Technical Note

Automatic Water Phantom MP3

Three good reasons for a moving mechanism made of stainless steel

I. Stainless Steel allows a Mechanical Construction of High Precision

Stainless Steel compared with other adequate materials has a high modulus of elasticity (rigidity)[1)], i.e. the moving bars bend only slightly when forces are applied.

Example

Comparison between stainless steel (C12CRNIS188) and Perspex (Polymethylmethacrylat, PMMA), Assumption: The moving arms have the same resistance to movements, the weight of the ionization chamber and the holder as well as the cable drag result in a force of up to 5 N. The force is applied to the arm at its weakest point, i.e. for the bar fixed at one end at the tip, for the bar fixed at both ends in the middle.

	MP3 bar stainless steel	**Perspex bar same shape**
module of elasticity:	200,000 N/mm²	3,300 N/mm²
max. bend for a force of 5 N: a) bar fixed at one end:	0.15 mm	8.83 mm
b) bar fixed at both ends:	0.01 mm	0.55 mm

The table shows that a Perspex bar fixed at both ends deflects about 3.7 times more than the C-bar of the MP3 which is fixed only at one end!

II. Stainless Steel is not hygroscopic. Milling perspex causes internal stresses.

When Perspex moving bars are milled internal stresses are caused in the material. These stresses may be removed by tempering, however, tempering does not change the hygroscopic properties of Perspex. At a temperature of 20 °C Perspex absorbs water up to about 1 % of its weight.[2)] This causes a change in length of 0.2 % which corresponds to 1.1 mm for a moving bar of 550 mm length. To nullify this effect one may use springs or gaps in the mechanical constructions. As a matter of fact positioning accuracy of ± 0.5 mm[3)] as guaranteed with the MP3 could not be achieved. Moreover, moving bars that are not built symmetrically will extend at different rates. The reason for this is, that the amount of water absorbed is directly proportional to the surface area. As a consequence non-uniform expansion will result.

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III. The Stainless Steel does not produce detectable stray radiation or neutron contamination.

Experiments with the MP3 [4)] with different distances between moving bar and ionization chamber showed that within the precision of the measurement no influences are detectable if the recommended distance of 30 mm is used. This is guaranteed with all MP3 chamber holders.

The above mentioned experiments were performed at 8 and 16 MV photons as well as 5 and 25 MeV electrons and therefore comprise all physical effects. As far as neutron production due to (γ, n) – processes are concerned we considered the according cross sections for water and steel which amount up to 10 mbar in the region of the giant resonance. It can be seen from the figure [5)] that a maximum of about 430 neutrons are produced in 1 cm³ water or steel by 1 Mio. photons. It can be estimated how many neutrons from the complete C-arm of the MP3 can arrive at the ionization chamber due to the solid angle. To estimate the maximum number of neutrons only the inverse square law is taken into account, the absorption of neutrons in water and in steel is neglected. The line integral along the 550 mm long arm gives a number of 3500 neutrons for a photon energy of 19.5 MeV (maximum of cross section [6)]). The ratio between the number of neutrons and photons at the detector is therefore less than: 0.004 even if neutron absorption is not considered. That means the influence of the neutrons coming from the MP3-arm is not measurable. This theoretical estimation is therefore in accordance with the experimental results.

1) Modulus of elasticity – The Stress required to produce unit strain, which may be a change of length or a change in volume (see Handbook of Chemistry and Physics 56th edition, 1975 – 1976).

2) Kunstoffhandbuch Band IX, Polymethalacrylate, Hrsg. R. Vieweg und F. Esser, Carl Hanser Verlag München 1975

3) Superpositions of uncertainties in all three directions with the cable drag taken into account. Reproducibility of positioning: ± 0.1 mm

4) Schüle, PTW-Freiburg, Szeglin, Nuclear Associates, 1984.

5) Values calculated from atomic cross sections of the Sigma-Center in Brookhaven, Upton, Long Island, New York. Neutrons with energies above 3.7 MeV where taken into account.

6) Replacing the stainless steel bar by water and performing the same calculation, 1200 neutrons would hit the ionization chamber.