NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

RPT No. 1026

IMPROVEMENT OF VISION THROUGH THE PERISCOPE

Background and Proposed Solutions

by

J. F. Socks
and
S. M. Luria

Naval Medical Research and Development Command
Research Work Unit M0100.001-1017

Released by:

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SUMMARY PAGE

PROBLEM

Owing to a marked increase in the incidence of eyeglasses among young men, the pool of visually qualified candidates for submarine service has decreased. This has necessitated a relaxation of visual standards and an increase in the number of waivers. There is now concern as to the level of visual performance of periscope operators in the fleet.

FINDINGS

Two solutions have been proposed. Studies are now underway to assess the feasibility and effectiveness of two methods of improving the visual acuity of periscope operators, the use of contact lenses and the modification of the periscope to permit an operator's full refractive correction to be added to the periscope.

APPLICATION

If these methods prove to be successful, they will allow a relaxation of current visual standards for periscope operators, result in an increased pool of available candidates for submarine service, while at the same time producing 20/20 visual acuity for all periscope operators.

ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit M0100.001-1017 - "Use of contact lenses on submarines." It was submitted for review on 13 Jul 1984, approved for publication on 26 Jul 1984, and designated as NSMRL Report No. 1026.

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ABSTRACT

The necessity of improving the visual acuity of periscope operators is discussed, and two methods of doing so are outlined. They are (i) the use of contact lenses and (ii) a modification of the periscope which permits the operator's full refractive correction to be added to the periscope. The advantages and disadvantages of each are pointed out, and the reasons for instituting both are discussed.

INTRODUCTION

In order to qualify for service in the Submarine Force, men must meet clearly defined visual standards (1). In its recruitment efforts, the Navy now faces a serious problem; the incidence of eyeglasses has been increasing appreciably during the last generations (2), and it is becoming more difficult to find men who meet the visual standards. The Naval Recruiting Command estimates that between 10 and 15% of otherwise qualified men are rejected owing to excesive refractive error (3). Indeed, a recent survey of the U. S. Naval Academy class of 1985 showed that 18 officers who expressed a preference for submarine service, are not visually qualified owing to the presence of excessive refractive error (4).

Three kinds of visual defects are covered by the standards--color defects, spherical refractive errors, and cylindrical refractive errors. Color defects have long been given considerable attention, since most are inherited and cannot be cured. The refractive errors, on the other hand, are in principle easily correctible with the proper lenses. In the real world, however, they present more of a problem.

The refractive errors manifest themselves as reductions in visual acuity and can interfere with the performance of submarine duties, many of which require 20/20 vision (5). Among such duties are the periscope watch. Despite the theoretical ease with which refractive errors can be corrected, the actual situation involving periscope operators present two difficulties. The first is that it is difficult to look through the periscope while wearing eyeglasses; this tends to eliminate one of the ways of correcting refractive errors. Another way of making these corrections is to build a system of optical correction into the periscope. This has, in fact, been done just as it has with field-glasses. That is, a certain amount of adjustment of the focus can be made by the operator, but unfortunately, the range of adjustment is limited from about +2.00 to -4.50 diopters (D.), and there are now many applicants for submarine service who have refractive errors that are too large for the range of adjustment provided.

The Problem of Astigmatism

Even if the range of adjustment on periscopes were large enough, another problem would still remain. It is that such optical adjustments are found only for the spherical refractive errors; there is no feasible way to correct for cylindrical refractive errors. These errors, which produce the visual defect called astigmatism, must be corrected with lenses which must be carefully oriented to the axis of the optical defect. (Spherical errors have no axis, and these corrective lenses do not have to be fitted to a particular orientation.)

It is for these reasons that visual standards are stringent for men whose duties involve the use of the periscope and particularly stringent for cylindrical errors. Yet, according to optometric authorities, astigmatism is the visual defect which is "undoubtedly the most widely prevalent anomaly presented for correction (6, p.127). It is found in more than 80% of all patients examined (7). In our survey of 1000 submariners--men constituting a highly selected sample who had already been screened for visual defects--we found that 56% had the defect (2), suggesting that an appreciable percentage of men may be disqualified from submarine service on this account. What is the percentage of periscope operators who suffer from refractive errors which cannot be corrected with the periscope optics?

Refractive Errors of Periscope Operators

We have surveyed 23 submarines based in New London and found that 210 officers and quartermasters wore glasses all the time (Table I). Assuming that there are 12 officers and 5 quartermasters in each crew, this amounts to 53% of the men. This is comparable to that found in the survey of 1000 submariners (2). Table II shows, further, that of these 210 individuals, 36, or 17%, had refractive errors which approach or exceed the limits of optical correction available in the periscope for spherical errors. Moreover, only 4 of these 36 men had no astigmatism. Since cylindrical errors cannot be corrected with the periscope optics, this means that the vision of 88% of these men will be substandard. As for the total sample of operators surveyed, 83% had some degree of astigmatism; the performance of their duties will suffer to some extent.

It may be noted that in general the junior officers have higher refractive errors than senior officers. This paradoxical fact does not, of course, indicate that vision improves with age; it simply reflects the relaxation of visual standards in recent years to permit more men to qualify for submarine service. The vision of many of these officers will get worse with age; what will their vision be when they become commanding officers?

The Magnitude of Performance Decrement

To what extent is the visual performance of men degraded by a given amount of refractive error? We may pass over the spherical errors briefly, since there are several diopters of correction for these defects in the periscope optics. There is a general relationship between the magnitude of refractive error and visual acuity, although different investigators have proposed somewhat different figures. Sloan (8) estimates that each -0.18 D. of error leads to a reduction of one line in Snellen acuity. Thus -0.75 D. of refractive error is associated with a Snellen acuity of about 20/40, and -1.00 D. of error with an acuity of 20/60. Hirsch (9) suggests that -0.50 D. of error leads to an acuity of 20/25, and -1.00 produces an acuity of 20/65. Other investigators suggest slightly different relationships, but they are roughly comparable. If a half diopter of error leads to an acuity of 20/25, this means that what the normal individual can see at 25 feet, the myopic individual can see only if he comes to within 20 feet. And if a one diopter error produces an acuity of 20/60, this indicates that what the normal individual can see at 60 feet, the myopic individual can see only at a distance of 20 feet.

The problem of astigmatism is of more interest, since cylindrical errors cannot be corrected by the periscope optics. We have investigated the effects of various degrees of astigmatism on practical performance (10). We measured the distances at which observers with various degrees of astigmatism could discriminate pairs of ship silhouettes, such as the pairs shown in Fig. 1, drawn on 3x5 cards. The results are shown in Fig. 2. The pairs of silhouettes could be discriminated by observers with no refractive errors at an average distance of 27 feet. The observers were then required to make these discriminations while observing through lenses which produced various degrees of astigmatism. [It should be noted that the axis of the astigmatism was 90 deg, the orientation which produces the least amount of degradation in the perception of ships (9).] When 0.75 D. of astigmatism was introduced, the mean distance at which the ships could be discriminated dropped to about 20 feet. Increasing magnitudes of astigmatic refractive error reduced the distance; with 4.00 D., it was reduced to about four feet. If the axis of the astigmatism was other than vertical, then the reductions would have been even greater. In Table II, the axis of the astigmatic error is the third number in the designation of the refractive error. For example, Officer 1 in Table II has a refractive error in his right eye of -7.25 D. of spherical error and an additional astigmatic error of -1.50 D. with an axis of 11 deg. In his left eye, the axis of astigmatism is 178 deg. Table II shows quite clearly that in most cases astigmatic axis does not fall at 0 or near 90 deg. Borish, in fact, states that the axis of astigmatism falls near 90 deg only 20% of the time (6, p.127). The results presented in Fig. 2, therefore, err on the optimistic side.

Actual conditions are most likely to be much worse, of course since, as noted above (6) and as Table II shows, astigmatic errors are usually accompanied by spherical errors. Figure 3 taken from Peters (11), gives a general idea of the level of Snellen acuity to be found in individuals who have a combination of both spherical and cylindrical errors. Officer A. (point A on Fig. 3) with no spherical error would, of course, have 20/20 acuity. If he had 1.00 D. of astigmatism, he would have an acuity of about 20/40 (point B). The photographs in Fig. 4 give an idea of what the vision of such an individual is like. The photo on the left is what appears to an observer with 20/20 acuity. The photo on the right shows how the scene appears to an observer who has 1.00 D of astigmatism. If that observer had in addition (as would be quite possible) -1.00 D. of spherical error, his Snellen acuity would be about 20/80--twice as bad (point C). An individual with 2.00 D. of astigmatism and no spherical error would have a Snellen acuity of about 20/70--also about twice as bad as the vision depicted in the photo in Fig. 4 (point D). It should be noted at this point that the visual standards prescribed for periscope operators permit 2.00 D of astigmatism (12).

The periscope optics will correct for a certain degree of spherical refractive error. How much can be corrected depends on the type of periscope. Consider an operator with -5.50 D. of spherical error, the current Navy limit for spherical error and entrance into the Submarine Force (12). If the type 18 periscope corrected for up to its claimed -4.75 to -5.00 D., it would leave this man with an uncorrected residual myopia of -0.75 D. This is indicated in Fig. 4 as point E. He would have a visual acuity of around 20/40. Actually, the periscope corrects for only about -4.50 D., leaving this man with an uncorrected myopia of -1.00 D. and a visual acuity of 20/60. If this man were transferred to a submarine with a Type 15 periscope, he would have greater difficulty, for the type 15 eyepiece will correct only up to about -3.50 D. This operator will now have almost two diopters of uncorrected myopia, and his best acuity will be around 20/100 or worse (point F). And if this spherical error is compounded with some cylindrical error--which is the case in most individuals--his visual acuity will be even worse.

It is clear that if the refractive errors of periscope operators can be fully corrected, it would not only enhance the vision of those officers whose errors are not fully corrected by the eyepiece, but it would moreover permit a relaxation in the current visual standards to allow the accession of additional officers who are not currently qualified for submarine service.

Improving the Acuity of Periscope Operators

There are two feasible methods of fully correcting the refractive errors of periscope operators. One is the substitution of contact lenses for eyeglasses. The second involves a minor modification of the periscope eyeguard to permit the insertion of the operator's full refractive correction into the optical line-of-sight of the periscope. Both methods have their strong points and their drawbacks, but together they complement each other and promise to solve the problem.

Contact Lenses

Contact lenses have a number of advantages over spectacles, particularly for periscope operators. With contact lenses, the refractive surface of the lens closely coincides with the cornea increasing the field of vision and retinal image size. Lens thickness is significantly reduced compared to those in spectacles (.05 mm vs 2 mm) increasing light transmission and decreasing optical aberrations. Reflections from the back surface of the spectacles are eliminated. These advantages are even more apparent for those individuals who are highly myopic (near sighted), and their visual acuity is also especially improved.

Once the contact lens is upon the eye, it is possible to bring the eye into close proximity to the periscope, whereas with spectacles, the frames and lenses do not allow the operator to get close to the periscope eyepiece. Therefore, the expansion of the field of view (which is a feature of contact lenses compared to eyeglasses) is even more pronounced when looking through the periscope. In addition, an operator wearing contact lenses can quickly look from the periscope around the control room and back to the periscope; when wearing eyeglasses, the periscope operator must constantly don and doff them.

It may be mentioned in passing that contact lenses have other benefits as well. Submariners may be required to wear an emergency breathing mask in the event the air in the submarine becomes contaminated. Drills are constantly being held to ensure that all personnel can quickly don such masks. Many types of eyeglasses cannot be fitted under the masks, and even when the eyeglasses can be worn, there is a tendency for the eyeglass frames to interfere with the seal and allow leakage to occur around the temples (13). Contact lenses do not interfere with either vision or the seal of the mask.

Although contact lenses have many advantages, they are not without some disadvantages. Hard lenses and even the daily wear soft lenses must be removed when sleeping. When a submariner is awakened unexpectedly for drills or for an emergency, there is often no time to put in the contact lenses. Although glasses can be worn in these instances, they suffer from the disadvantages already outlined above. This problem with the contact lenses can be alleviated to a great extent by using extended wear contacts; they are approved by the Food and Drug Administration for continuous wear up to 30 days at a time between removal for cleaning and disinfecting.

Another problem with contact lenses is the increased probability of ocular inflammation, infection, and injury to the cornea. Moreover, environmental contaminants present in the submarine atmosphere, such as dust, smoke, and vaporized hydrocarbons increase the risk of irritation and inability to wear the lenses. Some men will never be able to wear them in submarines; others will be forced to remove them frequently, and should an emergency arise, it will require extra time to insert the lenses.

Finally, there is the possibility that a submariner has been qualified for submarine duty because he has a waiver based on the use of contact lenses could claim a contact lens problem in order to get off the submarine--in effect, "devolunteering" from submarine duty.

For these reasons, a second solution is desirable.

Modified Periscope Eyeguard

Another solution to the problem of visual performance of periscope operators is to modify the periscope eyeguard to permit the insertion into the periscope optics of the operator's full refractive correction (14). A model is shown in Fig. 5. This would permit the operator to be fully corrected, without interfering with his ability to put his eye into the eyecup. It would ensure maximum visual acuity through the periscope for every operator and would greatly increase the pool of men who would have 20/20 acuity through the periscope.

This method is not without its disadvantages also. The main problem is that such an operator would not have optimal acuity when he looked away from the periscope; if the operator is continually looking back and forth between the periscope and the control room, his acuity would be degraded in the latter situation. Thus, although he would have maximum acuity when looking through the periscope, he might have to put his eyeglasses on when looking around the control room.

A second problem is that if two men are using the periscope alternately, and both require a refractive correction to be inserted, then each man must remember to remove his correction before the other man uses the periscope.

Finally, if the corrective inserts are not kept at the periscope station, then each man must remember to bring his insert to the periscope.

Advisability of Instituting Both Solutions

The disadvantages attendant to both methods strongly suggest that both methods should be evaluated, and it seems likely that both would have to be implemented together. Since it is somewhat awkward to have to insert and remove the periscope insert each time an operator wishes to look through the periscope, and since an operator would likely be uncorrected once he took his eyes away from the periscope and began to look around the control room, it is clear that the use of contact lenses is preferable. On the other hand, the inability of a substantial number of men to wear contact lenses, the possibility of losing a lens during a patrol, the time it takes to insert a lens in the eye should an emergency find the wearer without his lenses, and the possibility (if not the liklihood) that a man could use the contact lenses as an excuse to devolunteer from duty, indicates that a backup system, such as the modified periscope eyepiece is desirable.

Need for Evaluation at Sea

These possible problems with both the contact lenses and the periscope inserts necessitates evaluations at sea. It is necessary to ascertain (a) how many men have difficulty wearing contact lenses aboard submarines and what kinds of difficulties are encountered, and (b) how acceptable the periscope inserts are, whether or not they are cumbersome to use, and are there any unforeseen problems. To answer these questions, CNO requested studies of the feasibility of both contact lenses on submarines (15) and an evaluation of the modified periscope eyepiece (16). At the present time, 150 officers and quartermasters assigned to local nuclear submarines have been fitted with contact lenses and their experience with the lenses at sea is being monitored. In addition, the crews of five submarines have volunteered to evaluate the modified periscope eyepiece on patrol. The results of these evaluations will be analyzed and published in subsequent reports.

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Table I. Officers and quartermasters wearing glasses full time

Submarine		# Officers	# quartermasters
SSBN	1	7	0
	2	8	1
	3	9	4
	4	13	0
	5	8	1
	6	11	1
	7	13	1
	8	5	0
	9	5	4
	10	6	1
	11	5	3
	12	9	1
SSN	1	7	1
	2	7	0
	3	10	1
	4	8	1
	5	7	0
	6	5	1
	7	6	0
	8	6	4
	9	7	0
	10	10	1
	11	11	1

Table II. Some representative high refractive errors among crews in New London area

Officer	1	O. D.	-7.25	-1.50	x 11
		O. S.	-7.25	-1.25	x 178
"	2	O. D.	-4.00	-0.25	x 05
		O. S.	-5.00		
"	3	O. D.	-5.25	-0.50	x 50
		O. S.	-4.25	-0.50	x 130
"	4	O. D.	-3.75		
		O. S.	-4.00		
"	5	O. D.	-4.25	-0.25	x 45
		O. S.	-3.75	-1.00	x 125
"	6	O. D.	-4.00	-0.50	x 15
		O. S.	-4.25	-0.75	x 180
"	7	O. D.	-0.50	-2.00	x 97
		O. S.	-0.50	-1.75	x 65
"	8	O. D.	-6.00	-1.00	x 05
		O. S.	-5.25	-1.25	x 05
"	9	O. D.	-6.00	-0.25	x 152
		O. S.	-4.00		
"	10	O. D.	-5.00		
		O. S.	-4.75		
"	11	O. D.	-0.50	-1.50	x 90
		O. S.	-0.50	-1.50	x 85
"	12	O. D.	-6.75	-0.50	x 27
		O. S.	-6.25	-0.50	x 159
"	13	O. D.	-4.50	-0.75	x 115
		O. S.	-4.75	-0.75	x 78
"	14	O. D.	-4.50	-0.75	x 09
		O. S.	-4.75	-1.00	x 175
"	15	O. D.	-1.50	-2.50	x 90
		O. S.	-2.00	-1.75	x 87
"	16	O. D.	-4.50	-0.50	x 90
		O. S.	-4.50		

"	17	O.D.	plano	-2.00	x 95
		O.S.	-0.50	-1.50	x 90
"	18	O.D.	-5.50		
		O.S.	-4.50		
"	19	O.D.	-0.75	-2.25	x 116
		O.S.	-2.00	-2.00	x 110
"	20	O.D.	-2.75	-0.25	x 85
		O.S.	-3.00		
"	21	O.D.	-2.75	-1.00	x 95
		O.S.	-2.00	-1.25	x 103
"	22	O.D.	-5.00	-1.25	x 70
		O.S.	-5.00	-1.25	x 130
"	23	O.D.	-3.50	-1.00	x 70
		O.S.	-3.50	-0.75	x 70
"	24	O.D.	+0.75	-1.75	x 165
		O.S.	+1.50	-2.50	x 165
"	25	O.D.	-3.25	-0.25	x 180
		O.S.	-3.75	-0.25	x 165
"	26	O.D.	-4.50	-0.50	x 180
		O.S.	-4.50	-0.50	x 180
"	27	O.D.	-3.50	-0.50	x 175
		O.S.	-3.50	-0.50	x 10
"	28	O.D.	-5.25	-0.50	x 47
		O.S.	-4.50	-0.50	x 135
"	29	O.D.	-3.75	-0.25	x 105
		O.S.	-4.00		
"	30	O.D.	-4.00	-0.50	x 25
		O.S.	-4.00	-1.00	x 167
"	31	O.D.	-3.00	-1.00	x 83
		O.S.	-5.00	-0.50	x 07
"	32	O.D.	-2.75	-1.25	x 35
		O.S.	-2.75	-1.25	x 145
"	33	O.D.	-5.25		
		O.S.	-3.50	-1.00	x 20

"	34	O.D. -4.25 O.S. -4.00
QM	1	O.D. -4.25 O.S. -4.25
QM	2	O.D. -2.00 -1.75 x 03 O.S. -2.00 -0.75 x 177

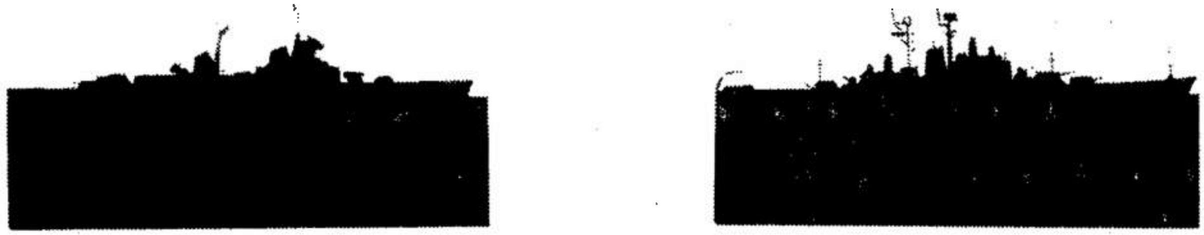

Fig. 1. Two silhouettes taken from Jane's Fighting Ships. Observers were tested to determine the viewing distance at which they could identify silhouettes such as these.

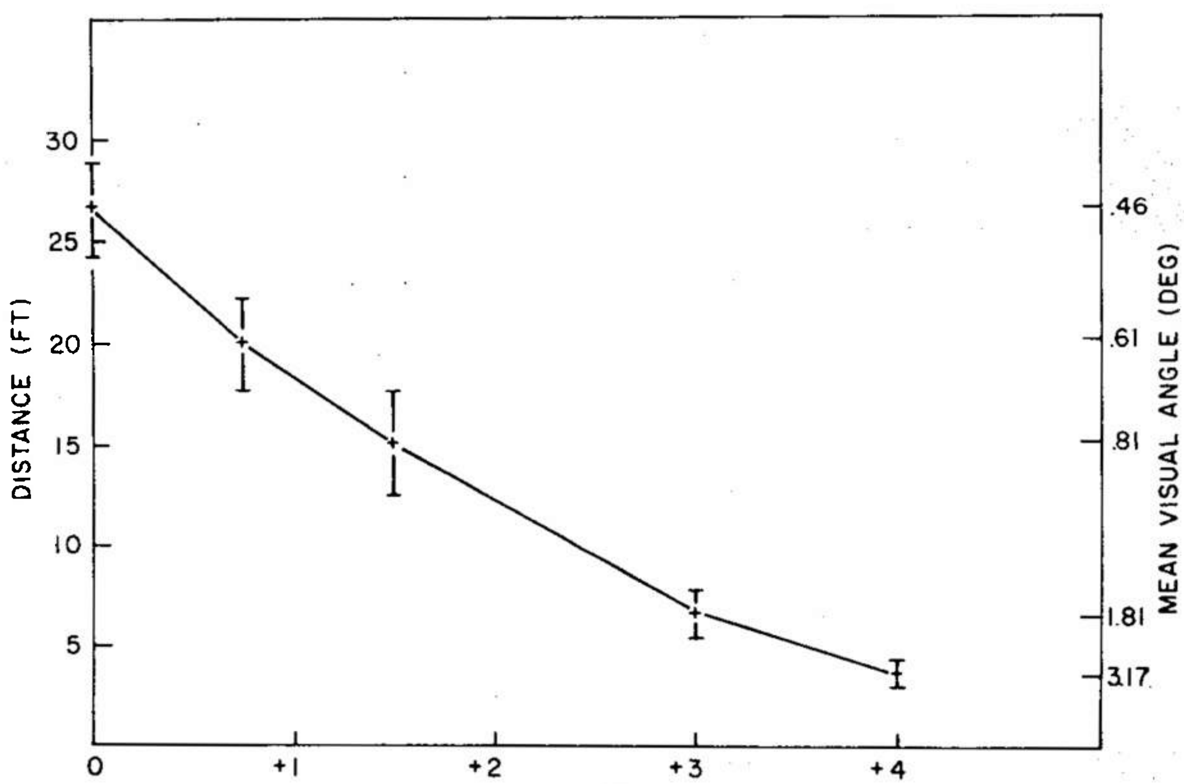

Fig. 2. Mean farthest distance at which silhouettes of ships, such as those in Fig. 1, could be correctly identified by observers with various magnitudes of astigmatism. The direction of the astigmatic distortion was vertical. The vertical lines indicate the standard errors of the means.

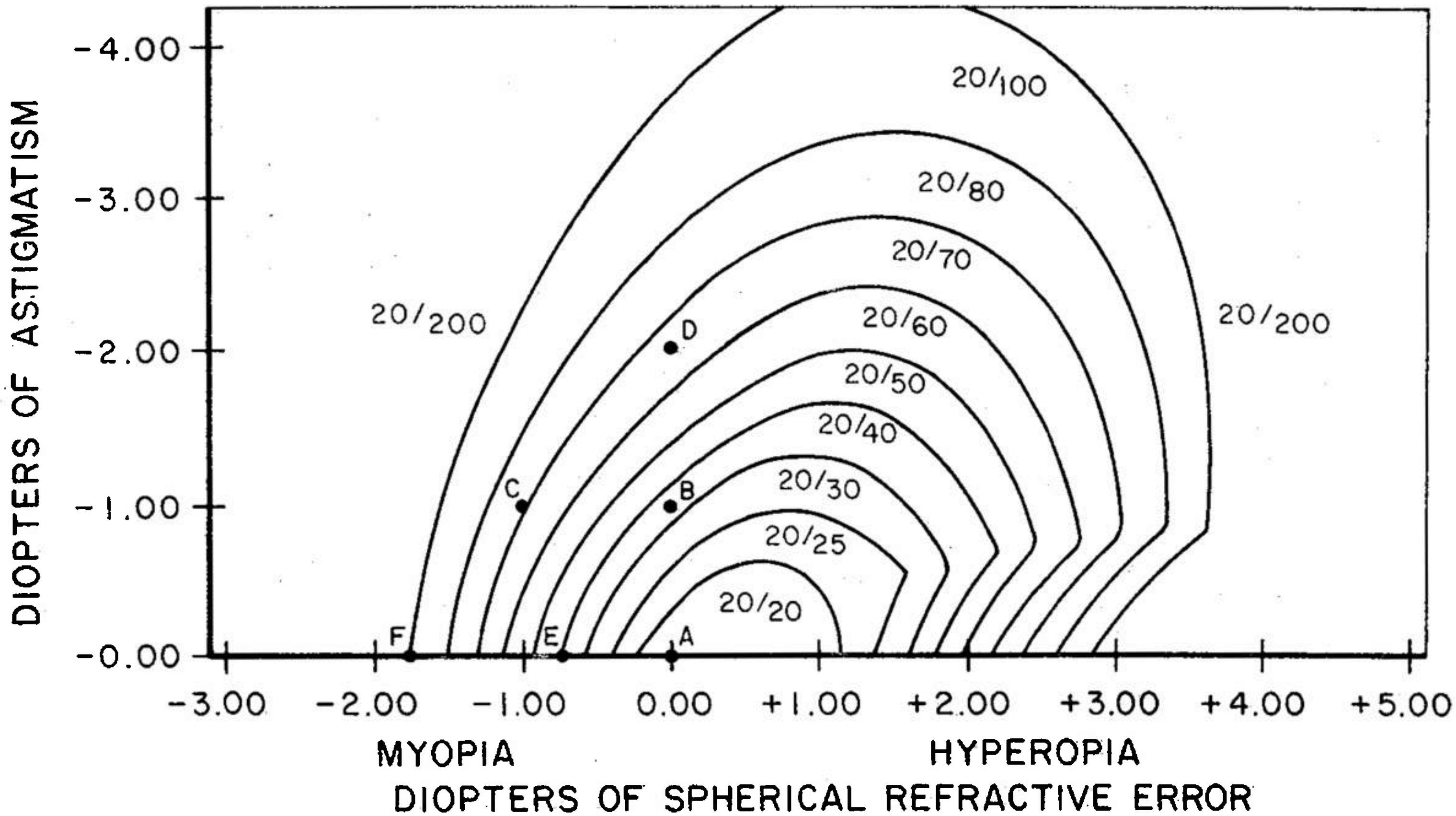

Fig. 3. Nomogram showing the level of visual acuity produced by given magnitudes of spherical and cylindrical refractive errors (Taken from Peters, 11).

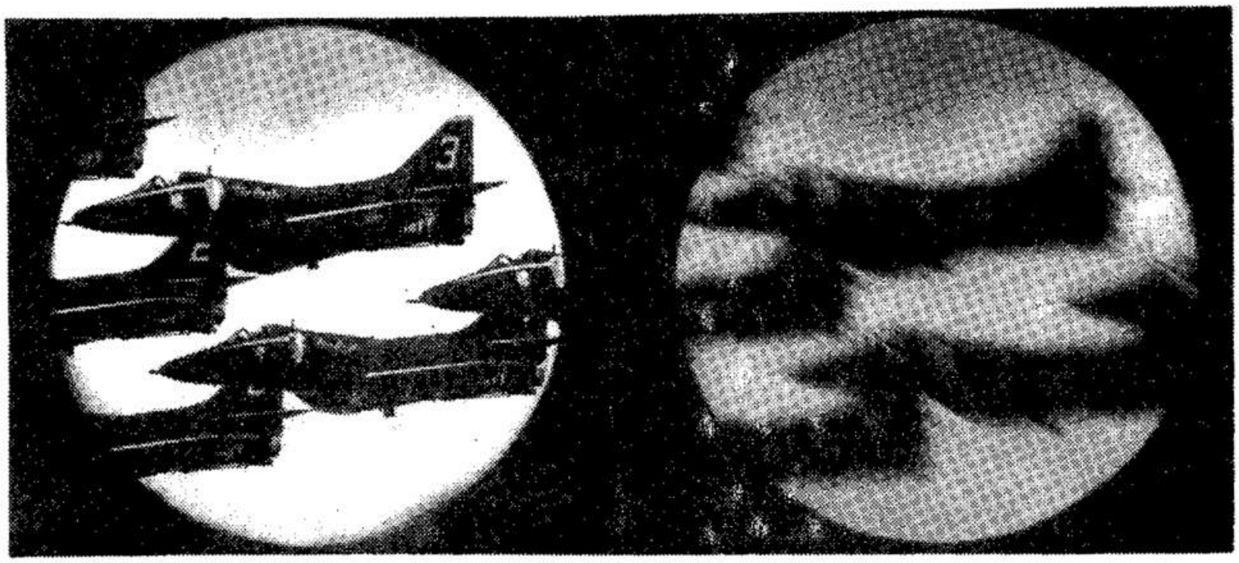

Fig. 4. The photo on the left shows a scene as it appears to an observer with 20/20 visual acuity; the photo on the right shows the same scene as it appears to an observer with 1 diopter of astigmatism, half that allowed by current visual standards.

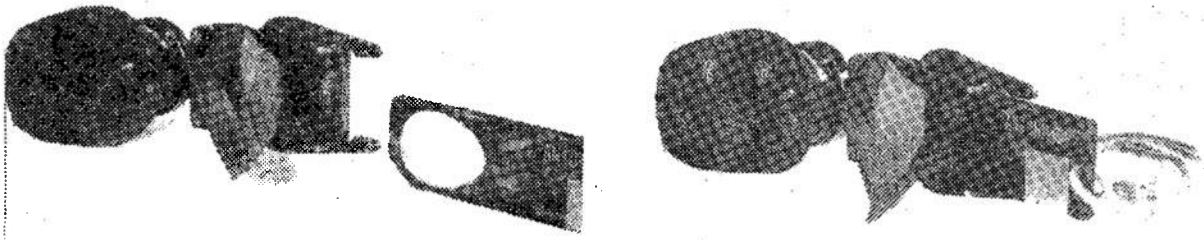

Fig. 5. A periscope eyeguard modified to permit the refractive correction of the operator to be inserted without interfering with the positioning of the eye at the exit pupil.

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The necessity of improving the visual acuity of periscope operators is discussed, and two methods of doing so are outlined. They are (i) the use of contact lenses and (ii) a modification of the periscope which permits the operator's full refractive correction to be added to the periscope. The advantages and disadvantages of each are pointed out, and the reasons for instituting both are discussed.

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