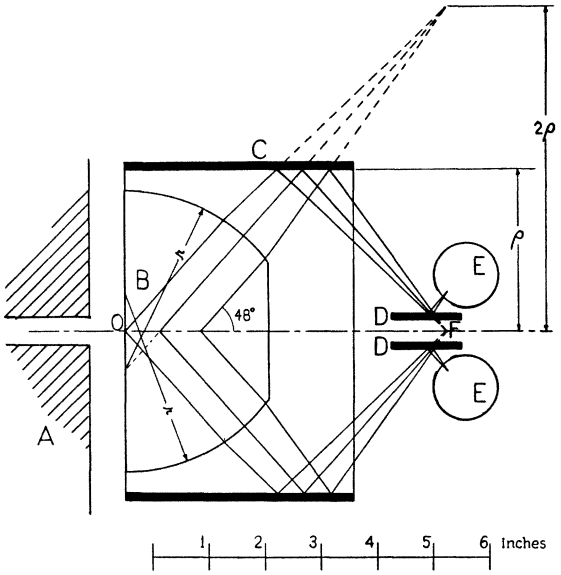

FIG. 1. Counter arrangement (explanation in text).

The arrangement is shown schematically in Fig. 1. The block, A, is a lead collimator through which electrons from a thin ($\frac{1}{8}$-in.) radiator in the betatron beam enter the system. The radiator, B, is made of Lucite or Plexiglas. It is a figure of revolution generated by rotating a circle around an axis in its plane, but not through its center. The radius of curvature, r, is so chosen as to focus the Čerenkov radiation into a sharp ring with a radius of approximately 2ρ, where ρ is the radius of a cylindrical reflector, C, made by silvering a piece of large diameter glass tubing on its inner surface. The cylindrical reflector focuses the light on the axis of the system at F where, in principle, a photo-multiplier could be placed to count the incident particles. Because of noise, it is much preferable to use a fast coincidence system operated by two photo-multipliers. To focus the light on two multipliers, two plane mirrors, D, are used. The photo-multipliers are of type 931-A.

The coincidence and counting circuit can be described briefly as follows. The pulse out of each multiplier was clipped with a 9-in. length of 173-ohm coaxial cable shorted at its far end, and was fed into two Spencer-Kennedy distributed amplifiers in cascade through 173-ohm line. The impedance level was reduced to 100 ohms at the output of the second amplifier and the pulse was clipped again to reduce its width, which at this point was broadened somewhat by the amplifiers. The pulses were then limited in height by a series crystal diode carrying current in a direction opposite to that in the pulse. Finally, the pulses in the two channels were combined at the center of a length of 100-ohm line and fed through a crystal discriminator to a linear amplifier, discriminator, and scaler. This coincidence circuit is similar in principle to one rumored to have been developed by Bell and Jordan.

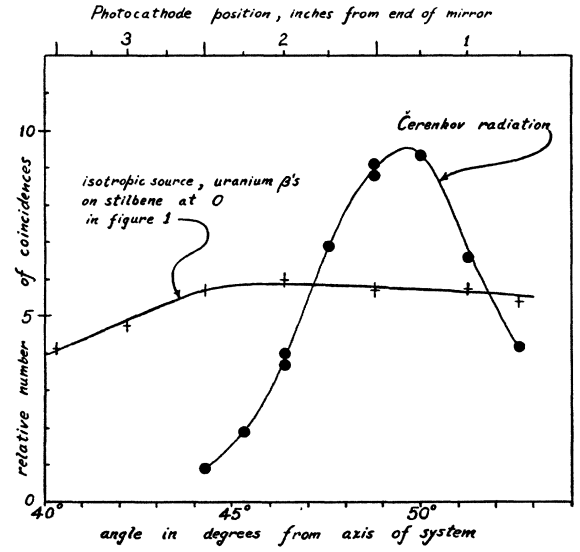

FIG. 2. Angular dependence of coincidence rate.

The Čerenkov counter was set up so that fast electrons, emitted from a lead radiator at about 0.1 radian from the forward direction of a collimated x-ray beam, could enter the system through its collimator after being deflected slightly by a small magnet. The direct x-ray beam was absorbed in 16 in. of lead. Coincidences were observed and it was found that the insertion of enough line in either channel to delay the pulse by 2×10^{-9} sec. reduced the counting rate by a factor 6. The same coincidence circuit excited by uranium betas on stilbene had its counting rate reduced by the same factor by a time delay of about 4×10^{-9} sec. It is apparent that the light pulses are quite short. It is felt that the resolving time obtained is as short as can be expected from the system even from an infinitely fast light pulse.

The counting rate was linear with betatron intensity as indicated by an ionization chamber. An absorption curve in iron taken with good geometry gave a relaxation length of 3.30 ± 0.1 cm, which indicated an effective x-ray energy of approximately 30 Mev.

The position of the multiplier tubes was varied to measure the angle of emission of the light from the forward direction of the electrons. The results are given in Fig. 2. The Čerenkov angle for Lucite ($n=1.5$), with particles of velocity C, should be about 48°. The observed angle indicates a slightly higher index of refraction which may perhaps be explained by assuming that most of the effective light is in the ultraviolet.

A two stilbene crystal coincidence absorber arrangement which should give approximately 100 percent counting efficiency for electrons above 5 or 6 Mev counted at ten times the rate of the Čerenkov counter in the arrangement used. At higher electron energies, the Čerenkov counter should be considerably more efficient than the 10 percent indicated here because of the longer electron ranges and reduced scattering to be expected. A variation of the arrangement described here will be tried with protons from the cyclotron when it comes into operation.

* Work supported in part by the ONR and AEC.
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Magnetic Shielding of the Proton Resonance in H_2, H_2O, and Mineral Oil*

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November 30, 1950

WE have measured the differences in magnetic shielding of the proton magnetic resonance in H_2, H_2O, and mineral oil (Nujol). These particular results are reported at this time because the proton resonances in water and mineral oil are used frequently as standards. The theoretical value[1,2] for the magnetic shielding in H_2 can be combined with these data to reduce other observations to the unshielded proton.

Experimental procedures were similar to those described previously.[3] A major improvement was made by reducing the *total variation* in the field of the permanent magnet to 0.15 gauss over a volume 2 in. in diameter and 1 in. thick. Half-maximum line widths of from 0.03 to 0.08 gauss were observed in these experi-

ments, using 30-cycle modulation. Measurements were made with a dual system, excited by a single oscillator at 27.2 Mc, and incorporating two samples in separate probes in the field. The difference in resonance magnetic fields for the two samples was obtained by measuring alternately the dc field-biasing current necessary to center first one resonance on an oscilloscope and then the other. The small difference in the applied fields at the two samples, due to residual field in homogeneities, was cancelled in the case of H_2O *versus* mineral oil by interchanging samples.

The effects of bulk diamagnetism are appreciable. The field, H_i, in the sample will differ from the applied field H_0, by an amount[4]

$$H_i - H_0 = (\tfrac{4}{3}\pi - \alpha)\kappa H_i = (\tfrac{4}{3}\pi - \alpha)\kappa H_0.$$

Here κ is the volume susceptibility of the sample, and α is the demagnetization factor which is 2π for an infinite cylinder and $4\pi/3$ for a sphere. Spherical samples are indicated but experimental difficulties prevented their use. Instead, "infinite cylinders" 8 in. long and $\frac{3}{8}$ in. in diameter were used for H_2O and mineral oil. Diamagnetic corrections were made using an α of 2π and κ's of -0.70 and $-0.65\pm0.05\times10^{-6}$ cgs units for H_2O and mineral oil respectively. The mineral oil κ was estimated from hydrocarbon data. κ for H_2 may be neglected.

H_2 was observed at 30 atmos in the pressure probe shown in Fig. 1. A photograph of its resonance and that of mineral oil is reproduced in Fig. 2. The phasing of the 30-cycle voltage on the

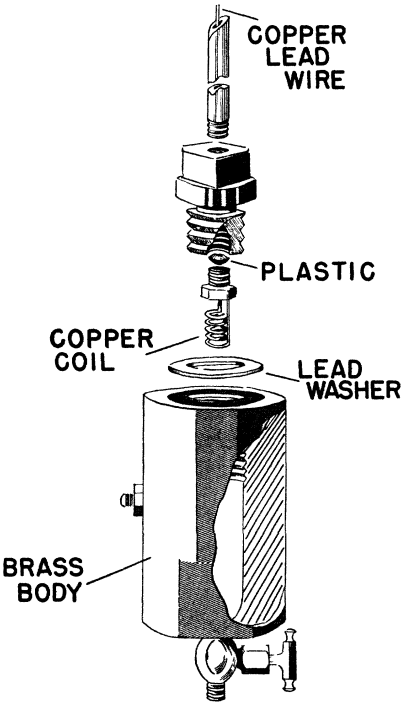

FIG. 1. Pressure probe for nuclear magnetic resonance experiments with gases. A null-T rf bridge was used with this assembly.

x-axis of the oscilloscope is adjusted to superimpose the first relaxation wiggle; this provides a sharper setting point than the resonance line itself. The pressure and reference probes were mounted rigidly in the gap. A length of $\frac{3}{32}$-in. copper tubing connected to the bottom inlet of the pressure probe was used to introduce, or remove hexane from the sample cavity. By comparing its resonance field with that of a hexane sample of the same shape in the reference probe, the difference in applied fields at the two positions was obtained. In all experiments with H_2 the sample in the reference probe was contained in the same Pyrex tube, 8 mm internal diameter and 8 in. long, with a thin glass barrier at the middle, and placed in the same position with

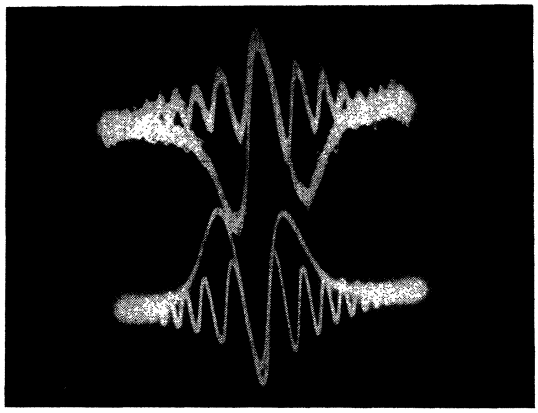

FIG. 2. Proton magnetic resonance lines in H_2 gas at 30 atmos (top) and mineral oil (bottom). The phasing of the 30-cycle reference voltage on the oscilloscope x-axis is adjusted to superimpose the first relaxation wiggles to provide a sharper setting point. Total modulation sweep is about 0.75 gauss.

the glass film below the bottom of the rf coil. For "infinite cylinders" the whole tube was filled.

The results are summarized in Table I. The stated errors are probable errors, which include the calibration of the field-biasing current, uncertainties in the diamagnetic corrections, and the probable error of the measured field-biasing currents themselves. The H_2O *versus* mineral oil results are in good agreement with those of Lindström,[5] whose data are equivalent to the applied

TABLE I. Magnetic shielding of the proton resonance in H_2, H_2O, and mineral oil at 27.1 Mc (6365 gauss). The applied field for mineral oil is higher than for H_2. Field differences are in gauss.

Sample	Difference in applied field corrected for diamagnetism	Fractional effect corrected for diamagnetism	Difference in applied field for "infinite cylinders"	Fractional effect for "infinite cylinders"
Mineral oil (Nujol)	0.0235 ± 0.0020	$(3.7\pm0.3)\times10^{-6}$	0.0150 ± 0.0010	$(2.3\pm0.15)\times10^{-6}$
H_2O (distilled)	0.0020 ± 0.0020	(0.3 ± 0.3)	-0.0075 ± 0.0010	(-1.2 ± 0.15)
H_2 (g, 30 atmos)	0.0000 ± 0.0020	(0.0 ± 0.3)	0.0000 ± 0.0020	(0.0 ± 0.3)

field for H_2O being less than that for paraffin oil by the fractional amount $4.1\pm3.0\times10^{-6}$. The absolute value of the proton magnetic moment is virtually unaffected[6] by the results reported herein, because differences in magnetic shielding constitute only about five percent of the stated error in the most recent determination.[7]

We wish to thank C. J. Hoffman for his assistance with several of the measurements. Equipment was provided by a Grant-in-Aid from Research Corporation.

* Supported in part by the ONR.

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[5] G. Lindström, Phys. Rev. **78**, 817 (1950).
[6] The value obtained in reference 7 cannot be compared directly with these data as their water sample contained ferric ions.
[7] Thomas, Driscoll, and Hipple, Phys. Rev. **78**, 787 (1950).

The Production of π-Mesons in Proton-Proton Collisions

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RECENT measurements[1] on the production of π-mesons in 345-Mev $p-p$ collisions have shown that the spectrum of the mesons has a strong maximum near the upper energy limit. This has been attributed to the interaction between the resulting

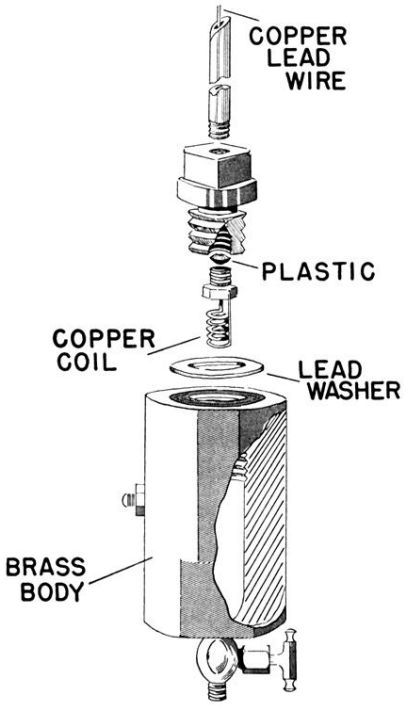

FIG. 1. Pressure probe for nuclear magnetic resonance experiments with gases. A null-T rf bridge was used with this assembly.

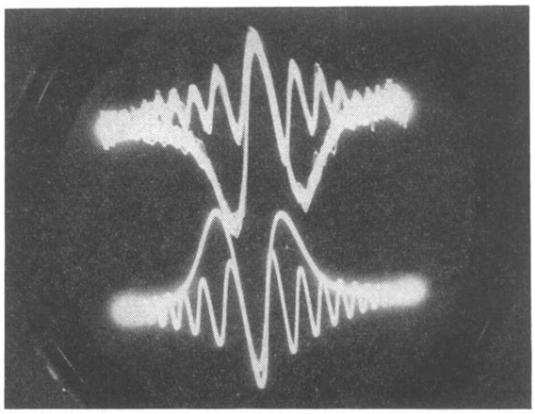

FIG. 2. Proton magnetic resonance lines in H_2 gas at 30 atmos (top) and mineral oil (bottom). The phasing of the 30-cycle reference voltage on the oscilloscope x-axis is adjusted to superimpose the first relaxation wiggles to provide a sharper setting point. Total modulation sweep is about 0.75 gauss.