inverse of the closest distance (in meter) at which the vision is sharp.

For example, a rather young observer may have an accommodation width of 12dpt, implying that every object beyond 1/12 meter can be focused on. Through a binocular of magnification $m = 8$, this minimum accommodation distance is moved away by the factor m^2, yielding 64/12dpt = 5.3m. On the other hand, an elder observer with $\delta_{\text{akk}} = 1\text{dpt}$ would be able to get objects beyond 64m in focus, while observing through the same binocular.

Actually, this picture is somewhat simplified, since a (mathematically) perfect focus it is not required to regard an image as sharp. A certain degree of fuzziness, defined in terms of the *circle of confusion*, and expressed in units of arcmin, is tolerable without considerable loss of perceived image quality. Albert König has defined the maximum tolerable angular diameter of that circle of confusion to be 3.4 arcmin[15]. When taking into account the focal tolerance allowed by the circle of confusion, then an additional margin of $1/d_{\text{e}}$ dpt to the depth of field arises, where d_{e} stands for the diameter (in mm) of the observer's eye pupil. The validity of this approximation is restricted to pupil diameters beyond 2mm, however, since otherwise diffraction effects would turn dominant.

In combination with the optical instrument, it is once again the effective exit pupil diameter d' which is of relevance, being defined as the smaller of both exit pupil and eye pupil. Due to the circle of confusion, the binocular does not need to be focused on infinity to get distant objects into focus. Instead, the (*hyperfocal distance*)

$$E(\text{hyperfocal}) = m^2 \cdot d' \cdot 1000\text{m} \qquad (10.38)$$

replaces the infinity setting and thus extends the range of distances in which objects appear sharp. This leads to the modified minimum accommodation distance of

$$E_{\text{min}} = \frac{m^2}{\delta_{\text{acc}} + 2/d'}\ , \qquad (10.39)$$

where the effective exit pupil d' is given in mm in order to yield E_{min} in units of m. As stated above, the validity of both equations is restricted to $d' \geq 2\text{mm}$.

Figure 10.16 displays the instrument-aided accommodation ranges of binoculars, which are set to the hyperfocal distance (dashed curve), as a function of magnification. Two observers of different ages and corresponding different accommodation ranges experience depths of field which differ in their minimum accommodation distance. For example, a 25 years old observer with 10dpt accommodation width takes her 8x42 binocular, focuses on the hyperfocal distance of 192m, and is able to accommodate on objects between 6m and infinity. On the contrary, an observer of 50 years age and with reduced 2dpt accommodation range sets his 12x50 binocular to the hyperfocal distance of 432m and gets every object between 54m and infinity in focus. In all calculations we have assumed an effective exit pupil of $d' = 3\text{mm}$, an average value during daylight observations.

At low ambient light, the observer's pupils turn wider, and so does the effective exit pupil, which now adopts the value of the binocular's exit pupil diameter. With 8x42, and $d' = 5.25\text{mm}$, the young observer now experiences a depth of field between $E_{\text{min}} = 6.17\text{m}$ and infinity, the elder, equipped with his 12x50, a range between $E_{\text{min}} = 58\text{m}$ and infinity. These ranges differ marginally from their daylight values, indicating that – contrary to the dominating influence of the magnification – the pupil size contributes little to the depth of field of visual optical instruments.

[15] A. König, H. Köhler, *Die Fernrohre und Entfernungsmesser*, p. 123, Springer-Verlag (1959); note that the maximum resolution of the unaided eye under ideal conditions is of the order of a single arcmin, considerably higher than 3.4 arcmin.