NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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STANDARDS FOR PROTECTIVE GOGGLES FOR USE IN THE COLD

by

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Naval Medical Research and Development Command
Research Work Unit M0095.001-1040

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SUMMARY PAGE

PROBLEM

To determine the characteristics of goggles to be worn in the cold needed to protect the eyes from intense natural light.

FINDINGS

On the basis of laboratory experiments, field studies and a survey of the literature, the filter characteristics needed to protect the eyes are recommended.

APPLICATION

These specifications are pertinent to the production of new protective goggles for men operating in cold environments.

ADMINISTRATIVE INFORMATION

This investigation was undertaken under Naval Medical Research and Development Command Work Unit M0095.001-1040 - "Protective devices for the eye in cold weather." This report was submitted for review on 9 November 1983 and approved for publication on 21 December 1983. It was designated as NAVSUBMEDRSCHLAB Report No. 1014.

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ABSTRACT

The characteristics of goggles needed to protect the eyes in cold environments are specified, based on laboratory investigations, field-studies, and a survey of the literature. The transmittances of the filters, the magnitude of distortion, the degree of chromaticity, resistance to fogging, and the physical standards of the filters are considered.

INTRODUCTION

In 1948 Farnsworth published his recommendations for standards for general purpose sunglasses.[1] He specified the percent transmission of infrared (IR), ultraviolet (UV), and "visible" light which should be permitted; the degree of excitation purity (that is, saturation) which a lens could be permitted if it were tinted; and the geometric optics which the lenses could exhibit. In addition, he discussed the optimal size of the lenses, the characteristics of the frames, and the physical specifications of the glasses.

Farnsworth recommended: 10-16% transmittance of the visible light with the two lenses "matched to within 1/5 of transmission"; less than 10% trasmittance of the infrared radiation (700-1400 nm); less than 10% transmittance of the ultraviolet; chromatically neutral lenses, although an excitation purity of up to 25% was acceptable. He recommended the largest available lenses, although smaller sizes were "acceptable for small heads"; the lenses should be "free from visible defects" with no more than 1/8 prism diopter and 1/16 diopter focal power. He recommended dark, opaque frames, and he accepted the physical specifications which were promulgated in 1946 for aviators.

The Naval Support Force, Antarctica currently adheres to a set of recommendations for sunglasses made by Hedblom in 1961.[2] He recommended glasses with two distinct density bands, one transmitting 1.5% of the visible light and another transmitting 13.5%. The lighter band was to enable the wearer to have greater visibility in a limited part of the visual field while still screening out most of the radiation. Central to Hedblom's recommendation was that the ratio of "visible" to IR (680 to 900 nm) transmittances should be at least 0.8.

Clark[3] has stated that Farnsworth's specifications can be used only as a guide, since his "transmission of the visible light" is undefined. Moreover, Farnsworth's recommendation that the two lenses should match within 1/5 of the transmittance of the less dense lens is apparently based not on any psychophysical experimentation, but simply on his observation that this "difference in transmission between lenses was easily apparent by visual inspection."

Although Farnsworth recommended a transmittance of 10-16% for general purpose sunglasses, he suggested that for such very bright environments as would be experienced by lookouts at sea or men working in snowfields, much denser sunglasses might be required--perhaps transmitting only 3% of the visible light. Clark[3] has suggested that part of the discomfort resulting from less dense glasses may be due to the transmittance of IR wavelengths and that if they were filtered out, glasses transmitting as much as 10% of the visible light would then be comfortable. Again, this has not been adequately tested.

Hedblom's conclusion that the ratio of visible to infrared light is the cause of ocular distress in bright light is based on a single trial exposure carried out on himself. Hedblom wrote[2,p.95] "To test this theory, the author suffered classic and profound calorophthalgia during and after brief, intense illumination viewed through a... glass which had very low visual but a very high infrared transmittance, peaking at 800 mu." (Calorophthalgia is Hedblom's term for ocular distress presumably resulting from IR radiation.) Hedblom arrived at his recommended ratio of 0.8 by calculating the ratio for a variety of sunglasses which had been rated for acceptability. He concluded that those glasses having a ratio of less than 0.8 were rated poorly whereas those with a higher ratio were highly rated.

Aside from the problem of accepting conclusions based on one experimental trial by the author, a trial in which the duration of exposure and the intensity of the illumination were not specified, there are other difficulties in accepting his recommendation. The lens which he used to test his theory also had a very high transmittance in the UV. Hedblom had at his disposal another filter which duplicated the spectral transmittance of his test lens in the visible and IR but screened out the UV. Had he used this second lens as a control, he would have been on more secure ground in making his pronouncement. Moreover, in calculating his cut-off ratio, Hedblom did not take into account the differences in total transmittance of the various filters. In fact, there is a strong relationship between the ratings of the various filters and their total transmittance: in general, the greater the transmittance, the lower the ratings except for the most dense filter which was also downgraded. Thus it is not completely clear whether the judges rated the filters primarily on the basis of Hedblom's "calorophthalgic index" or simply the total transmittance. In any event, it is not clear why the level of discomfort should be related to such a ratio. Why should a given level of infrared radiation in conjunction with a high level of visible radiation be more comfortable than the same level of IR with a lower level of visible radiation?

Farnsworth specified that the filters should not exhibit distortions more than 1/8 prism diopter or a focal power greater than 1/16 diopter. These values are taken from the commercial standards for ground and polished lenses, CS78049 and CS-159-49 (See Ref.4). Farnsworth concluded that the standards do not represent what will give the best eye protection or what constitutes a good sunglass but are designed simply to exclude the poorest quality. Although he complained that these standards simply implied that the lenses were free of gross optical defects, he incorporated these values because "The Armed Forces-NRC Vision Committee...without dissent...agreed" on them. It is, again, not clear on what basis they were able to agree on these values.

The question is raised because these dioptric values are very small. Peters[5] reported that for individuals 25 to 35 years of age, uncorrected visual acuity remains

20/20 when refractive error ranges from more than +1.00 to -0.25 diopters; and a number of other investigators have found even greater tolerances.[6] A distortion of 1/8 prism diopter would thus appear to be trivial for more individuals and leads one to wonder how much psycho-physical experimentation preceded the adoption of these standards.

There are, thus, many questions about the previous standards. In addition to such questions, recommendations for standards must be revised from time to time simply because of the availability of new data. Much more is known now about the deleterious effects of light radiation on the eye than a generation ago, and standards must be revised to take account of new findings. This report summarizes our recent work aimed at recommending standards for protective goggles to be used by troops in the cold, and it updates the standards based on recent research.

RECOMMENDED STANDARDS FOR PROTECTIVE GOGGLES FOR THE COLD

Visible Light (400-700 nm): Only the short (blue) wavelengths in the visible spectrum appear to be injurious.[7,8] We have calculated[9] that it is necessary to filter out 98% of the natural radiation between 400 and 500 nm in high intensity environments. That is, the filter density should be 1.7 in this region of the spectrum. In addition, we have found[10] that the average observer under the age of 30 rated "most comfortable" filters with a density of about 1.0 (transmittance about 10%). Older observers may prefer somewhat denser filters, but over the age of 40 their acuity fell sharply with increasing density. It appears that the total transmittance should fall between 5 and 10%.

Near Ultraviolet Light (320-400 nm): Based on the ACGIH (1982) threshold limit values,[11] we calculated[9] that no more than 16% of the near UV light should be permitted to reach the eye. A filter density of 0.8 is thus required in this region of the spectrum.

Far Ultraviolet (295-320 nm): Based again on the ACGIH standards, we calculate that no more than 5% of the natural radiation in this region of the spectrum should be permitted to reach the eye. This requires a density of 1.3.

Infrared (700-1200 nm): The levels of infrared radiation occurring naturally do not seem to pose a hazard to the human eye, since they are below those which have been found to produce damage.[12] Nevertheless, Hedblom[2] may be correct, as Clark has noted,[3] in his contention that the level of comfort is related to the relative amount of infrared to which the eye is exposed. Although there are no adequate tests of Hedblom's theory, it would be prudent to filter out as much of the IR as is feasible.

Chromaticity: Several recent experiments have now demonstrated that yellow filters produce a small improvement in the ability to detect the presence of relatively large targets.[13-16] Nevertheless, yellow filters should not be used if they will interfere with color vision. It is widely agreed, however, that yellow filters of excitation purity less than 20% will not degrade color vision.[1,16-19] We recommend, therefore, that a yellow tint not to exceed a purity of .20 be used.

Optical Distortion: We have tested such things as acuity through binoculars, depth perception, riflery, and contrast sensitivity through goggles exhibiting various optical distortions.[20-21] Surprisingly such practical tasks are not significantly affected until the magnitude of distortion is relatively high compared to the distortions which are typically permitted in optical instruments. A number of Air Force studies confirm that the loss of depth perception due to distortions in glass canopies is small; much greater losses occur when the glass is tilted with respect to the observer.[22-24] This is not a problem with goggles, of course.

We have measured the magnitude of the optical distortion by projecting a Snellen acuity chart through the goggle filter and determining the Snellen line which can then be read.* We have found that when mean Snellen acuity of observers (who can normally read the 20/20 line) is reduced to 20/25, this degree of optical distortion results in a statistically significant degradation of performance.

It must be noted that there is no information on the relation between small optical distortions and comfort over extended periods of time.

Resistance to Fogging: Goggles which become fogged must be removed. It is reported[26] that for that reason competitive cross-country skiers do not wear them, voluntarily risking injuries to their eyes. It is clearly important to minimize fogging.

Three different grades of protective goggles are advertised by manufacturers. The cheapest are said to have no protection against fogging; the next grade have been treated to resist fogging; and the best grade have double filters which have been treated to resist fogging. We have found that, on the average, the manufacturers' claims have been substantiated.[27] Those goggles advertised to resist fogging appear to be better than those which are not so advertised. We recommend, therefore, that goggles should be so treated.

Physical Dimensions: This has become a somewhat unexpected problem in recent years, because there has been a dramatic rise in the number of young people who must wear refractive corrections.[28] Some of these people can not carry out their duties without wearing

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* Clark[3] reports that Hoffman[25] used the same technique.

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glasses, and any protective goggles which they wear must be designed to fit over eyeglasses.

Physical Standards: Resistance to scratching and breakage is important. Virtually unbreakable lenses made of polycarbonate are available and should be considered if their cost is not prohibitive.

SUMMARY

The following standards are recommended for protective goggles to be used in the cold, on the basis of laboratory studies, field tests, and a survey of the literature.

Visible Light (400-700 nm) -	No more than 2% transmittance between 400 and 500 nm. Total transmittance between 5 and 10%.
Near Ultraviolet (320-400 nm) -	No more than 16% transmittance.
Far Ultraviolet (295-320 nm) -	No more than 5% transmittance.
Infrared (700-1200 nm) -	The levels of IR occurring naturally do not seem to pose a hazard. It is possible that observers would be more comfortable if this radiation were filtered out.
Chromaticity -	A slight yellow tint of no more than 20% excitation purity.
Optical Distortion -	Snellen acuity should not be degraded to 20/25 when the Snellen chart is projected through the filter.
Resistance to Fogging -	Filters should be treated to resist fogging.
Physical Standards -	Shatterproof filters are desirable. Polycarbonate lenses would provide excellent protection against flying objects.

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