9 Binocular evaluation and field testing

Anyone who is about to purchase a new pair of binoculars has an enormous selection of models to choose from. Even after specifications and price sector have been largely determined, there is still a choice between various brands or manufacturers. So a comparison must be made, to facilitate the final decision in favour of a particular model. Various discussion forums exist on the Internet with countless experience reports, written by users with very different requirements and experiences. Test reports can also be found in consumer magazines, sometimes including long tables of figures, obtained in specialised optical laboratories. Although this information is definitely helpful, it should always be viewed with a certain degree of scepticism: ultimately, the observer is out and about with the binoculars himself, and what then counts is his own experience with the instrument. There is therefore no better test than the one you have carried out yourself.

In this chapter, the reader will find tips and advices on test strategies and procedures that are practicable and doable by the layman who has no access to the instrumentation of optical labs. The methods described here are by no means unique. Instead, they have proven particularly useful or simple. The sections of this chapter will follow a path of gradually increasing complexity: Beginning with a selection of quick tests in the store, all the way up to extended field tests which may extend over several days, and which reputable manufacturers should preferably conduct with the prototypes of their products under development. The prospective owner of a binocular will have to decide for himself, up to which level he is willing to take his testing procedures, and at this point a warning is appropriate: the testing of gear may easily turn into an end in itself if the tester is failing to define its purpose at the outset, and gradually getting lost in details that are of little or no relevance to practical observations. This should be kept in mind, since in the course of testing, the sample may be subjected to extreme situations, which are deliberately staged to enable the detection of flaws, but are possibly absent under conditions in which the instrument may actually be used. A realistic and balanced analysis of the test results is therefore mandatory, and more often than not skipped in those reviews that are commonly circulated on the Internet.

Let us begin with a short summary of professional testing procedures as they are occasionally described in the technical literature.

9.1 Laboratory tests

Laboratory tests are routinely performed by manufacturers as part of their quality control procedures. Internationally agreed testing standards and norms exist, which may or may not be applied during these procedures. Some technical journals hire the service of manufacturer's labs or independent institutions for their product reviews, in which binoculars are tested for optical performance and mechanical durability.

On Albrecht Köhler's web-site there exists a list of standards and norms that are used to test optical parameters[1]. They include measurements of the angular magnification, entrance pupil diameter, exit pupil diameter, angle of field, eye relief, suitability for spectacle wearers, dioptre adjustment and zero

[1] `www.akoehler.de`: *Prüfen von Fernrohren* (in German).

setting (all as per DIN ISO 14490-1), resolution (DIN ISO 14490-7), image quality (DIN ISO 9336-3), transmission (DIN ISO 14490-5), veiling glare index (DIN ISO 14490-6) and binocular alignment (DIN ISO 14490-2). Image quality is determined by measuring the contrast transfer function – a sophisticated and costly procedure. The veiling glare index is measured using a large photometer sphere, and to check the usability for spectacle wearers, a special adapter (designed by Weyrauch, Section 8.12) is attached to the eyepiece.

Spectral transmission is measured with a spectrophotometer; however, before determining the integrated visual transmission data, the transmission curve needs to be weighted with the spectral stimulus response of the eye (Section 8.7), which implies that the finally recorded visual transmission values in daylight (photopic vision) and low light (scotopic vision) differ.

The resolution is measured at full aperture of the entrance pupil. As previously discussed (Section 2.4.2), such a test should be repeated after the exit pupil has been stopped down to values below 2.5mm, because the human eye performs best under these conditions, in which the binocular should therefore perform close to its diffraction limit[2]. A majority of handheld binoculars have exit pupil diameters above 4mm, which are exhausted only in low light in which the resolution of the eye remains well below the diffraction limit (Section 6.5). Thus, measurements taken at full aperture are often of limited relevance in the field - with the exception of applications in astronomy.

Testing the quality of phase-correcting coatings (Section 3.2.6) requires two polarising filters, placed at both ends of the telescope tube with their transmission axes orientated parallel or perpendicular to each other[3]. The roof edge has to be aligned with the transmission axis of one of the polarisers. Narrow-band green light is used to assess the differences in brightness of the exit pupils, depending on the relative orientation of the polarising filters: without phase coating, the exit pupil is brighter with the parallel-setup of both polarisers, compared to the perpendicular-setup. It would be the opposite in the presence of an effective P-coating.

Figure9.1

Not recommended: testing for mechanical durability and water resistance may yield undesirable results (with kind permission: Barry Simon).

Tests for mechanical ruggedness and water resistance are an essential ingredient of the design of any high-quality binocular. The manufacturers follow here their own procedures, the details of which are not made public, but we do have the maintenance guide A050/1/501 of the East German NVA, which describes in detail the regular stress tests, to which their standard military binocular, the EDF 7x40, was subjected to:

[2] Thanks to David W.J. Norton for this important remark.

[3] A. Weyrauch, B. Dörband, *P-Belag: Verbesserte Abbildung bei Ferngläsern durch phasenkorrigierte Dachprismen*, Deutsche Optikerzeitung Nr. 4, 1988 (in German).

Figure9.2

Zeiss (Jena) 7x40 EDF, the standard handheld binocular of the East German NVA ("Nationale Volksarmee", Field of view: 131m/1000m**)**

- **tightness**: implementation of an internal overpressure of 50.7kPa. Requirement: pressure drop not permissible.
- **submersible water test**: submersion depth: 1m. Water temperature: 10°C to 15°C lower than unit temperature (resulting in a negative pressure in the unit). Duration: 1h. Requirement: no water or fogging in the interior.
- **drop test**: Drop height: 0.75m. Direction: lying broadside with stretched central hinge, one fall.
- **impact test**[4]: acceleration 15g. Pulse duration: 5 – 10ms. Direction: 250 strokes on objective standing, 150 strokes on broadside lying with stretched central hinge, 150 strokes lying on narrow side with stretched central hinge.
- **impact test**: acceleration 120g. Pulse duration: 1 – 5ms. Direction: 2 strokes on objective standing, 4 strokes on broadside lying with stretched central hinge, 4 beats lying on narrow side with stretched central hinge.
- **vibration load**: frequency range: 30-80Hz. Acceleration: 6g. Duration: 2h standing on objective lens, 1h lying on broadside with stretched central hinge, 1h lying on narrow side with stretched central hinge.
- **cold resistance**: −50°C, duration 2h, after the equipment has reached the required temperature, rubber parts to −40°C.
- **heat resistance**: 60°C, duration 2h, after the units have reached the required temperature. Requirement: no grease leakage.
- **cyclic temperature test**: upper temperature: 60°C, lower temperature: −50°C. Duration: 5 cycles per 2h. Requirement: no grease leakage.
- **storage temperature**: 80°C, duration 1h, after the units have reached the required temperature. Requirement: no grease leakage.
- **resistance to sea mist**: Temperature: 27°C. Duration: 168h. Composition: sodium chloride 27g/l, magnesium chloride 6g/l, calcium chloride (anhydrous) 1g/l, potassium chloride 1g/l. Requirement: no corrosion.

The German consumer association, *Stiftung Warentest*, revealed additional details in its testing brochure (September 2006), featuring tests for resistance against humidity, cold/heat and other environmental factors (DIN ISO 10109-4 and DIN ISO 9022), shock resistance (DIN ISO 58390) as well as abrasion resistance (DIN ISO 58196-4).

None of these test methods are usually available to the ordinary binocular user. If the intention is to use a new set of binoculars at very low temperatures, it certainly makes sense to leave the instrument inside

[4] The unit g does not stand for gram here, but for the acceleration due to gravity. NASA astronauts were subjected to stress tests which included a maximum acceleration of 20g.

a freezer for a night and to check whether the focusing mechanism and other mechanical parts remain operational. If not, unsuitable lubricants, which turn hard in the cold, were applied. This may lead to a temporary failure of the instrument in the field. Apart from these simple manipulations of the environmental conditions, the binocular purchaser does not have many options for testing ruggedness, and instead has to rely on the manufacturer's tests and the warranties they are granting. Additionally, he may search the Internet for reports from long-term users. Not surprisingly, the purchase of a technical instrument such as a binocular also requires a certain degree of common sense: who demands minimum weight, may not expect the durability of a military device. It is also highly unlikely that a cheap branded binocular has ever enjoyed the treatment of a vibrating table as a part of its design procedure.

9.2 A quick test in- and outside the store

Whoever is interested in purchasing binoculars may not necessarily have the opportunity to take several samples home and evaluate them against one other. It is therefore crucial to arrive at first conclusions, and perhaps to shortlist the lineup of interesting candidates, right in front of the counter of the store. With some experience, it is possible to learn a lot about the properties of a binocular within just ten minutes; this paragraph provides tips and hints about how to conduct quick tests in- or outside the shop.

9.2.1 First impression: design, ergonomics, haptics

More often than not, the first impression sticks. This is a fact long known to advertising psychologists, even if the critical buyer would care to dispute it. "Gut-feeling" prevails over the rational assessment of technical properties[5]. A well designed binocular with a high quality appearance can leave a lasting impression on us, and we may thus overlook or ignore technical flaws and imperfections. The most important theme of the following quick tests is therefore to put function above beauty, since the latter will turn out rather irrelevant during practical applications in the field.

At the moment when the binocular is first picked up, it is advisable to pay attention to the following aspects:

- Is it easy to adjust the settings of the instrument, i.e. ...
- ... is the central hinge neither too lose nor too stiff?
- ... do the eyecups have a fold-down or twist-down mechanism, and do they allow bringing the eyes into a comfortable position behind the eyepieces so that the entire field of view can be seen?
- is the field of view sufficiently wide, or does an impression of tunnel vision arise?
- does the rim of the eyecup feel comfortable, or does it leave pressure marks on the skin that may turn uncomfortable after extended observations?
- does the instrument rest comfortably in the hands, and does it remain well balanced while manipulating the focusing unit?
- does the covering material offer a good grip so that the binocular is safely operated even with sweaty hands or gloves?

In a next step, the focusing mechanism may be tried, after pointing the instrument toward a convenient target inside the store. Is it possible to operate the focusing mechanism without the need of changing the grip of the hands, so that the binocular, in

[5] "Consumption creates subjective well-being and thus has to stay emotional". After: Hans Weigum.

particular one with higher magnification, remains in optimum position? The central focusing barrel, if present, should turn smoothly and precisely, without any jerk or play. The entire focus travel should be exploited to check whether the torque remains constant, or whether any glitches in the gears emerge. The dioptre setting is tested in the same way. To prevent undesired changes of its setting after an unintentional contact, it should turn with somewhat higher resistance or, alternatively, be lockable.

Once a binocular has passed these initial tests, the next sample may be evaluated for the same criteria, or otherwise the second phase of testing as described below may follow.

Figure9.3

Many users apply their binoculars to observations at close distances, at which the minimum close-focus range represents an important parameter.

9.2.2 Checking for additional rejection criteria

It is advisable to compile a list of rejection criteria prior to testing, which allows the reduction of the initial lineup of potential candidates at an early stage of the evaluation. If observations of insects at close ranges are required, then those binoculars with a minimum focus distance of 3m or above are quickly eliminated. Luckily, this can be tested even inside the smallest shop. It should be verified that a close target is observable in a relaxed state of accommodation and without any eye-strain. Binoculars of the ordinary Porro type (i.e. not reverse Porro constructions) have a disadvantage here due to the wide separation of their objectives, which leads to a significant parallax when aiming at close objects (Section 4.3.2). The shortest focal distances of binoculars with roof prisms often reach 2m or below, while with Porro prisms as much as 3m may already become tedious. An observer, who is used to focusing clockwise from close to far distances, may be confused with a focusing mechanism that turns the opposite way.

Figure9.4

View into the objective tube. Left: clone of a military binocular with metallic reflections on the tube walls. Right: stray-light baffles of the Zeiss Jena 7x40 EDF (visible reflections are caused by the flashlight on the objective lenses).

A small pocket lamp serves as an indispensable tool for the quick tester, even if the shop salesman may frown upon its application. It allows checking for visible damages like scratches on the lens- or prism surfaces. Once pointed from below into the eyepiece while simultaneously looking into the objective enables the detection of dust or impurities inside the glass material. It should be noted that a few dust particles or air bubbles inside the glass are rarely a serious issue; they turn relevant only if located in immediate proximity of the focal plane, which usually concerns the field lenses of the eyepieces, or reticles of military binoculars.

At this point it is advisable to assess the quality of the anti-reflective coatings (Section 2.4.3). The various reflections caused by the flashlight are expected to be colourful and not too bright, i.e. of low intensity. In contrast, a bright white reflection would indicate an uncoated surface. When pointing the light downwards into the tube, shiny metallic parts which could cause stray-light should be absent, the prism entrance should ideally have a surrounding baffle, the flanks of Porro prisms should be covered with a non-reflective layer and their reflective surfaces covered with shields (Section 4.6). Ideally, the tubes are coated with matt varnish and supplemented with internal stray-light baffles (Figure 9.4).

Next, a distant target should be located to check for the state of collimation of the binocular. This may be difficult inside most stores, and a permission is required to take the instrument(s) outside and find some easy distant objects, e.g. a church-clock or roof antenna. Any object of distance beyond 1km may safely be regarded as "infinitely far" away. When adjusting focus, attention should be payed to the amount of extra focus travel remaining beyond the infinity setting. Such a reserve travel should remain to meet the needs of short-sighted observers who want to use the device without their spectacles. After careful adjustment and focusing, an easy and relaxed view onto the distant object should result. In case it is necessary to squint to properly see the object, or if a double-image appears, then the two tubes are most likely not properly aligned and the binocular therefore out of consideration.

If instead a minor degree of de-collimation is suspected, one may proceed as follows: one eye remains closed and the target is observed for a little while using monocular vision. Then, upon opening the second eye, a single image of the object should result instantly. If instead two images are visible, which rapidly merge together, then a sub-standard alignment of both binocular tubes is likely. Even though both eyes manage to find a superposition of both images, the application of such a binocular over an extended period will likely cause headaches or watery eyes.

It should be noted that this procedure may not be applied by observers suffering from heterophoria, who would experience a double image even with a flawless instrument[6]. An alternative test works as follows: a distant, almost point-like object is brought into focus and into the centre of field. Then the binocular is gradually shifted away from the eyes, carefully keeping the object firmly in sight. During this process, the discernible field of view rapidly shrinks, and when the binocular is $20-30$cm apart from the face, the object should simultaneously remain visible at the centres of both exit pupils. This method requires a steady hand and some experience - it actually works better if the tester moves back and away from a binocular mounted on a tripod.

A quick inspection of the exit pupils does also reveal the vignetting of the light beam, which is frequently caused by undersized prisms (Section 4.5.1). Figure 9.5 displays how the test is carried out[7]: when looking straight toward the eyepiece, the face-on exit pupil should be perfectly circular and of full size according to the specifications; otherwise, the principal ray-fan would be partially obstructed and the instrument's performance in low light were compromised. Next, the instrument is turned so that

[6] Thanks to Klaus Müscher.
[7] Thanks to Heiko Wilkens.

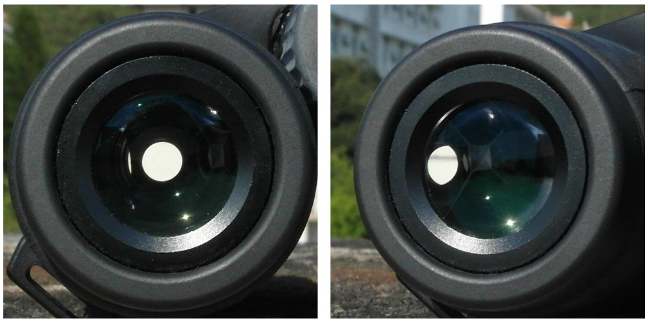

Figure9.5

Vignetting of the edge pupil: the exit pupil is circular if seen face-on (left). But once seen at an angle, at which it touches the lens-edge, it becomes partially vignetted (right).

the exit pupil is seen from an angle, until it touches the perimeter of the eyepiece-lens. This is the exit pupil as it appears close to the edge of field, also called edge pupil (German: *Randpupille*). Usually, the edge pupil is no longer circular, but obstructed to a cat-eye shape as a result of vignetting of the peripheral rays of the light cone. A moderate degree of vignetting does not significantly affect the performance of the binocular; in fact, it may even prove useful to the optical designer: the stopping-down of rays arriving off-axis hides their aberrations, in particular coma and astigmatism. As a result, the off-centre brightness of the image is somewhat reduced, but its sharpness is increased. Yet, the optical design of binoculars intended to be used in low-light should apply vignetting sparingly, since at night, with widened eye pupils, the loss of light in the peripheral parts of the image becomes bothersome and affects the binocular's performance (Section 6.9). Apart from that, a high degree of vignetting of the edge pupil creates negative side-effects for the ease of view, because it promotes the perception of a partial shadowing of the image with a swivelling eye.

Once a subset of binoculars has passed the selection criteria as described above, a couple of further tests may be performed to evaluate the imaging characteristics of their optics. During the following, one-on-one comparisons of the images of selected pairs will facilitate the selection of the highest performer among the remaining ones.

9.2.3 Evaluating optical performance

In order to arrive at definitive and final conclusions about the optical properties of the binocular, extended field tests are mandatory. However, with a certain degree of experience, a first and quite conclusive assessment is actually possible at a trade fair, in a department store or optics outlet, by making good use of the available targets.

Perfect test objects are the lit billboards which are abundant at department stores. Focus carefully on such a board in the centre of the field, and then slowly pan the binocular, letting a selected letter or number move through the field of view, and observe how the sharpness varies between the centre and the edges of the image. The edge of the billboard will probably show some degree of colour fringing. While keeping the direction of view fixed on that edge, pan the binoculars again and let the edge move through the centre of field, at which the colour fringes should disappear, and toward the opposite edge, where the fringes will emerge again. These colour fringes are the result of lateral chromatic aberration (Section 1.7.6), which can never be entirely eliminated, but should not be too obtrusive. In the course of panning, you will possibly register the billboard edge bending: its two ends will seemingly bend away from the centre of the field when the image is moved towards the periphery of the field. This is caused by pincushion distortion, which is often implemented intentionally to reduce the globe effect (Sections 2.1.3 and 8.11). If the billboard edge remains straight all over the field

Figure9.6

Testing colour rendition and brightness with the paper test: a photo of a white sheet of paper is taken through the binocular-objective, and afterwards the brightness is scaled down by five f-stops. This reveals a slight tint of red for the Leica and Nikon, and a tint of green for both Zeiss instruments (with kind permission: Tobias Mennle).

of view, then the image is said to be free of (rectilinear) distortion. The observer may then possibly perceive a distinct globe effect during panning. A minor quantity of such a distortion should therefore not generally be regarded as an imperfection of the binocular, but rather as the deliberate choice of the optical designer, who had to find a delicate balance between optical perfections of the static and the dynamic (panning) images.

In many cases, a bright spotlight may be utilised. It should be used to test the optics for ghost images (multiple reflections on the glass surfaces), and hence the effectiveness of the anti-reflective coatings, while panning the spotlight slowly across the field of view. It is also instructive to position the light source just outside the field of view, then moving it clockwise along the edge of field – a test, which evaluates the quality of the stray-light baffles. During such a procedure, no glaring or diffuse loss in contrast should occur. In the following section, dealing with the test procedures outdoors in the field, further checks regarding the stray-light protection of binoculars will be carried out.

The white paper test , as previously described by the technical journalist and camera expert Walter E. Schön, offers an easy way to assess natural colour rendition and transmittance of binoculars or camera lenses: a white sheet of paper is observed through the optical instrument, which, in the case of binoculars, is held upside down, i.e. while looking into the objective tube. It is then easy to see whether the light that has picked up any colour tint or has been dimmed down considerably. Two different binoculars can easily be held in each hand for a comparison. The ambient light should be neutral, ideally daylight, but even artificial light works reasonably well. The precise character of such colour rendering depends primarily on the characteristic spectral transmission of the anti-reflective coatings, the absorption of the optical glass, and the spectral reflection characteristics of the reflective coating, if any, on the roof prisms (Section 8.7).

A slight degree of colour bias is usually compensated by the colour adaptation of the eye, does not affect the observation and may therefore not be regarded as a flaw. When observing in daylight over long distances, a warm colour bias – a result of a reduced transmission in the short-wavelength range of the visible spectrum – may turn out to be an advantage, as it suppresses atmospheric scatter and increases contrast (Section 8.6). On the other hand, binoculars, which are optimised for low-light observations, often exhibit a somewhat cool colour rendition as a result of an elevated transmission of the shorter wavelengths. This reflects the shift of the sensitivity of the human eye toward the blue end in situations, in which scotopic (night-) vision dominates (Section 6.6).

At this stage, the optical and mechanical characteristics of the test candidates should be sufficiently developed to compile a shortlist of preferred candidates which may be taken home for additional, detailed field tests. In an ideal situation, the test procedure is now over, because a single instrument has been identified which performs well and best matches the requirements. The procedure may then be concluded by taking a look at the accessories supplied with the instrument. The strap should be mounted and its functionality checked. The protective caps should fit tightly, but also be removable in an instant when the binocular is needed in a hurry. If a bag comes with the instrument, it should allow the stowing or removal of the binocular without having to adjust the central hinge, and it should close safely and stay closed when on the move. In any case: if some of the accessories turn out to be less than perfect, it should not deter a buyer from purchasing an otherwise good instrument. Better and more adequate accessories can always be purchased afterwards from third party suppliers.

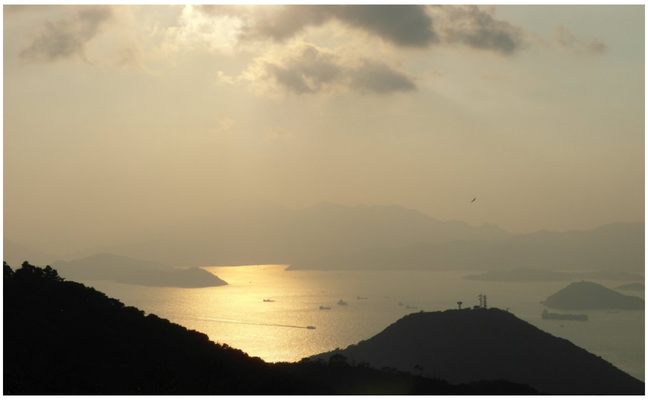

Figure9.7

Nature offers a diversity of lighting situations which can only inadequately be simulated in a lab.

9.3 Field tests

The rather subtle character of a binocular comes to light once the instrument is taken out into the field. That is why – in the past – the design process for any new binocular used to include extensive field tests on prototypes by professionals or amateur testers. This strategy allowed the elimination of flaws or imperfections prior to the introduction of the final product onto the market. Unfortunately, cost pressure today often induces manufacturers to skip this important phase of field tests; instead, the optical engineer relies on the output of his computer simulations, which are restricted to idealised models of both the instrument and the environmental conditions. An accurate assessment of the instrument's stray-light characteristics is virtually impossible, since it would have to encompass the reflective properties of the tiniest screw at any possible angle, or the reflectivities of all surfaces as a function of the angle of incidence.

Simulations are thus complemented by laboratory tests which permit the measurement of some of the stray-light properties of the instrument, though hardly all of them. Standardised lab tests struggle to reproduce the tremendous diversity of lighting situations in nature, in combination with the delicate responses of the observer's eyes (such as pupil diameter and eye-placement) under real-life conditions. Hence, its application in the field still provides the ultimate test for the instrument, and it is always interesting to observe how even premium binoculars do sometimes reveal their limitations.

9.3.1 Resistance against stray-light

Among the most characteristic, but also best hidden features of a binocular is its response to varying light situations. Particularly difficult to characterise is its susceptibility to generate stray-light (glare). No single instrument exists which is absolutely immunised against this class of effects: too many options exist for a ray-pencil to run astray and enter the optical path through an unwanted direction. Tests for the degree of resistance against stray-light must therefore not be limited to a single test setup, but rather be conducted in the widest possible variety of circumstances, thus forming a permanent part of the entire testing procedure.

Figure9.8

Exit pupils. Left: Hensoldt 10x50 Dialyt with brightly illuminated prism edges. Right: Zeiss (Oberkochen) 10x50, with well shielded prisms.

As a matter of fact, stray-light can originate from virtually any point in the optical path. Yet, it is often possible to determine its origin without the need to disassemble the binocular in question. Figure 9.8 presents an example, in which the exit pupils of two different binoculars are displayed. The vintage Hensoldt Dialyt to the left exhibits a bright frame-like structure around the exit pupil, caused by reflections from the edges of the Abbe-König prism which appears to be improperly shielded.

In addition, at a clock angle of 4 o'clock, and very close to the edge of the exit pupil, a small bright spot is visible, a false exit pupil or prism-leak. False exit pupils are formed, when "parasitic light" enters the prism from outside the field of view and arrives at the eyepiece through an alternate optical path. The binoculars shown in the example are of size 10x50, i.e. their exit pupils measure 5mm. In daylight, the eye pupil of the observer is always smaller than 5mm, which implies that the binoculars show an impeccable image. However, at lower light levels during dawn or dusk, when the eye pupils are dilated, they are prone to take parasitic light from the peripheral regions of the exit pupils, leading to a visible drop of the image's contrast: a typical case of a stray-light effect which turns apparent only under certain lighting conditions.

Figure 9.8 shows on the right hand side the exit pupil of a vintage Zeiss 10x50 Porro glass with superior stray-light suppression. Despite the discernible illuminated areas outside the exit pupil, stray-light problems do not arise here, because those affected areas are sufficiently distant from the exit pupil: the eye pupil would have to widen up beyond 6mm to get in touch with these structures, but that would only happen in situations of advanced darkness, in which potential sources of stray-light are usually absent. An exceptional situation might arise in astronomy when areas in the vicinity of the moon are observed.

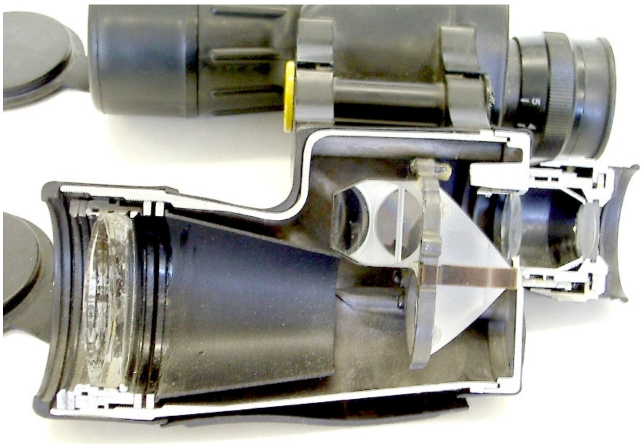

Figure9.9

Fujinon 7x50 MTR cutaway model: a cemented doublet objective, a Porro prism and an eyepiece of type Kellner (with kind permission: William J. Cook).

Figure 9.9 shows an effective method to eliminate the stray-light effects mentioned above: a second inner tube, which is painted matte and which narrowly encloses the light-cone, is placed inside the objective tube. This inner tube prevents light which, e.g., enters the objective from the lower left, to reach the upper Porro prism on a direct path, potentially causing stray-light. As an additional measure to neutralise reflections on the inner wall of the stray-light tube, a short stray-light baffle could be placed directly in front of the prism entrance (Figure 3.4).

Such a stray-light tube is rather effective, but it does add to the weight of the binocular. Consequently, manufacturers often dispense with such baffling. Alternately, the sides of the upper prism could be painted black and the two reflecting flanks covered with small sheets of metal. The latter must not, however, touch the polished surface, otherwise it would affect its total internal reflection capability. In addition, prisms of the Porro type should have a small groove cut across their hypotenuse to block parasitic light, as discussed in Figure 4.24. Prisms of the Schmidt-Pechan type should have a ring-shaped diaphragm placed into the narrow space between the two prisms in order to further reduce the impact of stray-light (see also Section 4.6).

Figure9.10

Checking for glare after sunset.

Additionally, stray-light may arise on the other side of the prism, in front (or even inside) the eyepiece. This is particularly relevant with binoculars that were originally designed to allow the passage of light cones which are wider than actually needed. As a common example, an 8x42 may be turned into a 10x42 after a replacement of its eyepieces. A careless manufacturer may not be willing to spend the effort to re-design the entire setup of baffles, in order to match the now reduced angle of view. As a result, the eyepiece is fully illuminated, and its field stop may not be sufficient to prevent unwanted skew-rays shining onto the inner walls of its barrel or onto the lens-edges. The latter should therefore be blackened with a special paint, a procedure that has to be carried out manually, making it costly.

A good opportunity to test for stray-light arises during twilight. In the direction of the sun (being below the horizon), the sky is bright, while large parts of the landscape lie in the shadow. When observing e.g. a forest edge, it is still possible to discern details of the trees, such as branches and leaves, but the illuminated sky right above the scene tends to throw a significant amount of unwanted light into the tubes. Under twilight, the eye pupils tend to be wide, thus allowing stray-light to enter from the perimeters of the exit pupils – a phenomenon, which rarely occurs in daylight. As a result, the contrast

$$C = \frac{L_t - L_b}{L_b} \tag{9.1}$$

is reduced. Here, L_t is the luminance of an object (e.g. a deer) to be observed in front of a background with a luminance L_b (e.g. tree trunks). Assuming that the entire field of view is filled with homogenous stray-light of luminance L_s, then this amount has to be added to both luminance values, yielding a new contrast of

$$C = \frac{L_t - L_b}{L_b + L_s} \,. \tag{9.2}$$

Depending on the magnitude of L_s, C may have dropped significantly and details are lost.

Stray-light originating close to or within the eyepiece often results in a diffuse veil which covers only the peripheral areas of the image. If the incoming stray-light enters from the sky above the observed object it may exclusively shine into the lower parts of the barrel, then leading to an arc-like veil around the lower edges of the field. Air-spaced objectives are also prone to stray-light, in particular those with a less than perfect polish. In this case, however, the entire image suffers from an almost uniform loss of contrast (a “whiteout”). Mounting simple self-made stray-light hoods significantly reduces such a loss of contrast; manufacturers should therefore consider installing such pull-out or screw-in hoods, as they are commonly found on camera objectives. The stray-light performance of many binoculars could be improved considerably with the help of these – technically speaking – simple gadgets.

9.3.2 Ghost images

Ghost images are the result of multiple reflections on glass surfaces. If all optical elements of a binocular are coated with a sufficiently effective anti-reflective coating, then these ghost images do not show up. Strictly speaking, these reflections are nothing but yet another type of stray-light, but since they have a particular cause and they offer an accurate assessment of the quality of coatings, they should be addressed in a separate test setup.

Figure 9.11 may give an impression about how many times a light beam has to enter and exit glass elements within a binocular of moderate complexity. As a rule of thumb, an uncoated glass surface reflects roughly 5 % of the incoming light. If the glass is treated with a single-layer coating, as patented by A. Smakula of Zeiss in the early 1930s, then the reflectivity reduces to values of about 1.5 %. Modern multi-layer coatings can reduce that loss to values below 0.3 % over the entire visible spectrum of light and a wide range of incident angles (details are discussed in Section 2.4.3).

The formation of a ghost image does always require an even number of reflections: two reflections cause a ghost image of the first order, four reflections result in a ghost image of the second order, and so on. In binoculars with up-to-date anti-reflection coatings, only ghost images of the first order are of any relevance. Assuming a transmission of $T = 0.995$ of an incoming light-ray, which is an average value for a multi-coated surface, a first order ghost image would have an intensity that is reduced by a factor of $(1 - T)^2 \approx 0.000\,025$. This implies that

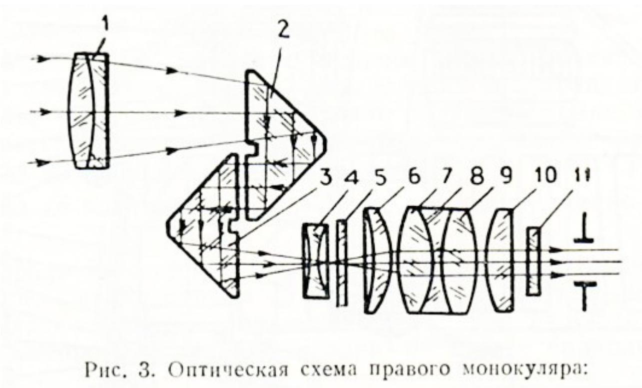

Figure9.11

Optical train of the KOMZ BPO 7x30 (taken from the instruction manual). It displays an orthoscopic eyepiece (elements 7-10), preceded by a Smyth lens (4), a reticle (5), an additional field lens (6) and an optional yellow filter (11). Note the small grooves cut into the prism hypotenuses to suppress stray-light.

such a ghost image may be potentially observable only at night and on a bright light source such as a street lantern. In astronomy, the reduction of a factor 0.000 025 corresponds to a decrease of eleven magnitudes (Section 8.5.1), so that only the moon and none of the stars or planets would have sufficient brightness to generate a visible response.

The situation is different with binoculars of vintage origin. Before 1978, only single-layer coatings were commonly applied to binoculars, and a light-ray entering a single-coated glass surface would have a transmission of about $T = 0.985$, yielding a reduction in brightness of $(1-T)^2 \approx 0.000\,23$ for the first order ghost image. This corresponds to nine stellar magnitudes, and under unfavourable conditions, the planet Venus may be able to cause a reflection. Ifglass surfaces exist, which, for cost reduction, remain entirely uncoated, then the situation turns out to be worse. It occurs with some of the cheaper imported products, in which the coating process of the prisms has been dispensed with. Note that Porro prisms are usually un-cemented, and the bases of both prism elements are set up face-to-face with a narrow air space. Ghost images of first order are now suppressed by the factor $(1-0.95)^2 \approx 0.0025$, which corresponds to roughly six magnitudes. This implies that virtually all of the bright stars and planets are likely to cause irritating reflections, and the panoramic view onto a city centre at night creates flitting fireworks.

Figure9.12

Lights of different intensities enable the testing for ghost images.

The facts mentioned above indicate that bright and ideally pinpoint light sources at night are ideal test objects to analyse the susceptibility of a binocular for ghost images, and hence the quality of its coatings (the "lantern test"): a light source, e.g. a bright street lantern at a distance of several 100m, is inspected while slowly panning, such that the light is repeatedly moved across the entire field of view. Reflections of that light may show up, and, depending on their origins, they may move at different rates. If the image stays entirely free of reflections, then another, brighter light source may be selected. Such a test is best done with more than one test sample, which simplifies a comparative rating of their coatings.

The interpretation of the test results may turn tricky at times. Not solely the coating of the lenses, but also their mutual placements and curvatures may affect the intensities of the resulting ghost images. Common examples are field lenses of the eyepieces, which for some designs are located close to the focal plane, at which the image of the lantern is well focused. Naturally, the intensities are highest here, and the resulting ghost images may turn out to be particularly intense. Military binoculars, which require a reticle right in the focal plane of the instrument, are particularly prone to this problem. In some instruments, the ghost images may turn out highly diffuse (because far off-focus) and remain altogether undetected even with less than perfect coatings. Here the ghost image only adds to a general diffuse stray-light background that slightly reduces the contrast of the entire image.

The locations of ghost images may yield information about the state of centring of the lens elements: in a perfect optical setup, all reflections on the lenses should exhibit a rotational symmetry about the centre of field. Hence, if several ghost images are visible, they should form a perfectly straight line which runs through the main image of the lantern. If the latter is placed into the centre of field, all ghost images have to be concentric. If this happens to be otherwise, then one or more lens elements must be de-centred or tilted. In some instances, experienced testers have been able to estimate the most probable eyepiece types of vintage binoculars, solely by examining the appearances and relative positions of their ghost images.

With roof-prism binoculars, the lantern-test exhibits another phenomenon of entirely different origin: since the roof-prism edge cuts through the light-path like a very fine thread, the resulting diffraction of light may now become visible as a short, linear spike, not unlike the situation shown in Figure 3.22. The orientation of that spike is perpendicular to that of the roof edge, and since the prisms in the left and the right barrels are usually orientated in different directions, the resulting diffraction effect resembles two crossing spikes. The intensity of that artefact is a function of the width of the roof edge, and it almost disappears with a well cut and polished prism. The lantern test thus assesses the quality of the roof prisms, too.

In some instances – staying with the street lantern as the test object – a second, slightly blurred image can be observed next to the primary image, but this time, the position of the secondary image does not change in relation to the primary one, even when the instrument is panned and the image moved across the field of view. This effect is usually observable in one of the barrels only. The effect in question originates in a reflection, caused by a prism which has not been cut with adequate precision. It occurs at times with cheap roof-prism binoculars, in which the extremely narrow tolerances for the 90° angle between the two roof faces are not met (Section 3.2.1).

The discussions of the present section provide convincing arguments in favour of the capabilities of the lantern test to yield abundant information about the characteristic properties and the condition of an optical instrument. Yet, a word of warning is adequate here: the lantern test is extremely sensitive – reflections are diagnosed which are sometimes ten thousand times weaker in intensity than the primary image. The detection of isolated ghost images does not necessarily imply a flaw in the instrument, nor a quality impairment that would necessarily affect the performance of that binocular in daily-life situations. When comparing high-performance devices, which commonly arrive with state of the art coatings, the lantern test may reveal certain minor differences that are of little to no relevance in the field. The test should rather be regarded as a sort of checkup on vintage or cheaper binoculars, since it enables the detection of uncoated glass surfaces, imprecisely cut roof edges, or optical surfaces that are insufficiently polished.

9.3.3 Off-centre sharpness

A star in the night sky represents a mathematically perfect pinpoint light source and is therefore an ideal object to test the image quality of an optical instrument[8]. Moreover, at night, the eye pupils are wider than during the day, and the entire light cone, which has passed the binocular, contributes to the image without being stopped down by the iris. Tests of the imaging properties of stars thus offer reliable results that are easier than, yet similarly accurate as tests conducted in bright daylight. However, test results need to be analysed and interpreted with care: not only the binocular, but also the human eye is liable to aberrations. To most observers, a bright star appears surrounded by starry spikes instead of being point-like – a consequence of the spherical aberration of the eye (Section 6.5). This is easily verified with the bare eye when observing a bright star: once tilting the head to the side, the rays emerging from the star image are rotating. These effects remain invisible with stars of lower – second or third – magnitude, which are therefore more suitable for our testing purposes than the very bright ones. Another caveat: observers with astigmatic vision need to put on their individually adjusted vision aids before testing the instrument.

As a matter of fact, binoculars are usually incapable of producing diffraction-limited images, including the central (paraxial) areas of their field. But the aberrations should be sufficiently suppressed and visible only with the help of a booster (Figure 8.4). A decent binocular should thus display stars in the centre of the field as pinpoint objects, and if that fails, then it may safely be assumed that the optics are flawed, so that any further testing would become unwarranted.

Once the star is shifted off-centre towards the edge of the field of view, its image will turn increasingly blurred. If we now imagine a straight line cutting through the centre of the field, we may further imagine a linear scale which reads the percentage of the distance to the edges. The message: “*a star appears sharp within* 60 % *of the angle and turns blurred further outside*” then defines the (relative) size of the so called “sweet spot” of that binocular. Naturally, each observer applies his individual standards when he has to decide from which angle onwards the image may be called “soft” or “un-sharp”. Thus, a sweet-spot size is generally an individual measure, but independent observers are usually able to rank sets of different binoculars with reproducible and consistent results.

The sweet-spot sizes of different instruments commonly vary between values of 60 % and beyond 90 %. Not surprisingly, vintage binoculars, in particular wide-angle models, with fairly simple eyepiece constructions, perform poorly in this test. Historically, binoculars were primarily military instruments, used by young soldiers with wide accommodation ranges and thus capable of compensating the excessive amount of field curvature in these devices (Section 1.7.3). Instead, modern binoculars are often supplemented with field-flattening lenses (Section 4.2.2) and sometimes literally offering an edge-to-edge sharpness. Yet, a positive side of field curvature also exists: when observing a landscape, field curvature can effectively increase the perceived depth of field (Section 2.3).

Further aberrations may contribute to the image blur. As long as the fuzzy star near the edge of field can be re-focused into a sharp image, field curvature was the exclusive origin of the blur. Otherwise,

[8] Harold Richard Suiter, *Star testing astronomical telescopes*, Willmann-Bell, 2008.

astigmatism, sometimes in combination with coma, affect the off-centre resolution. Additionally, lateral chromatic aberration (Section 1.7.6), responsible for colour fringes along contours near the periphery of the field, most certainly also has an impact here. The latter is easily detected on the moon edge, once the moon is shifted to the periphery of the field.

In practice, the quantity of off-centre image blur is not always distributed isotropically. It is therefore instructive to examine the image blur in several different directions, starting from the centre. Since, in principle, an optical system has centrosymmetric properties, a non-isotropic distribution of image blur would be the result of an imperfect alignment. Sometimes, both tubes show exactly identical asymmetric distributions: more often than not, the lower half of the field appears sharper than the upper half, raising the suspicion that the manufacturer may have intentionally tuned the optics, e.g. by slightly tilting the prisms towards the optical axes, to cover a poor edge-sharpness during terrestrial observations: when observing in daylight, the majority of objects are often scattered about the lower half of the field of view, the upper half being often occupied with structureless sky. Of course, this is not so in the case of astronomical observations, during which non-isotropic distributions of sharp and blurred areas in the image leave a rather unpleasant impression.

To estimate the objective angle of field, it can be quite useful to observe star constellations in the night sky. A well-known constellation should be selected and a pair of stars located which just barely fit into the field of view. Afterwards, the angle between the two stars is determined using a star atlas or catalogue. Computer programs are also readily available for this purpose, and so are star maps on the Internet, created with these programs, which directly indicate angles between selected pairs of stars. The advantage of using stars to measure the field angle lies in their infinite distance: if instead the field of view were measured on a ruler placed at close range, then inaccurate specifications may result (Section 4.3.2).

9.3.4 Low-light performance

The performance of a binocular should be assessed in a variety of different lighting situations. A particularly useful time for a tester is the twilight: within 1 – 2 hours, daylight conditions are gradually transforming into low-light conditions. Not only is this transition accompanied by a constant variation of illumination; but there also exists a highly complex modification of the way our visual perception functions. The increasingly dilated eye pupils begin to receive light from the peripheral areas of the exit pupils – we refer to Section 9.3.1 for a discussion on how this affects the stray-light performance. The mode of operation of our "sensor", the retina, changes dramatically. During a first stage, the sensitivity of the retina is increased. Thereafter, a shift in colour perception occurs: the scotopic vision of the rods increasingly supersedes the photopic vision of cone cells, and the ability to distinguish colours diminishes during that process (Section 6.7). At the same time, resolution at the centre of the field declines and peripheral vision turns rather more significant. The ability to spot details of an object gradually gives way to the identification of object contours, and data pre-processing in the retina becomes increasingly complex (Section 6.9).

In the common case, in which the transmission curve of the binocular is not entirely flat, the spectrum of the incoming light undergoes a modification. This may turn relevant under twilight conditions: instruments that have been optimised for observation in twilight tend to show particularly high transmission levels at the short-wave end of the spectrum, and may thus exhibit a somewhat cold colour rendition on sunny days. On the other hand, those binoculars, which excel in daylight with an excellent correction

Figure9.13

As dusk progresses, surface details diminish, and the detection of object contours and movements gains importance.

of chromatic aberration, lose that advantage in low light when any stark contrast fades. A high level of total visual transmission, which is not that important in daylight, can make a difference after sunset when every single photon contributes to the signal-to-noise ratio of hardly discernible objects.

An observer testing the low-light performance may first assess how the binocular accurately displays colours of selected objects far into the twilight. Once again, such a test is most telling if several instruments are compared and rated against one another. Additionally, the amount of details displayed on textured surfaces (e.g., the structure of bark, or individual leaves of bushes) should be analysed and compared through different binoculars. Then, after nightfall, it may be checked whether, and to what extent, the observation of a landscape through the binoculars still offers visual cues which enable general orientation: is it still possible to define one's position relative to surrounding objects and determine their distances and relative proportions accurately? During observations under these conditions of highly suppressed visual details, wide angles of view are of advantage since they allow the relation of each object to its surroundings. In addition, a wide stereoscopic base helps to discern the three-dimensional arrangement of objects (Section 8.9). In this context, experimenting with several binoculars of different designs and formats can be very instructive. Care has to be taken to keep the eyes of the tester fully adapted to the respective lighting levels, and therefore, any artificial light source should be left out of sight during these test procedures. Pocket lights, used while writing the observation protocol, should be covered with a red filter (a coloured and transparent plastic foil will do). Such a dimmed light would not compromise dark adaptation of the retinal rods, which are entirely insensitive to red light (Figure 6.7).

9.3.5 Chromatic aberration

Chromatic aberration appears particularly obtrusive wherever stark contrasts exist in the image. This is why e.g. overhead power lines and transmission towers are ideal test objects, which, when observed against the bright background skies, offer numerous contrast transitions throughout the entire field of view. First, the centre of the field may be examined. Here, no visible colour fringes should be visible, since in a well-centred optical system only longitudinal chromatic aberration should exist near the centre, and these should not be perceptible at the typically low magnifications of handheld binoculars. In other words: unless mounted binoculars are concerned, which are commonly used at very high magnifications, the centre of field should generally be free of colour fringes. Here it is important to have the eye pupils well aligned to the exit pupils, and thus the inter-pupillary distance has to be set accurately via the central hinge. An accidental misalignment may happen easily, especially with large exit pupils, when even poorly aligned eye pupils remain fully illuminated. Colour fringes do always show up if the eye pupils are partially clipped by the exit pupils, but these impairments are generated by the observer's eye, not by the instrument (Section 6.5). If, after careful alignment of the instrument with the eyes, the colour fringes remain visible near the centre of field, then the binocular is probably out of collimation and in need for a repair. Note that, in such a situation, different results for both barrels should be expected.

Figure9.14

Transmission tower: A perfect target to test for colour fringes.

Once the centre of the field has been examined, the periphery of the image is inspected. Off-centre, even the best binoculars exhibit a certain amount of colour fringes. They are an implication of the lateral chromatic aberration, which cannot be fully corrected in visual instruments of reasonably wide fields of view (Section 1.7.6). Even if a designer were to succeed in eliminating it, colour fringes would still emerge in certain situations: Observations in the peripheral areas of the field require the eyes to swivel around in their sockets, so that a concentric alignment with the exit pupil becomes lost. Thus, a complete elimination of these effects is technically impossible, but colour fringes can be substantially reduced with the careful design of the eyepiece, and the purpose of this paragraph has been to determine how well the manufacturer has succeeded with his task.

9.3.6 Ease of view: the unspeakable

"*Vision is experienced in a new way and with an intensity that defies description. All other sensations are extinguished. Eye and binocular – the near and the far – fuse into a perfect and harmonious unity.*"

This is how Hans Seeger describes his experience with his vintage 8x60 Zeiss binocular, made in the 1940s[9]. The expression "*The eye and the binocular . . . fuse*" vividly describes a mode of vision which is free of any distracting side effects; nothing interferes with the act of natural and relaxed observation. Instruments, which allow, via the eyepiece as their interface, a seamless connection between eye and optical image, possess a distinct quality for which the German term "Einblickverhalten" has been coined, and which is approximately translated with the expression "ease of view". Several criteria contribute to the attribute of having an outstanding ease of view: firstly, the virtue of an instrument to allow the observer to easily see over the entire field of view right from the moment when the binocular is placed before the eyes. Secondly, the absence of any irritating reflexes or dark shadows, which would show up while the eye is swivelling around to look at objects in peripheral areas of the field, or while the binoculars are panned over a landscape.

These criteria are all about tolerances, or, more precisely, about the deviations allowed for the relative placements of exit- and eye pupil, without any

[9] In: *Militärische Ferngläser und Fernrohre in Heer, Luftwaffe und Marine*, Verlag Dr. Hans Seeger, Hamburg, 2nd edition, p. 380 (2002).

Figure9.15

World War II era blc (Zeiss Jena) 8x60 submarine commander's binocular (left; field of view: 158m/1000m**, weight:** 2.3kg**; property of Hans Seeger), in size-comparison with a modern Nikon 7x50 IF WX (field of view:** 187m/1000m**, weight:** 2.4kg**).**

significant deterioration of the image quality. This is easier to achieve when the eye pupil, the exit pupil, or both, have large diameters, and a reason why many binoculars exhibit a superior ease of view in low-light situations, including the artificial lighting conditions in an exhibition hall or department store. Once taken out into broad daylight, the same instrument may then appear to lose some of its merits.

The occurrence of dark shadows, blocking parts of the field of view, is commonly referred to as kidney beaning. The effect arises when, during panning or sudden leaps of the line of vision, parts of the ray-pencil are blocked off by the iris and prohibited from entering the eye. To minimise these effects, binoculars should exhibit as little as possible vignetting of the edge pupil[10]. Since vignetting is often implemented to block off skew-rays, which suffer from insufficiently corrected astigmatism (Section 1.7.4), the optical designer then has to implement other, and costlier solutions to optimise the image. Furthermore, a proper correction of the spherical aberration of the exit pupil (Section 2.1.1) considerably improves the ease of view of the instrument. False exit pupils, or prism leaks (Figure 9.8, left) may cause irritating flashes of whiteouts during eye movements, and should be eliminated through sophisticated installations against stray-light. Particular challenges await the optical designer who intends to ensure a pleasant ease of view to spectacle wearers, since that additionally requires a sufficiently high eye-relief of the exit pupil. The difficulties encountered in building eyepieces and eyecups suitable for spectacle wearers are discussed in Section 8.12.

Besides the ease of view, additional factors exist that contribute to the ultimate viewing experience described by Dr. Seeger. An impeccable collimation and alignment, a wide subjective angle of field, and an image framed by a well-defined field stop are attributes that help to make the observation an unforgettable experience. Even the deliberate employment of carefully chosen quantities of aberrations into the optical design may contribute to the perceived performance of a binocular: a moderate degree of field curvature creates the impression of an increased depth of field (Section 2.3), and a well-chosen inclusion of pincushion distortion eliminates the globe effect when the binocular is panned (Section 8.11). Naturally, such aberrations are in conflict with the standards of exact optical image reproduction, and the definition of an adequate set of standards, which balance between perceived performance and optical bench quality, remains a challenging and even controversial task. As the binocular industry appears to approach a point of saturation with respect to traditional optical parameters, such a "human vision compatibility", i.e.

[10] Information provided by Dale Forbes on `birdforum.net`

a set of design paradigms, which address the perceived satisfaction level during observation, may become an increasingly important factor for the competitiveness of the product.

Figure9.16

SARD 6x42 Mark 43 (Field of view: 193m/1000m**) of the US Navy, with a respectable weight of** 1720g.

The Zeiss 8x60 binocular mentioned in the quote at the beginning of this section had a large exit pupil of 7.5mm, a high eye-relief of 24mm, as well as a wide subjective field of view of more than 70°; it was therefore well equipped to offer a competitive ease of view. The SARD 6x42 Mark 43 of the US Navy, used on anti-submarine aircrafts to spot submarines which surfaced during the nights to refill their air-tanks, had similar characteristics. With its wide exit pupil of 7mm and eye-relief of 20mm, its very wide field of view could be scanned easily even from a shaky airplane. A number of binocular enthusiasts and experts believe that the best of those instruments, which were produced during the 1940s, still represent the overall state of the art of binocular design, and that similarly high standards in terms of ease of view and comfort have never been reached again since then. When considering today's omnipresent trend towards size- and weight reduction, modern binoculars with their considerably reduced prism sizes are unlikely to ever reach similarly generous specifications regarding field of view, exit pupil diameter and eye relief. After all, the SARD weighed 1.7kg, and the Zeiss 8x60 scored 2.3kg.

Remarkably, with the recent arrival of the Nikon 7x50 and 10x50 WX models (Section 4.5.3), a line of currently made binoculars exists, which is capable of competing with these classic instruments in terms of ease of view, while, at the same time, delivering superior optical imaging. Obviously, as demonstrated in Figure 9.15, this competitiveness includes the features of bulk and weight.

9.3.7 Ergonomics and haptics

Inside the store, after the decision for the purchase of a binocular has been made, its ergonomic and haptic qualities have been checked and passed. However, surprises may be waiting for its new owner, once the instrument is taken outdoors into the fields for serious applications: all of a sudden, the high magnification binocular, which was so easily wielded at the shop counter, turns out to be hard to hold steady, particularly after a tiring up-hill tour. In cold air, the focus wheel suddenly turns much stiffer than before, and after the rain sets in, the initially tactile armor feels slippery. The carrying strap, so far considered an unimportant accessory, enters the stage and takes on a new and considerably less welcome role, by chafing the wanderer's neck!

It cannot be emphasised enough: a final assessment of the ergonomic and haptic qualities is not yet closed after a brief fumbling in the shop, and endless discussions on Internet forums are similarly unlikely to offer final answers. Different users employ their binoculars for different purposes, so that generalised advice is rarely useful. It is a common piece of wisdom that the selection of an ideal binocular is only possible out in the field. The requirements of different users as to the ergonomic and haptic properties do vary with the mode of application. When the instrument is used mostly as a stationary device, e.g. in a raised hide during hunting, on the bridge of a vessel, or on a checkpoint, then weight and ergonomics are less important than optical merits such as low-light performance or a wide field of view. Those who intend to carry the device around their neck during the larger part of the day and having to deal with varying weather conditions and opportunities arising suddenly, will appreciate binoculars which do not cause additional troubles.

In fact, arriving at relevant conclusions about ergonomics is thus quite simple: the binocular should be tested under the same conditions which are likely to prevail in later applications. Problems or issues, which are unlikely to evaporate with gaining experience, should be carefully registered and evaluated when the test procedure is over. Unfortunately, certain aspects and issues may turn bothersome only after a considerable time, when it is already too late to return the instrument to the seller. Such experiences should, without rancour, be taken as an apprenticeship and are unavoidable for one who is gradually becoming an experienced binocular user. After all, there is no way around this simple fact: even the best possible binocular design and concept cannot relieve the user of this individual learning process. An optical instrument must be mastered, and only the persevering use of the instrument in practice will finally lead to a perfect symbiosis of man and machine. In the end, after achieving such mastery, some of the performance parameters, which have been listed on the specification sheets and regarded as the holy grails of binocular design during endless debates in the Internet's discussion boards around the world, may suddenly be rendered irrelevant.