. For calculation of M/M_0 from the measurements of line amplitudes the maximum filling factor must be known. We obtained this factor comparing the experimental value M/M_0 for $\theta = 180°$ and $s = 2{,}80$ with theoretical value — 1. Using the factor obtained this way all other experimental results were compared with the theoretical curves (fig. 3). The agreement is fully satisfactory. The small discrepancy should be ascribed to the effect of relaxation (very small for our experimental conditions) and to the fact, that the scattered field H' is not entirely homogeneous.

The results of this work are a confirmation of the vector model of the nonadiabatic transition and form a simple illustration of this process. Moreover, as our method allows to mark the flowing liquid in a fraction of microsecond within the definite region, it can be used for investigation of hydrodynamical problems. From the shape of the envelope of recorded resonance lines some informations can be obtained concerning the history of flow between the auxiliary coil and the resonance coil.

The description of experiments in more details is now in print in *Acta Physica Polonica.*

REFERENCE

1. Purcell, E. M., R. V. Pound, *Phys. Rev.*, *81*, 279 (1951).