HISTORY AND FUNCTION OF PERISCOPES

ABOUT PERISCOPES

The periscope, also referred to as *driver's optics*, is an optical instrument that enables an observer to view surrounding objects over an obstacle or also from under a cover. The term "periscope" derives from the Greek (περί, *perí* and σκοπεῖν, *skopeĩn*) meaning "around", "surrounding", "near" and "see" or "view", respectively.

HISTORICAL BACKGROUND OF PERISCOPES

The invention of the periscope goes back to Johannes Hevelius (1611-1683), who was the first to describe one under the name of "polemoscope" in 1647 in his first book, *Selenographia, sive Lunae descriptio (Selenography, or an account of the Moon)*. "Polemos" (ancient Greek Πόλεμος, *Pólemos*) translates into English as "fight" or "battle" and denotes the personification of war in Greek mythology. The name chosen by Hevelius for the first periscope thus already indicates that he had a military use in mind for his invention.

In the year 1854, the Frenchman Hippolyte Marié-Davy designed the first exemplar of a periscope – a sighting tube for a submarine. This contained two parallel mirrors attached to the ends at a 45° angle while facing in opposite directions (see Figure 1.0 left).

In 1898, the Irishman John Holland constructed the first deployable submarine with an effective periscope based on this principle. But this and other periscopes developed in the 1880s still proved to be very primitive and were continuously revised and advanced in the decades to follow. In the United States Navy, Thomas H. Doughty invented a prismatic periscope that was used in the American Civil War (1861-1865 – see Figure 1.0 right).

In the year 1902 Simon Lake, a submarine engineer, developed a more effective foldable periscope with eight prisms for a 360° view and referred to it as "omniscope" or "scalomniscope". This enabled the crew to observe their entire surroundings at lower submarine speeds.

In the First World War (1914-1918) periscopes, in some cases attached to rifles, for the first time enabled soldiers to see over the tops of trenches and thus avoid enemy fire. From 1940 at the latest, periscopes fully found their way into the military sphere, for example in armoured vehicles, to enable relatively safe inspection of the situation from a crew compartment protected by the armour. An important milestone in this context was the 360° rotary driver's optics developed by the Polish engineer Rudolf Grundlach between the wars for combat tanks. This allowed a crew member – normally the commander - to observe the battlefield without needing to leave the armour protection. This design, patented by Rudolf Gundlach in 1936, was first used in the Polish 7-TP tank, which was produced from 1935 to 1939. Today, military tank technology would be unthinkable without the periscope, which is regarded as the progenitor of all modern in-tank viewing devices.

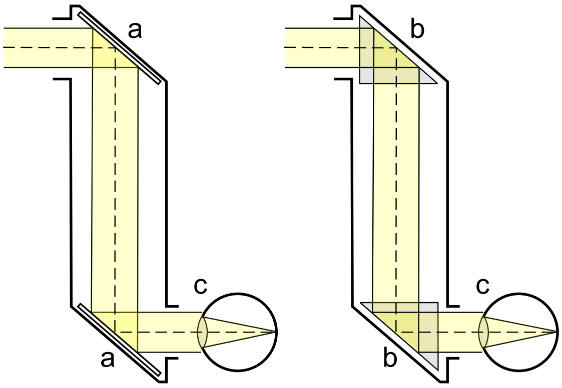


Fig. 1.0 Periscope with mirrors (a) or deflecting prisms (b) and the respective observing eye (c)
(Source: Schirm, Christian: https://commons.wikimedia.org/w/index.php?curid=522880)

THE OPERATING PRINCIPLE OF PERISCOPES

The basic structure of a periscope consists of an outer casing with two parallel mirrors, Sp_1 and Sp_2, mounted at the two ends at a 45 ° angle to the entering and exiting light beam.
The functionality of the periscope is based on the principle of repeated light beam reflection: a light beam entering through the upper opening hits mirror Sp_1 at an incidence angle of 45°. The mirror reflects the light beam vertically down the casing until it reaches the other opening, where it hits mirror Sp_2 at 45° and is deflected into the original incidence direction at a parallel remove. The incidence angle of the light beam makes no difference for this as it is always reflected vertically back to the viewer thanks to the mirror's position at 45°. An observer looking into the lower opening of a periscope thus has the impression of viewing the surroundings further above.

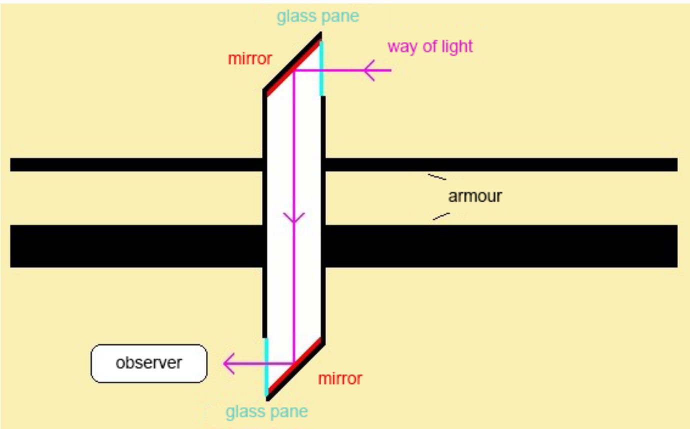


Fig. 1.2 Schematic structure of a driver's optics
(Source: Schoringer: https://de.wikipedia.org/w/index.php?curid=606498)

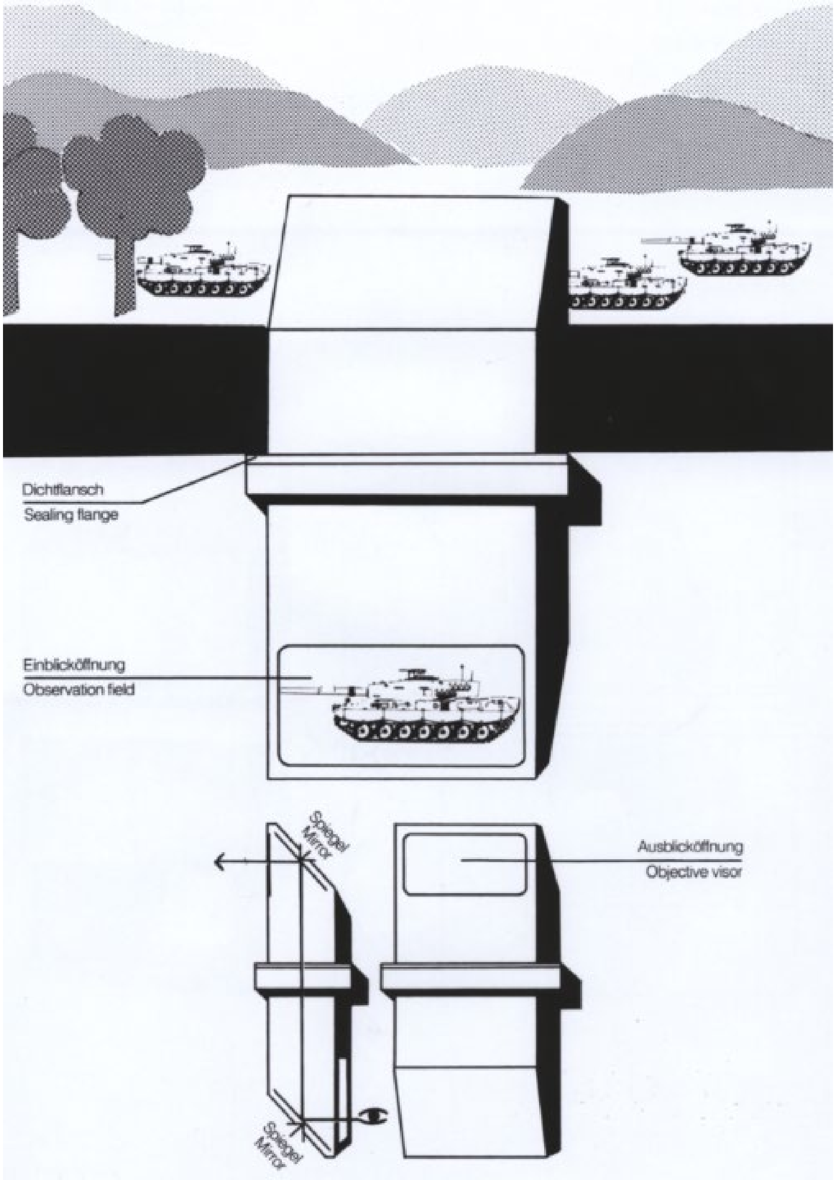


Fig. 1.3 Design principle of a driver's optics

FIELD OF VIEW (FOV)

Field of view or FOV refers to the extent of the observable world that can be seen at any given moment by the human eye, animals, technical equipment or optical devices such as periscopes, for example.

THE HUMAN FOV

The human field of view is the part of the visual environment perceivable with a fixed (motionless) gaze at an object. It includes both the central (foveal) and peripheral vision.

A differentiation is made between the monocular field of view of either the right or left eye and the binocular field of view provided by the two monocular FOVs together. In adults, the binocular (two-eyed) field stretches to ca. 180-220° horizontally, and ca. 60° to the top and 70° to the bottom vertically (s. Fig. 1.4).

Clear vision is only possible in the central area. The quality of the visual perception declines in acuity, pattern recognition and colour vision the more peripheral the visual stimuli are. The outermost periphery of the field of view hence features a "colour-blind zone", so that the colours yellow and blue are recognized first from the periphery to the centre, and red and green only further inside. The sensitivity for moving objects also diminishes peripherally, but less so than other visual functions, so that the motion perception is relatively superior to them in peripheral sight. The periphery of the field of view is therefore particularly important for detecting dangerous situations.

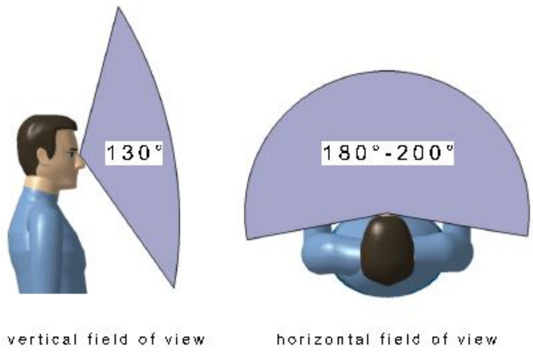
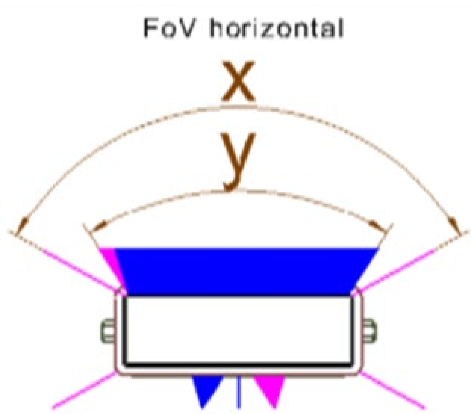


Fig. 1.4 Vertical and horizontal field of view

THE FIELD OF VIEW (FOV) OF PERISCOPES

With periscopes, a principal differentiation is made between the static and dynamic field of vision. This applies to the horizontal as well as the vertical viewing range. Static means that the observer is looking into the periscope's viewing window from a fixed position. And dynamic means that an observer's position can shift to the left and right or up and down, extending the viewing range.
The observer's field of view depends on various factors. The width of the viewer window is decisive for the horizontal viewing range, and its height for the vertical. In addition to this, the total height of the periscope is also decisive. One speaks of the periscopal height here. The greater this height is, the smaller will the field of vision be. And as an observer moves away from the periscope, the field of vision also grows ever smaller.



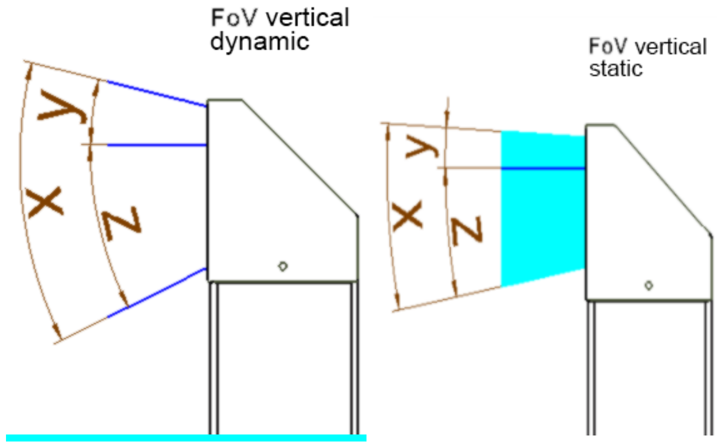


Fig. 1.5 Field of view (FOV) of periscope

PERISCOPE MATERIALS

The bodies of the periscopes installed in armoured vehicles are made from **polymethyl methacrylate** (PMMA) or glass to enable a ballistically protected observation of the outside from the interior protected by the armour. Personal safety is ensured by the fact that projectiles are not reflected downward when the periscope is shot at, unlike light beams. And on the other, no splinters can be carried inside by the blast wave (see Fig. 1.6).

Fig. 1.6 Bombardment of the periscope

Polymethyl methacrylate (or PMMA for short, commonly also referred to as *acrylic glass*, *Perspex®* or *Limacryl®*) is a thermoplastic, i.e. soft when heated, transparent plastic developed in 1928 at roughly the same time in Germany, Great Britain and Spain, reaching its market maturity in 1933. Today, PMMA finds a broad range of applications around the world thanks to its attributes. PMMA is an extremely stiff and hard material with an amorphous, i.e. glass-like, structure. It has a density of 1.19 g / cm³. This makes PMMA only ca. half as heavy as the same quantity of conventional normal glass. It also has a high surface hardness, making it less liable to scratch than other plastics. The impact strength of polymethyl methacrylate far exceeds that of conventional normal glass. Its temperature resistance ranges from -40 °C to + 70 °C,

but particularly heat-resistant types of PMMA will also withstand temperatures of up to 95 °C.
In contrast to acrylic glass, glass can look back on a 9,000 year-history as a material. The oldest finds date from as early as the stone age around 7,000 BC. Stone age people used so-called obsidians and tektites as cutting tools. These glass-like rocks were formed when quartz sand was molten by intensive heat, e.g. from volcanoes or lightning strikes in sandy areas. The organized production of natural glass did not get started until around 3,000 BC in the form of gemstones and small vessels, however.
Today, the production of soda-lime-silica glass (flat and container glass) basically requires six natural resources: ca. 70 parts quartz sand (SiO_2), 13 parts soda (Na_2CO_3), 10 parts lime ($CaCO_3$) and small fractions of dolomite ($CaCO_3$ x $MgCO_3$), feldspar and potash (K_2CO_3). The attributes of silicate glass can be changed by optimizing its composition and production conditions, making the material highly versatile.
Glass is an amorphous substance created by melting. In thermodynamic terms, glass is described as a frozen, undercooled liquid. This definition applies to all substances that are melted and cooled down at a corresponding speed. The latter ensures that although crystal nuclei are formed when the melt hardens into glass, there is not enough time left for the crystallization process. The congealing glass is quickly too firm to enable crystallization. The transformation range, meaning the temperature region wherein the glass transitions from melt to solid, extends to circa 600 °C with many types of glass. The atomic structure of glass thus roughly resembles that of a liquid, to put it simply. As a melt, glass can be brought into many different shapes (by pressing, blowing, rolling, etc.), while its attributes can be affected by various additives.
Given their thermodynamic properties (amorphous structure, glass transition, etc.), plastics such as acrylic glass (PMMA) are also categorized as glasses, although their chemical composition radically differs from that of silicate glass.
The signifying properties of glass in common parlance are high translucency, the many ways of shaping and colouring it, and its resistance to most chemicals.