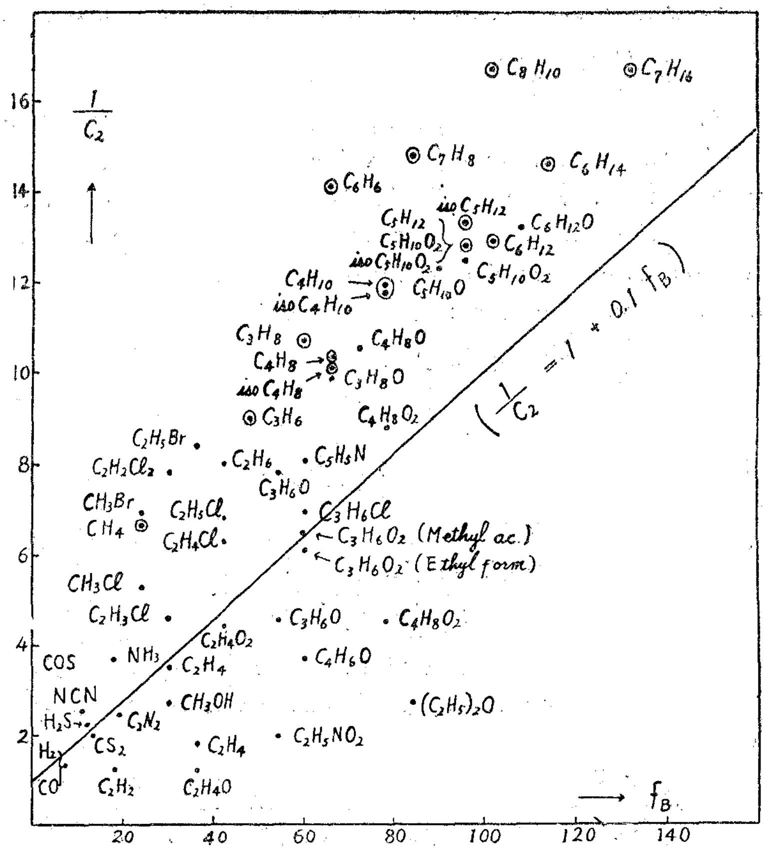

Fig. 1. Correlation between upper limit and degrees of freedom of fuels.

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4. The Dielectric Constant of Liquids at Microwave Frequencies. (II)

Measurements of the Dielectric Constant at 3 cm Wavelength

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The method of measurement of the complex dielectric constant ($\epsilon^* = \epsilon' - j\epsilon''$) at 3 cm wavelength with the waveguide apparatus was discussed and some measurements were made on aliphatic alcohols

The block diagramm of the test apparatus is shown in the figure. The details about waveguide components have been already reported (This Bulletin, 28, 55 (1952)).

For the medium and high dielectric loss liquid, the propagation constant γ_d in the dielectric-filled section of waveguide may be expressed as

$$\gamma_d = \alpha_d + j\frac{2\pi}{\lambda_d}$$

$$= j\frac{2\pi}{\lambda_0}\left(\epsilon' - j\epsilon'' - \left(\frac{\lambda_0}{\lambda_c}\right)^2\right)^{\frac{1}{2}},$$

where λ_0 is the wavelength in free space, λ_c the cut-off wavelength in the empty guide, λ_d the wavelength in the dielectricfilled waveguide and α_d the attenuation constant due to the dielectric loss of liquid.

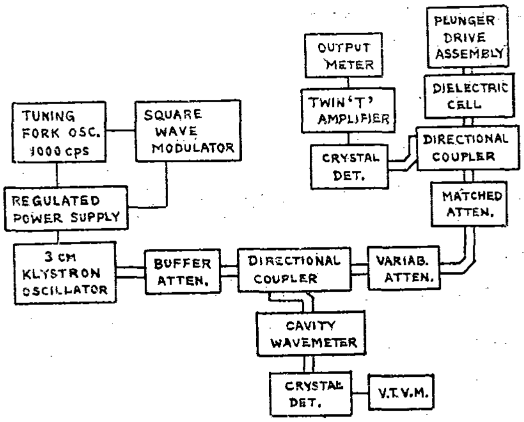

Fig. 1. Block diagramm of experimental apparatus.

From the above relation λ_d and α_d are written in the form

$$\lambda_d = \frac{\lambda_0}{\left[\epsilon' - (\lambda_0/\lambda_c)^2\right]^{\frac{1}{2}}} \cdot \left[\frac{1}{2}\left(1 + \left[1 + \left(\frac{\epsilon''}{\epsilon' - (\lambda_0/\lambda_c)^2}\right)^2\right]^{\frac{1}{2}}\right)\right]^{-\frac{1}{2}}$$

$$\alpha_d = \frac{\pi\epsilon''\lambda_d}{\lambda_0^2}.$$

Then the real and imaginary parts of dielectric constant are given by the equations

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2\left[1 - \left(\frac{\alpha_d\lambda_d}{2\pi}\right)^2\right] \quad \text{.............................. (1)}$$

$$\epsilon'' = \frac{1}{\pi}\left(\frac{\lambda_0}{\lambda_d}\right)^2 \cdot \alpha_d\lambda_d \quad \text{.............................. (2)}$$

Hence, the procedure for calculating ϵ' and ϵ'' is to measure λ_d and α_d in the liquid after determining λ_0 and λ_c characteristic of the appartus.

For a constant incident power, the amplitude of the reflected wave may be proportional to the magnitude of reflection coefficient, 'Γ', at the face of the dielectric sample. The latter will be given by the following equation, when the sample is terminated by an ideal open-circuited plunger,

$$\Gamma = \left|\frac{Z_d \coth \gamma_d l - 1}{Z_d \coth \gamma_d l + 1}\right|$$

where l is the length of liquid columm, and Z_d is the per unit characteristic impedance in the liquid-filled waveguide. For the TE mode Z_d is related to the dielectric constant and the wavelengths, λ_0 and λ_c, by the eqations

$$Z_d = \frac{\left[1 - (\lambda_0/\lambda_c)^2\right]^{\frac{1}{2}}}{\left[\epsilon - j\epsilon' - (\lambda_0/\lambda_c)^2\right]^{\frac{1}{2}}} = |Z_d|\, e^{j\phi_d}$$

$$|Z_d| = \left[\frac{1 - (\lambda_0/\lambda_c)^2}{\epsilon' - (\lambda_0/\lambda_c)^2}\right]^{\frac{1}{2}} \cdot \left[1 + \left(\frac{\epsilon''}{\epsilon' - (\lambda_0/\lambda_c)^2}\right)^2\right]^{-\frac{1}{4}}$$

$$\phi_d = \frac{1}{2} \cdot \tan^{-1}\left(\frac{\epsilon''}{\epsilon' - (\lambda_0/\lambda_c)^2}\right).$$

Since the output reading of a crystal detector coupled to the reflected wave by the directional coupler is proportional to $|\Gamma|^2$, for the lengths of the liquid which are odd integral multiples of $\lambda_d/4$, the set of values of the output reading i. e. $|\Gamma|^2$ may be written in the from.

$$|\Gamma|_n^2 = \frac{\left|\frac{1-Z_d}{1+Z_d}\right|^2 + 2\frac{1-|Z_d|^2}{|1+Z_d|^2}\exp(-n\alpha_d\lambda_d/2) + \exp(-n\alpha_d\lambda_d)}{1+2\frac{1-|Z_d|^2}{|1+Z_d|^2}\exp(-n\alpha_d\lambda_d/2) + \left|\frac{1-Z_d}{1+Z_d}\right|^2 \exp(-n\alpha_d\lambda_d)}$$

$$l = n\cdot\lambda_d/4,\ n = 1,\ 3,\ 5,\ \cdots\cdots .$$

For the large values of n and α_d, the above equation reduces to

$$\frac{|\Gamma|_n^2}{|\Gamma|_\infty^2} = 1+2\frac{1-|Z_d|^2}{|1+Z_d|^2}\exp(-n\alpha_d\lambda_d/2),$$

where

$$|\Gamma|_\infty^2 = \left|\frac{1-Z_d}{1+Z_d}\right|^2 .$$

Therefore, the dielectric attenuation per wavelength $\alpha_d\ \lambda_d$ is evaluated from the slope of $\ln\left[(|\Gamma|_n^2/|\Gamma|_\infty^2) - 1\right]$ plotted against. n.

Since λ_d is twice the separation between adjacent maxima of the output reading, the complex dielectric constant will be calculated from the equations (1) and (2).

The observed data on five aliphatic alcohols are shown in the following table.

Dielectric Properties of aliphatic alcohols at λ_0 =3.03cm

	n-Propanol	iso-Propanol	n-Butanol	iso-Butanol	iso-Pentanol
λ_d cm	1.74	1.69	1.83	1.92	1.96
$\alpha_d\ \lambda_d$ nepers/wavelength	1.146	1.24	0.849	0.800	0.663
ϵ' (20°)	3.36	3.52	3.13	2.88	2.90
ϵ'' (〃)	1.11	1.27	0.741	0.634	0.523
tan δ(〃)	0.33	0.36	0.24	0.22	0.18

5. X-Ray Study on Thallium Foils

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The crystal structure of thallium changes from the close-packed hexagonal (low temp. phase) into the face-centered cubic (high temp. phase) at about 231°C.

On cobalt, having the same stuctural relation as Tl, it has been studied by U. Dehlinger, Z. Nishiyama, A. R. Troiano, et al. that its high temp. Phase