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NOTES ON TELESCOPIC SIGHTS FOR SMALL ARMS

Glossary of terms used in this note

Magnification	The angular size of the image as viewed through the sight compared with the actual angular size of the image as seen from the objective lens of the sight.
Real field of view	The angular size of the field as seen from the sight.
Apparent field of view	The angular size of the field as seen through the sight.
Entrance pupil	The aperture controlling the light entering the sight. This is normally equal to, and coincident with, the clear aperture of the objective lens.
Exit pupil	The area which contains all the light which has passed through the telescope and is the image of the objective. The diameter of the exit pupil is equal to that of the entrance pupil divided by the magnification. The firer's eye must be placed at the exit pupil to observe the whole field of view.
Optical eye relief	The distance of the exit pupil from the final glass surface of the sight.
Mechanical eye relief	The distance of the exit pupil from the last rigid part of the sight e.g. the lens bezel.
Eye freedom	The amount of radial movement the eye can make before either field loss or serious loss of image quality occurs.

Figure 1 shows a schematic diagram of a normal telescopic sight with image erection produced by an intermediate lens. The ray paths of the image forming light is shown by:

a. A firm solid line for the axial ray passing centrally through all the lenses in the system.

b. A chain dotted line _____ _ _____ _ for the principal rays which pass through the centre of the objective lens and are led by the lenses to form the off-axis images.

c. Dotted lines _ _ _ _ _ _ for the marginal rays which pass through the edge of the objective lens and are associated with the principal rays to provide adequate illumination of the off-axis field and create the exit pupil. With the eyepiece set at zero dioptres, i.e. infinity focus, these rays are parallel to the associated principal ray.

The lens system of the sight creates an image at the first focal plane which is coincident with the graticule, and a second image at the focal plane of the eyepiece. The first image is inverted and the erecting lens converts this to an erect image at the second focal plane. The function of the field lens near the first focal plane is to direct the principal rays through the centre of the erecting lens. The function of the eyepiece is to focus the image at the second focal plane to infinity and to collect all the image forming rays to pass through the exit pupil which forms the eyepoint of the sight.

Figure 1 shows the axial beam and the beam associated with the upper limit of the field of view. A similar set of rays forming the lower limit of the field of view have been omitted from Figure 1 to preserve the clarity of the diagram. It will be seen from Figure 1 that unless the pupil of the firer's eye is within the exit pupil at the eye point the whole field of view cannot be simultaneously observed.

Often, for convenience or economy, the diameter of the eyelens is smaller than that necessary to pass a full pupil size for the rays relating to the edge of the field of view and almost all telescopic sights with large eye relief show a degree of this vignetting, sometimes as much as half the pupil.

A comparison is outlined below of three telescopic sights:

Schmidt u. Bender	4 x 25
Swarovski	1.5 x 14
Ring Sight MC-10-80	1 x 10

	Schmidt u. Bender	**Swarovski**	**MC-10-80**
Magnification	4 x	1.5 x	1 x
Objective clear dia	25mm	10.5mm	10.0mm
Exit pupil diameter	6.25mm	7.1mm	10.0mm
Eye relief	50mm	80mm	58mm
Field of view	5.7°	9.0°	10.0°
Length	235mm	199.5mm	83mm
Weight	345g	105 g	45 g

from such drawings as are available it appears that the vignetting of the exit pupil is:

1.2mm	2.5mm	5.0mm

so the remaining pupils at the edge of the field of view for these sights are:

5.05mm	4.5mm	5.0mm

Conventional or solid glass

Conventional telescopic sights have airgaps (this helps with the optical design) but means that they must be sealed. Under military conditions around the world it is difficult, if not impossible, to have a perfect seal. So a regular cycle of purging and refilling with dry nitrogen has to be done to guarantee no internal misting up and fungus growth.

It is for this reason that Ring Sights has designed solid glass telescopic sights. Erection of the image is achieved in the MC types by using concave mirrors in place of the field and erecting lenses (this enables us to put the graticule externally on the field "lens" which simplifies night illumination) and by using prisms in the TC types (but this needed a conventional internal etched and filled graticule for night illumination).

The MC design does not lend itself to having magnification. In addition there is no gain from increasing the exit pupil for the reasons given above.

The TC design can be unit power (with all its advantages) but can also have magnification up to, probably, x 2. However the TC types are inherently of a less convenient shape.

Magnification or unit power

Magnification makes target identification easier. It increases the visibility of the target in very poor light levels provided that the exit pupil is large enough to match the largest pupil diameter of the human eye under low light conditions: this has been established as 7mm.

In engagements where the weapon is unsupported magnification adds little to the accuracy of fire.

In telescopic sights magnification is normally accompanied by a smaller real field of view: this slows target acquisition. There is also a blind area since the apparent field of view seen by the eye at the eye point is greater than the real field e.g. with the Schmidt u. Bender 4 x the apparent field is 22.5° while the real field is 5.7°. There is therefore an annular zone of 8.4° width which cannot be seen either through the sight or around the edge. This is, of course, less pronounced in the 1.5 x Swarovski.

One advantage of unit power is that the firer can keep both eyes open looking at the target and the field as seen through the sight blends with the view as seen around it. This advantage is diminished or lost if the mounting arrangements obstruct the view around the sight.

Use with Night Vision Goggles

There is a general trend in armies worldwide to want to aim their small arms using NVG. There is no optical problem with reflex collimator sights provided that the optic surround is kept to a minimum. The reflex collimator sight injects its graticule into the NVG objective. The entrance pupil of the NVG (typically about 20mm diameter) is hardly affected and the NVG performance is maintained with the NVG capable of looking around the sight as well as through it.

The position with conventional telescopic sights is different. Magnifying sights have, as shown above, an exit pupil of 7mm or so while the NVG have entrance pupils of 20mm or so. As a result the NVG get one eighth of the light through the telescopic sight that they get ordinarily (20^2 divided by 7^2). And, with magnification, the view around is different from the view through so any outside view is useless. The outcome is that conventional telescopic sights are not suitable for injecting a graticule into NVG.

MC types of Ring Sight are different. They are unit power so the view through and around the sight is the same. The exit pupil is as wide as the optic. The surround (since they are solid glass) can be minimal. So the NVG can look through and around the sight with little degradation of performance. The same principles can apply to TC types of unit power.