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4.3 MEASUREMENT OF HYDROGEN DISTRIBUTIONS BY NEUTRON RADIOGRAPHY,

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1. Introduction

A powerful application of neutron radiography is the detection of hydrogen. This is possible because of the high scattering cross section of hydrogen. Thus hydrogen in Zr /1/ and Ti /2/ can be measured. Also experiments on the diffusion of H in Zr /3/ were performed. Other applications are the detectability of H-containing inclusions in steel /4/ eventually using cold neutrons /5/, the inspection of metal adhesions, of explosives of O-ring seals within apparatus and so on.

In the following the recent experiments performed at the Triga Vienna reactor will be reviewed. In a tangential beam hole of the reactor we have placed a conical collimator with length of 2200 mm. The diameter of the focal spot is 17 mm, the diameter of the useable beam 125 mm. The neutron flux obtained is $6.10^5\ cm^{-2}s^{-1}$, the gamma dose rate is 3.3 Rh^{-1} because of a 80 mm thick Bi-filter placed at the inner end of the beam hole. This leads to a neutron-gamma-ratio of $6.6\cdot 10^8\ cm^{-2}R^{-1}$.

2. Diffusion of liquids

Experiments were performed on the H_2O-D_2O and on the methanol diffusion process. The ratio of the total attenuation coefficients of normal water with heavy water for thermal neutrons is

$$\frac{\Sigma_{H_2O}}{\Sigma_{D_2O}} = 7.65$$

The experiments were done in the following way:
In a 5 mm thick Al-container first D_2O was filled and afterwards overlayered with H_2O. The container was held at constant temperature. Beginning immediately after the overlayering process radiographs were taken at different times. We used the direct exposure method with a 25 µm thick Gd-foil and Osray DW film. Thus a smearing out of the borderline between H_2O and D_2O with increasing time could be observed. Via the use of a standard series of H_2O-D_2O-mixtures the concentrations could be obtained from the density of the radiographs. By this way we got one concentration profile for each temperature and time. As shown in our previous paper /6/ from each curve separately the diffusion coefficient as a function of the concentration could be calculated. The values obtained agree quite well with the values in literature but show a rather concentration dependent diffusion coefficient. A remarkable deviation can also be seen for temperatures below the melting point of D_2O. Here we had an undercooled liquid associated with a hindering of the diffusional motion.

A second liquid system investigated is methanol. In this case the special diffusion processes under consideration were $CH_3OH \leftrightarrow CD_3OD$ and $CH_3OD \leftrightarrow CD_3OD$. The results obtained indicate that the methanol molecule diffuses as a whole /6/.

3. Water motion in non-liquid systems

Test experiments were performed with polyacrylamide (PAA) gel which is used in electrophoretic experiments as a carrier. The PAA gel consists of 15% Cyanogum, 2% tetramethyleneethyldiamine, rest water. Using for the production of the gel D_2O and H_2O alternatively a contrast between these two phases can be seen by neutron radiography. This leads to further possible applications in chemical studies, especially for investigations of the motion of water and hydration spheres with various ions.

Recently an experiment on water diffusion in concrete was made. Here a 5 cm thick concrete plate was heated at one end and the transmission of a fine collimated neutron beam meausred at different distances from the heated end. Alternatively radiographs were taken. The measurements were performed at different heating times and showed a very clear picture of water motion in concrete under a thermal gradient. The results will be published in due course.

4. Investigations of resolution of neutron radiography in the presence of hydrogen

As it is commonly well known the presence of greater amounts of H has negative influences on the quality of radiographs. This is an effect of the heavy scattering of neutrons by H. In detail it leads to a diminuation of spatial resolution and to a reduction of the contrast of radiographs. A possibility to overcome these problems is the use of an antiscatter grid. This is a collimator being placed between sample and film thus reducing the amount of scattered neutrons reaching the converter. This antiscatter grid must be moved during the exposure for avoiding the imaging of the collimator plates on the film. A further problem when in use with a conical collimator is that the neutron beam of a conical collimator is not parallel. So we have mounted the antiscatter grid in such a way that it was oscillated around an axis. The amplitudes of the oscillations were so chosen, that just in the extreme positions the beam was totally stopped in the antiscatter grid. The grid consisted of 20 mm broad and 1 mm thick Al-stripes painted with an boron containing paint. Thus the antiscatter grid had a L/D ratio of 20.

With this assembly we investigated the edge-spread function of an Cd-plate with differently thick polyethylene plates between film and Cd. The use of the antiscatter grid has a remarkable effect on the sharpness on the edge-spread function. This results in a better resolution of the radiographs.

It is to be remarked that the radiographs taken for these last experiments were not taken with photographic film but with a cellulose nitrate foil type CA80-15B of Kodak-Pathé. This is a track-etch foil coated with a boron containing substance. The great advantage of this foil is insensitivity to gamma rays. This allows the intercomparison of the edge-spread function with and without grid, because the exposure times are different and thus the gamma background on an ordinary film would have a troublesome influence on the edge-spread function. The image of this foil is being developed by etching in caustic soda. This leads very good images with good resolution.

Literature

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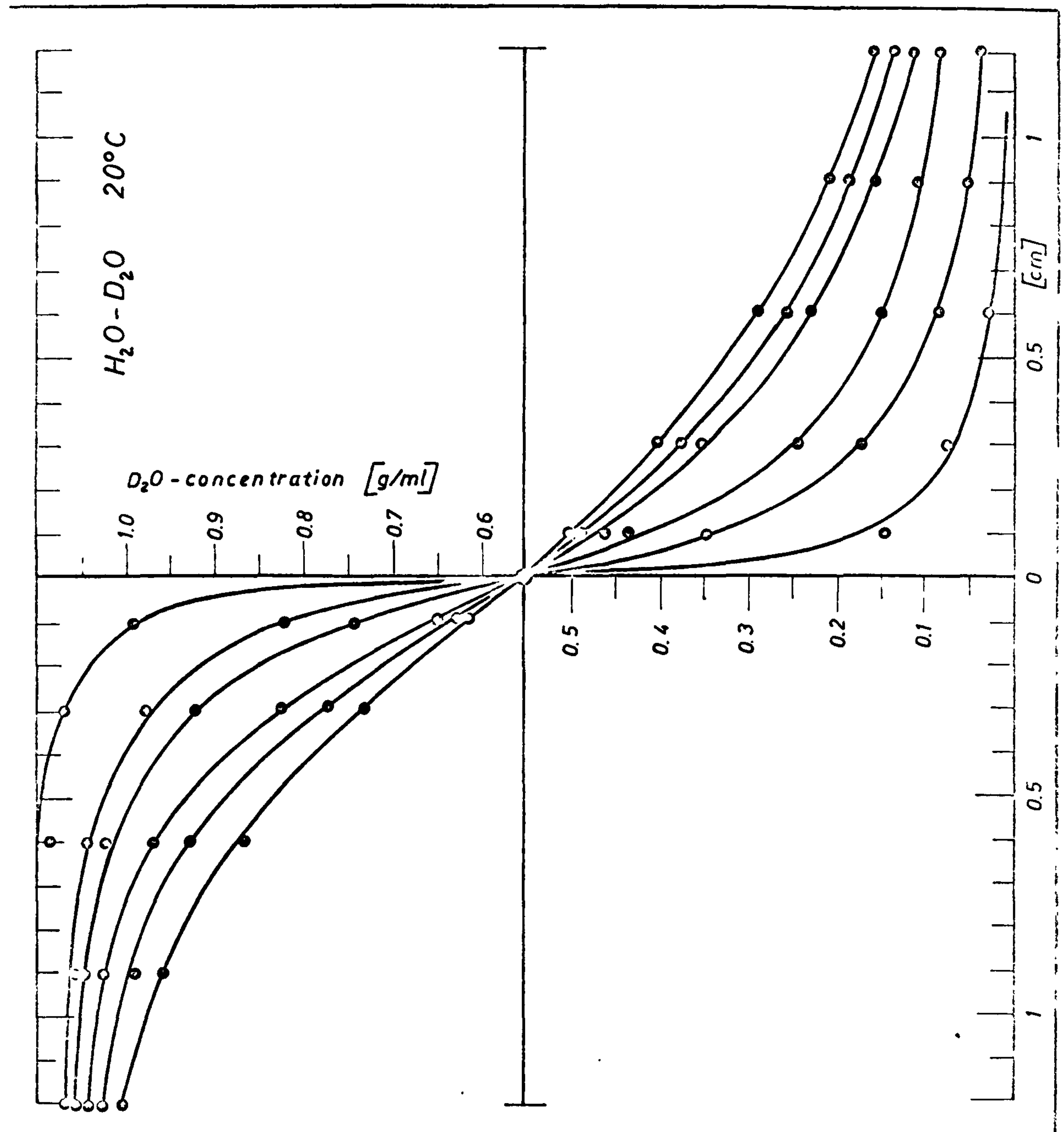

Fig.1: Concentration profiles of H_2O-D_2O diffusion process.

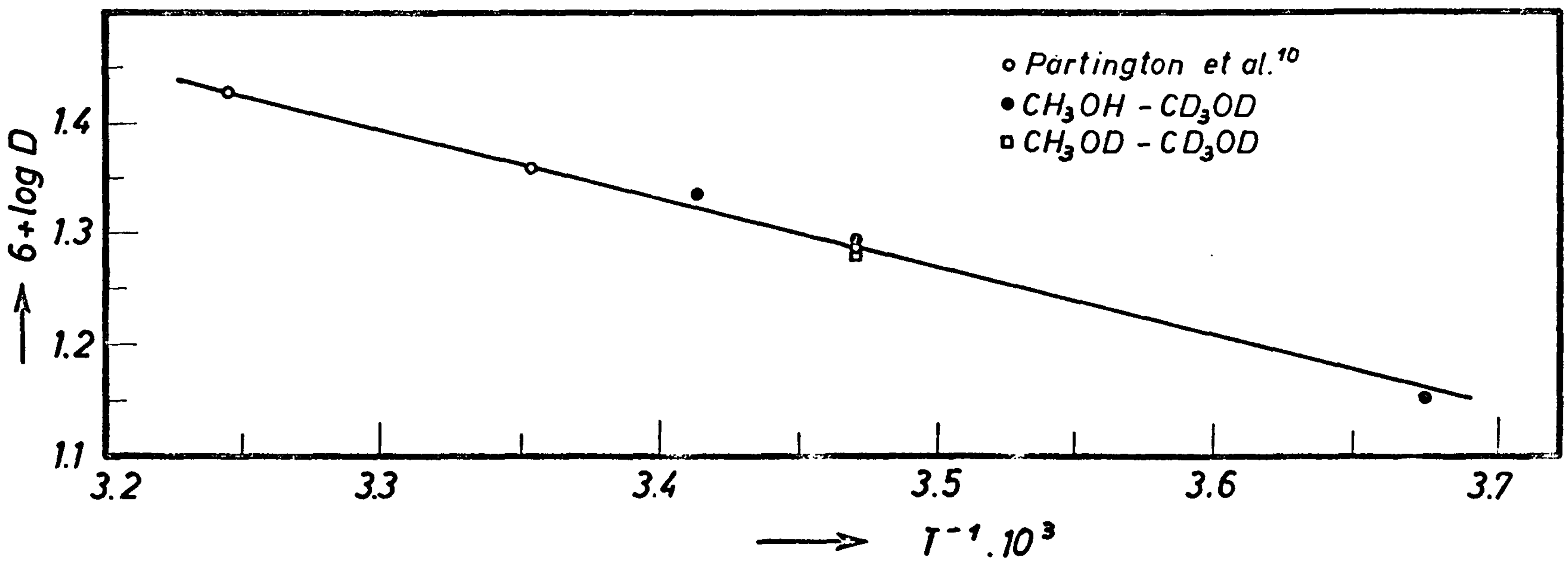

Fig.2: Diffusion coefficient of methanol as a function of temperature.

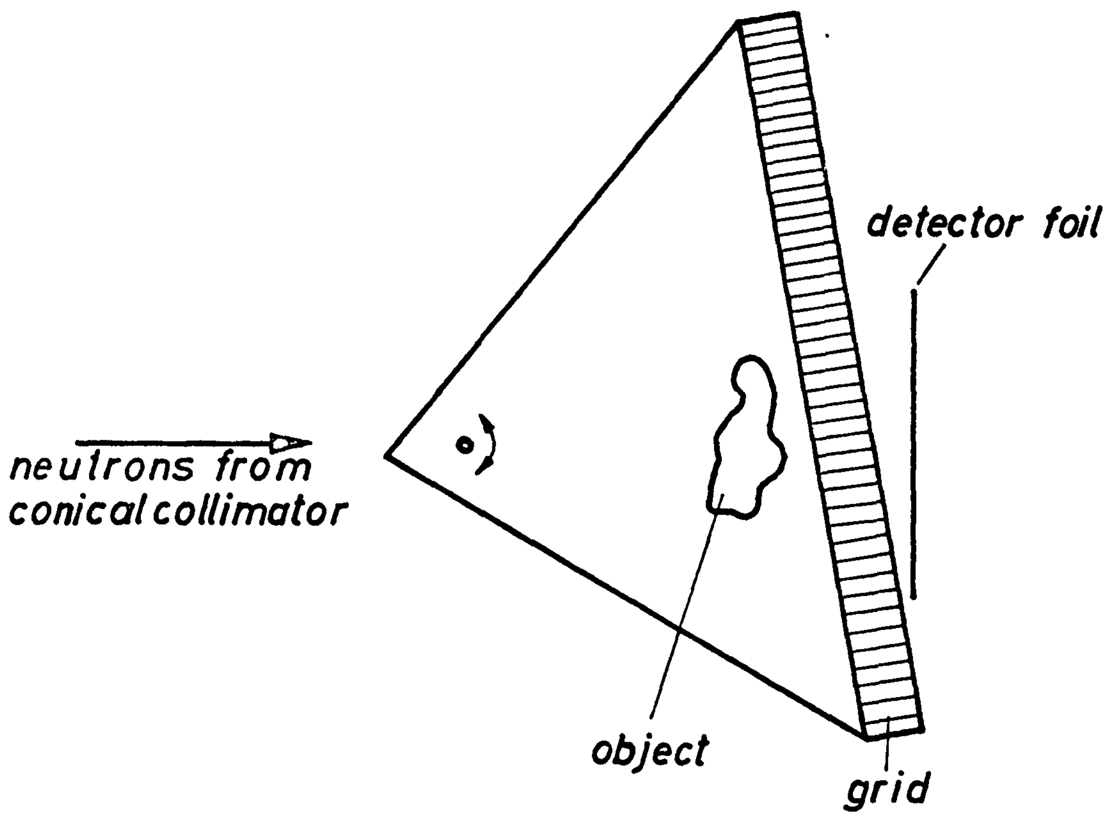

Fig.3: Scetch of antiscatter grid assembly.

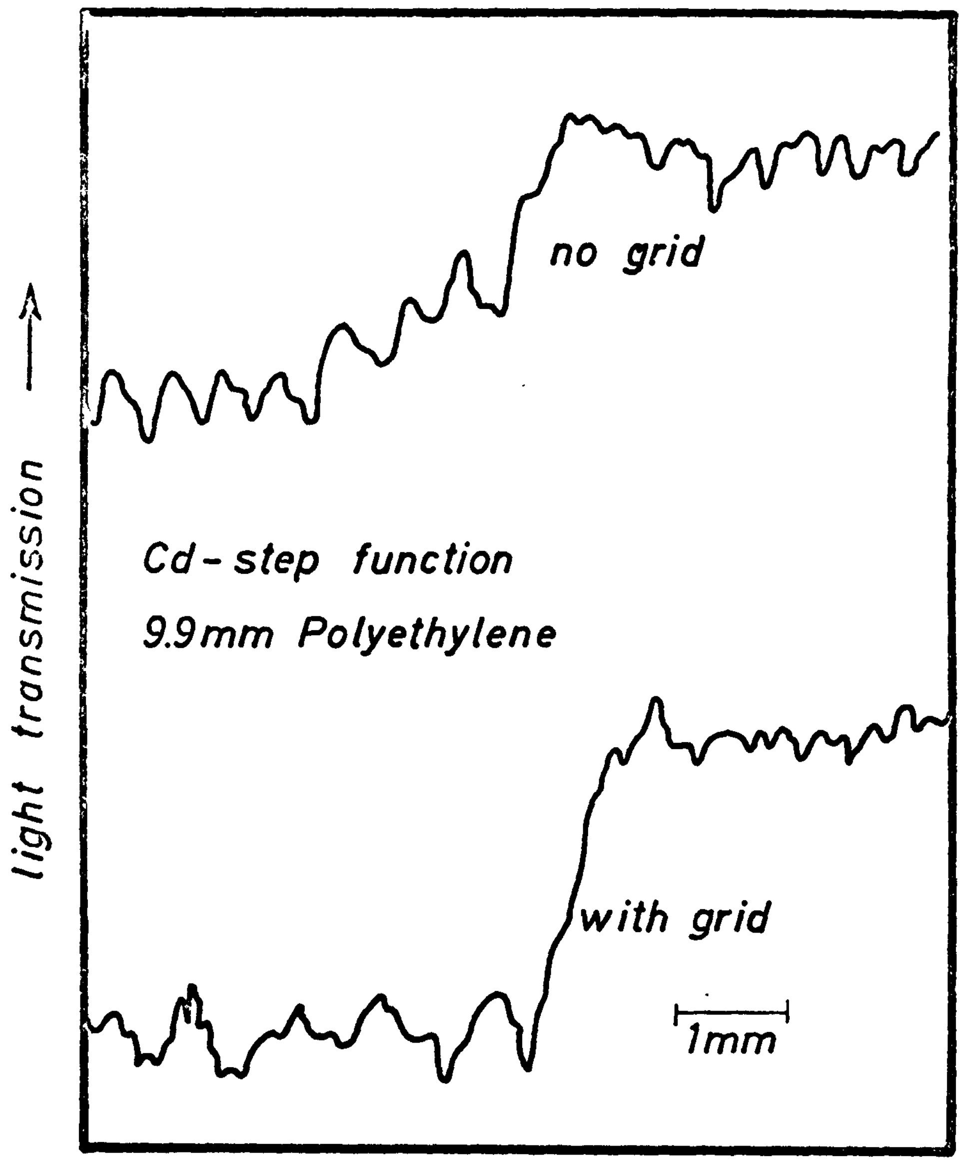

Fig.4: Edge-spread function of a Cd-step with 9.9 mm polyethylene between Cd and film. Light transmission through a track-etch foil as a function of position.

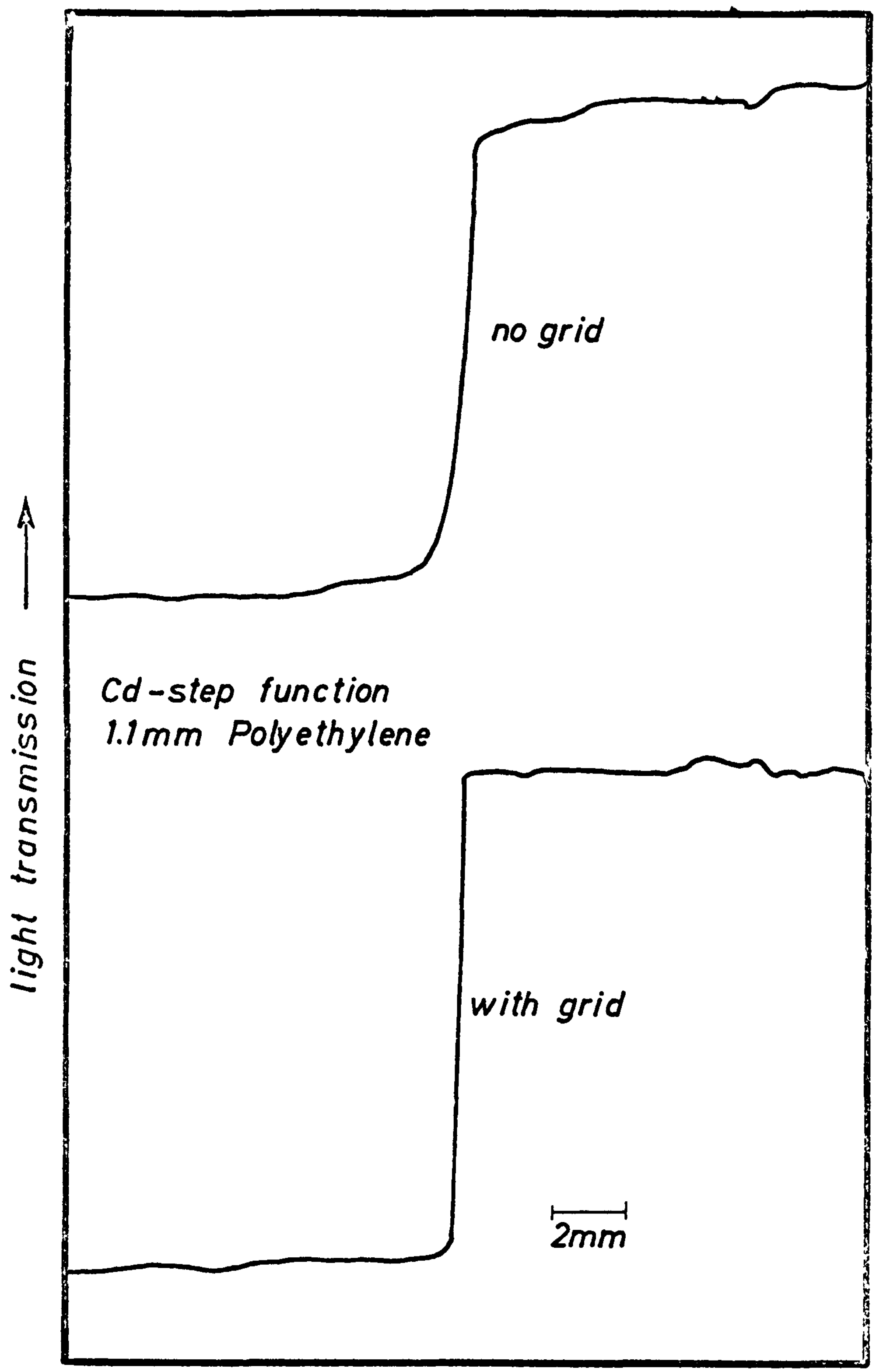

Fig.5: Edge-spread function with 1.1 mm polyethylene.