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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

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VISUAL AIDS AND EYE PROTECTION FOR THE AVIATOR

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Papers presented at the Aerospace Medical Panel Specialists' Meeting
held in Copenhagen, Denmark, 5--9 April 1976.

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PREFACE

This volume consists of a Summary, Preface, nine papers, discussions following each presentation and a General Discussion with closing remarks. This AGARD/NATO Aerospace Medical Panel Specialists' Meeting was held in Copenhagen, Denmark, 5-9 April 1976.

The aim of the meeting was to facilitate an exchange of information concerning visual aids and eye protective devices used by the aviator. Authors, observers, and Panel members from 12 NATO nations attended the meeting. Ten papers were selected for the program; nine were presented. A tremendous amount of discussion ensued, both following each paper and in the "wrap up" General Discussion. Interest in all of the topics was at a high level. Since this was the final session of the meeting, it was quite gratifying for the Session Organizer to see such an enthusiastic and well attended final discussion period. The discussions were the highlight of this meeting. Numerous questions were asked and problems identified. The ensuing discussions were quite helpful in clarifying points, issues, and technical matters.

The last complete presentation of the topic of VISUAL AIDS AND VISUAL PROBLEMS at an AGARD meeting was in 1961. Any reader wishing to compare that Session with the present one should read "VISUAL PROBLEMS IN AVIATION MEDICINE," edited by Dr. Armand Mercier (A Pergamon Press Book, 1962). A number of the topics of that 1961 meeting were discussed again at this present meeting. The reader can gauge for himself if any progress has been made.

The topics that have been discussed at this Session are about equally divided between devices to protect the eye and vision of the aviator and those which are intended to enhance and extend his visual capabilities.

THOMAS J. TREDICI, Colonel, USAF, MC
SESSION ORGANIZER AND EDITOR
VISUAL AIDS AND EYE PROTECTION FOR THE AVIATOR

EYE PROTECTION, PROTECTIVE DEVICES AND VISUAL AIDS

by

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SUMMARY

This paper discusses the major ocular hazards encountered in military aviation and describes some protective measures which may be adopted. The hazards considered are solar glare, bird strike, wind blast, miniature detonating cord, lasers and nuclear flash. The role of image intensifiers in aviation is also discussed.

INTRODUCTION

Excluding agents of chemical warfare the most important ocular hazards encountered in military aviation fall into three categories. Solar glare, trauma and high energy light. Protective devices against these hazards must be compatible with existing aircrew equipment assemblies and not inhibit the safe and efficient performance of aircrew tasks. These requirements apply also to visual aids.

Solar Glare

Protection against the discomfort and the reduction in visual acuity caused by glare from direct, reflected or scattered sunlight, is essential. In transport aircraft where slow donning and doffing is not a problem such protection may be provided by sunglasses. In high performance aircraft where protective helmets are worn photo stress is usually avoided by means of a tinted visor which is integral with the flying helmet. The visor should be capable of adjustment by the wearer to provide protection against external glare sources whilst permitting a view of his instrumentation below. In the fully lowered position the visor should be capable of preventing the ingress of all unfiltered light.

The filter for use in the aviation environment should have a luminous transmittance of between 10-15%; a transmittance significantly higher being only of cosmetic value. The densities of the filter(s) before each eye should be closely matched to avoid false projection (Pulfrich Effect). The tint must be neutral to avoid adverse effects on colour discrimination particularly the recognition of red warning signals. As discomfort from glare is eliminated it is important to ensure that infra red wavelengths outside the visible band (800-1400 nm) are also attenuated to avoid any possibility of retinal burns. Short ultra violet wavelengths may also be hazardous and there should be a complete attenuation of the solar erythemal band (290-320 nm).

As with all transparencies interposed between aircrew and the external scene care must be taken to ensure that the field of view is as wide as possible, and that the optical properties and the physical parameters conform to specification.

Birdstrike

Protection of the face against birdstrike. Fig. 1. The hazard of birdstrike is always present during flight (both day and night) at low level. Approximately 85% of birdstrike in the UK occur at altitudes below 500 ft agl whilst only 7% occur at altitudes above 1,000 ft agl. The incidence of birdstrike in low level flight is such that a hit in the cockpit area is a relatively common emergency (with respect to the various emergency functions to be provided by headgear). Whenever possible the strength of cockpit transparencies should be such that they will not shatter when a bird is hit. The strength necessary to meet this requirement when an aircraft flying at high speed hits a heavy bird may however be prohibitive. If practical, secondary protection to the aircrew should be given by a tough screen mounted within the cockpit. Again however this requirement may be incompatible with other functions, e.g. external vision, escape. Furthermore there are many aircraft in service at present in which protection of this type is not provided and yet they are being operated at high speed and low level. When a bird impact occurs onto a cockpit transparency both pieces of the bird and splinters (some of them large) of the transparency fly towards the head and shoulders of the aircrew member. The pieces of aircraft canopy in particular are propelled towards the face of the occupant. The most vulnerable organ is the eye and temporary or even permanent blindness may follow a birdstrike in the cockpit area. In the absence of other forms of protection (strong transparencies or internal cockpit screens) a helmet mounted visor made of a strong transparent material such as polycarbonate (3 mm thick) is essential for aircrew operating at high speed at low altitudes. The visor should protect all the uncovered area of the face as well as the eyes. Thus, the lower edge of the polycarbonate visor should abut closely (less than 5 mm gap) against the oronasal mask. As there is virtually no hazard of birdstrike above 2,000 ft agl the crew member should be able to remove the polycarbonate visor from in front of his eyes when flying above this height, since any layer in front of the eyes produces a small but significant impairment of vision. Whilst it is desirable that the user should be able to lock the polycarbonate visor in the down position for blast protection, there is no requirement to be able to position it in any position other than fully up or fully down. Although it would simplify and lighten the headgear if the strong polycarbonate visor could also act as the antiglare visor there are many flight conditions in which birdstrike protection is required without the antiglare function e.g. low level flight at dusk and night. A dual visor system is therefore essential where birdstrike and glare protection are required. Fig. 2.

Blast Protection

The head is exposed to very high aerodynamic forces on ejection at high speed. These aerodynamic forces impart very high angular accelerations to the head and impact of the head against the seat at high velocity. In addition the blast may damage the tissues of the face, in particular the eyes, by causing gross displacement and rupture of tissues. Furthermore the blast may displace the headgear which may well then be lost altogether. Protection against the effects of blast on ejection includes the retention of the headgear and the prevention of damage to the uncovered portions of the face and neck. Retention of headgear is necessary in order to provide impact protection to the head during the subsequent stages of the ejection sequence and the delivery of oxygen to the ejectee after escape at altitudes above 25,000 ft.

The UK approach to the blast problem is to rely on the protection given by the rigid flying helmet which is provided with a strong chin strap and oxygen mask suspension system. The eyes are protected by the polycarbonate visor which must be locked down on ejection. This system provides adequate protection against blast up to 600-650 knots.

Miniature Detonating Cord

Some aircraft, notably the Harrier, are fitted with Miniature Detonating Cord (MDC) This device consists of an explosive charge contained within a lead coat which is applied to the underside of the canopy. On ejection MDC shatters the canopy into relatively small fragments prior to the aircrew leaving the cockpit. The device has proved to be of great value in minimising personal and equipment damage on a through canopy ejection.

There have been a number of occasions on which lead spatter from MDC has caused superficial damage to the face and eyes. The most severe damage has been corneal penetration to a depth of .3mm by small particles of lead. Fig. 3. In this example the pilot had his visor elevated and deliberately kept his eyes open. It is considered unlikely in the extreme that any ocular damage will result if the visor is lowered and the eyes are closed. In order to prevent lead spatter tracking down the inner surface of the visor various guards have been developed both solid and of foam plastic, these devices may have the adverse effect of increasing visor misting.

Lasers

Lasers are devices which produce beams of monochromatic light which are usually of small diameter, intense and highly collimated. The energy density within the beam only decreases slowly with increasing distance from the laser. The eye has the ability to focus the collimated beams of some lasers and to concentrate the energy into small image sizes on the retina. Fig. 4. Thus, lasers can damage eyes at considerable distance from the source.

Neodymium, gallium arsenide and ruby lasers which emit at 1060 nm, 900 nm and 694.3 nm respectively are the most important lasers encountered in military aviation. The applications of these lasers include ranging and target illumination.

Laser protection is best provided by the adoption of safe working distances. STANAG 3606 gives guidance as to the method of calculating the Nominal Ocular Hazard Distance (NOHD). It must, however, be realised that the calculated NOHD does not make an allowance for atmospheric conditions giving rise to 'hot spots' or for intra beam viewing using optical instruments with a magnifying effect. The necessity for pilot protection from his own laser is debatable. The liklihood of a specular reflector in the range area orientated normal to the beam must be small, the probability has been calculated as less than 10^{-6}. Should such a reflector be present, its reflectivity at the laser wavelength is not likely to be high. It is considered that pilot protection is not necessary provided the target and surrounding area do not contain specular reflectors e.g. windscreens.

Where protection is considered necessary this may be provided by goggles or visors with the requisite optical density at the laser wavelength. Care must be taken to ensure that the luminous transmittance, effect of the tint on colour recognition and optical properties of any protective device are adequate for the task.

Nuclear Flash

The fireball resulting from a nuclear explosion is capable of producing direct and indirect flash blindness and indeed may cause a retinal burn. By day the small pupillary diameter and the optical blink reflex should prevent retinal burns at distances at which survival is possible. Similarly indirect flash blindness from scattered light within the atmosphere and the globe itself does not pose a problem. Direct flash blindness from the image of the fireball on the retina is difficult to avoid, but again at survival distances the irradiated area will be small. Even in the worst case of the fireball being imaged on the macula, para macula vision should allow all vital flight procedures to continue. At night with a dilated pupil the situation is much worse. Retinal burns are possible and more importantly from the operational stand point, indirect flash blindness may deprive the aviator of all useful vision for unacceptably long time periods. In short, protection against nuclear flash is not required by day but is vital at night. (Vos et al, 1964).

A number of protective measures have been proposed. If an exterior view is not required or only required infrequently it would be possible to cover all transparencies with opaque blinds. It has been advocated that filters with a fixed 1-2% luminous transmittance be worn but these are not necessary by day and are of limited value at night. Another suggestion has been an eye patch which may be removed when one eye has been affected, but this is essentially a two shot device. What is required is a visor which could be worn at all times when nuclear flash is a possibility. This visor should have a very high luminous transmittance when 'open' and a very low transmittance when activated by a nuclear flash, clearing rapidly when the flash is removed. The visor should, preferably, be made of polycarbonate or other high impact resistance material so that it may replace the one intended for bird strike protection in the dual visor system. Photochromic compounds are being developed which go some way to meeting these criteria. These compounds are activated by the ultra-violet component of the nuclear flash and darken rapidly to provide optical densities of approximately 2. They clear rapidly following the flash but may produce an afterglow. The spectral absorption may not cover the total desired range of 400-1400 nm but can be centred where desired and sideband filters added. These compounds have been doped in acrylic where their useful life is limited due to oxidation, successful doping of polycarbonates has not yet been achieved. The most promising host material to date is epoxy resin where the shelf life is unlimited. Epoxy resin may be laminated with polycarbonates to produce the necessary impact resistance.

An alternative United States approach is to use an electro optic shutter of Lead Lanthanum Zirconate Titanate in a ceramic wafer (PLZT). This device reacts within a few microseconds to produce optical densities in excess of 3. Although these characteristics appear ideal PLZT has two disadvantages. The open state luminous transmittance is low, about 22%, and it would be difficult and expensive to form into a curved visor.

The difficulties that would be caused in night flight by the low open state luminous transmittance are currently under investigation. Dark adapted subjects are required to distinguish targets against backgrounds illuminated to provide luminances of .0032, .032 and .32 candelas per square metre. These luminances correspond roughly to upper scotopic, low mesopic and low photopic levels of luminance. The threshold ability of the subjects to distinguish the target from the background is determined both with and without an interposed neutral density filter of 22% luminous transmittance. The liminal brightness increment (ΔI) is measured and the increase when wearing the filter calculated. The preliminary results are presented below.

Background luminance		$\Delta I + I$ cd/m^{-2}	I cd/m^{-2}	$\Delta I/I$ %	Mean increase in $\Delta I/I$% with filter
0.32 cd/m^{-2}	control	3.28	3.19	3.10	0.74%
	22% filter	3.29	3.17	3.84	
0.032 cd/m^{-2}	control	3.24	3.08	5.47	4.92%
	22% filter	3.38	3.06	10.39	
0.0032 cd/m^{-2}	control	3.71	3.31	11.80	7.56%
	22% filter	3.92	3.28	19.36	

If the complete laboratory investigations support the early promise and if aircrew opinion continues to be favourable a flight trial will be considered.

Image Intensifiers

The application of image intensifying goggles in aviation is currently being evaluated.

These devices incorporate one or two image intensifying tubes with the requisite optical system for binocular viewing. A beam splitter is of necessity incorporated into the optics of the single tube goggles. Most goggles provide the conventional controls to compensate for inter pupillary distance and individual spherical refractive error. The optics provide optimum focus at infinity but viewing of maps and instruments is possible either by manual focussing or by means of a bifocal segment although the limited depth of field particularly when combined with a small reading segment makes map reading difficult. The field of view of different goggles varies but an average figure would be 40°. The desired magnification is unity. The goggles are designed to operate in the passive mode but an inbuilt diode is usually provided which emits in the near infra red to provide supplementary illumination at close range.

The goggles are designed to operate in starlight (10^{-3} lux) but in practice it is considered that their greatest value is in quarter to half moonlight conditions. In full moonlight or brighter the naked eye is able to perform as well or better. The resolution provided by the goggles can vary both between manufacturers and between samples from the same manufacturer. It is considered that of the goggles evaluated none would provide wire recognition at a safe distance. The view, obtained through the goggles, of a standard vision test chart is shown in Fig. 5.

The image presented is generally green and appears close to the peak of the photopic response of the eye. Should the gogles have to be removed the eyes would require time to dark adapt. Colour coding on maps is of little value and ideally specially printed maps are required. Cockpit and aircraft lights must be virtually extinguished to avoid flare and provision made to enable warning lights and instruments to be seen. The main disadvantage of the goggles evaluated is their weight, this being approximately 1 Kg. The goggles require to be mounted at the front of the aircrew protective helmet and the displacement this produces in the centre of gravity of the head/helmet system causes considerable discomfort and precludes wearing the goggles for prolonged periods.

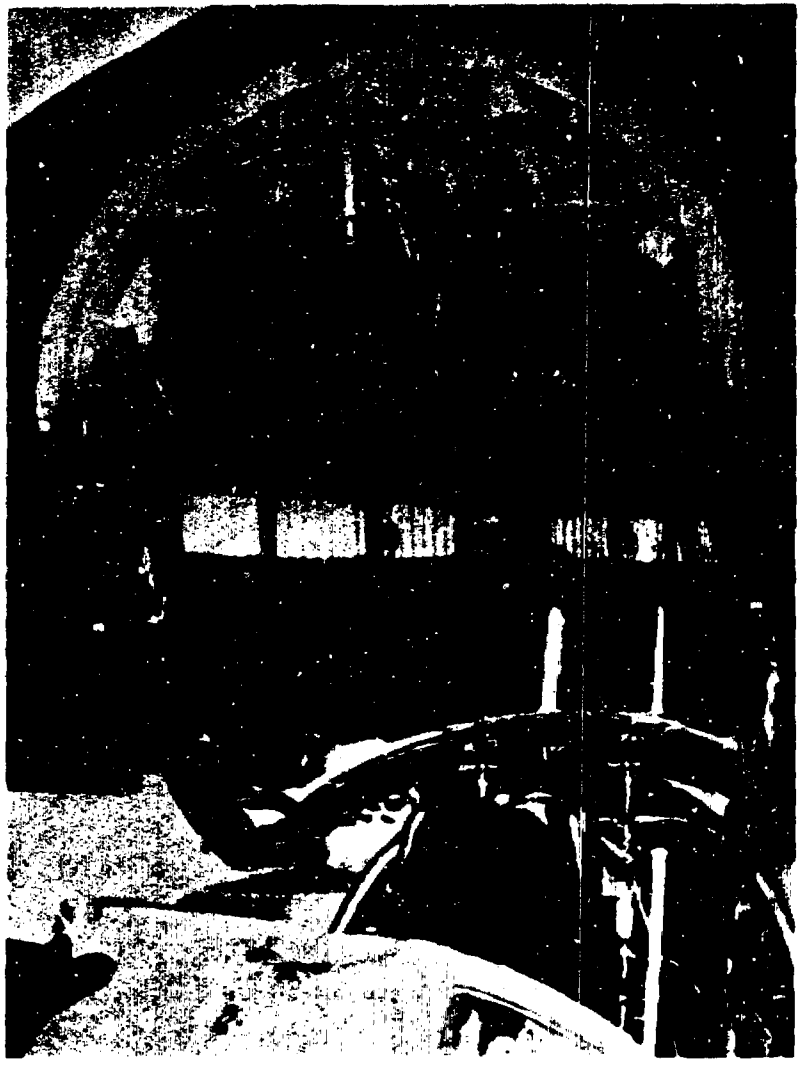
In conclusion, image intensifiers are a valuable transit aid for night flight in good meteorological conditions but development is required.

REFERENCE

1. Vos, J.J. Frederikse, J.W., Walraven, P.L. and Boogaard, J. Some reflections on the danger of and the protection against nuclear flash blindness and retinal burn. Institute for Perception RVO-TNO Report No. IZF 1964-25.

ACKNOWLEDGEMENT

I am grateful to Group Captain J Ernsting RAF for his help and advice.



Figures 14 & 15

Front windscreen on a Canadair aircraft and bird debris on visor, resulting from a strike by a herring gull

Figure 2

Dual visor helmet

Figure 3

Lead spatter from M.D.C. on face and eyes

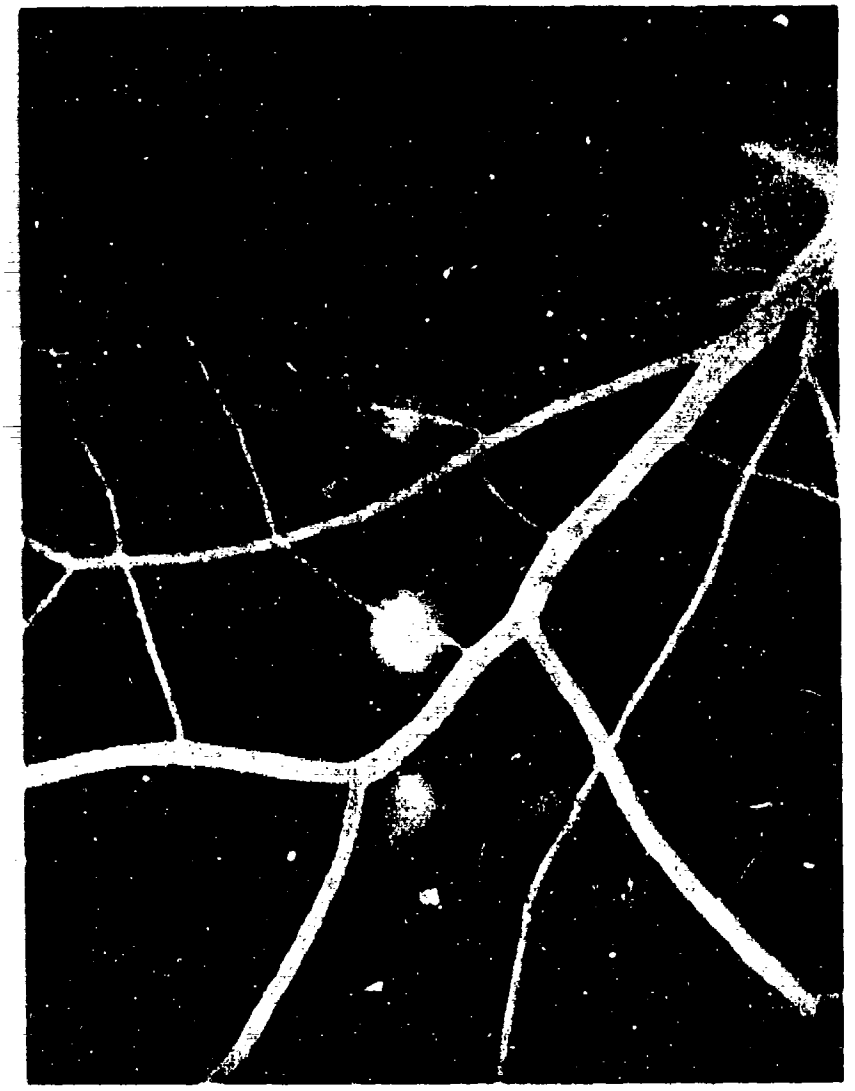


Figure 4

Fluorescent angiogram of laser lesions on a rhesus monkey retina

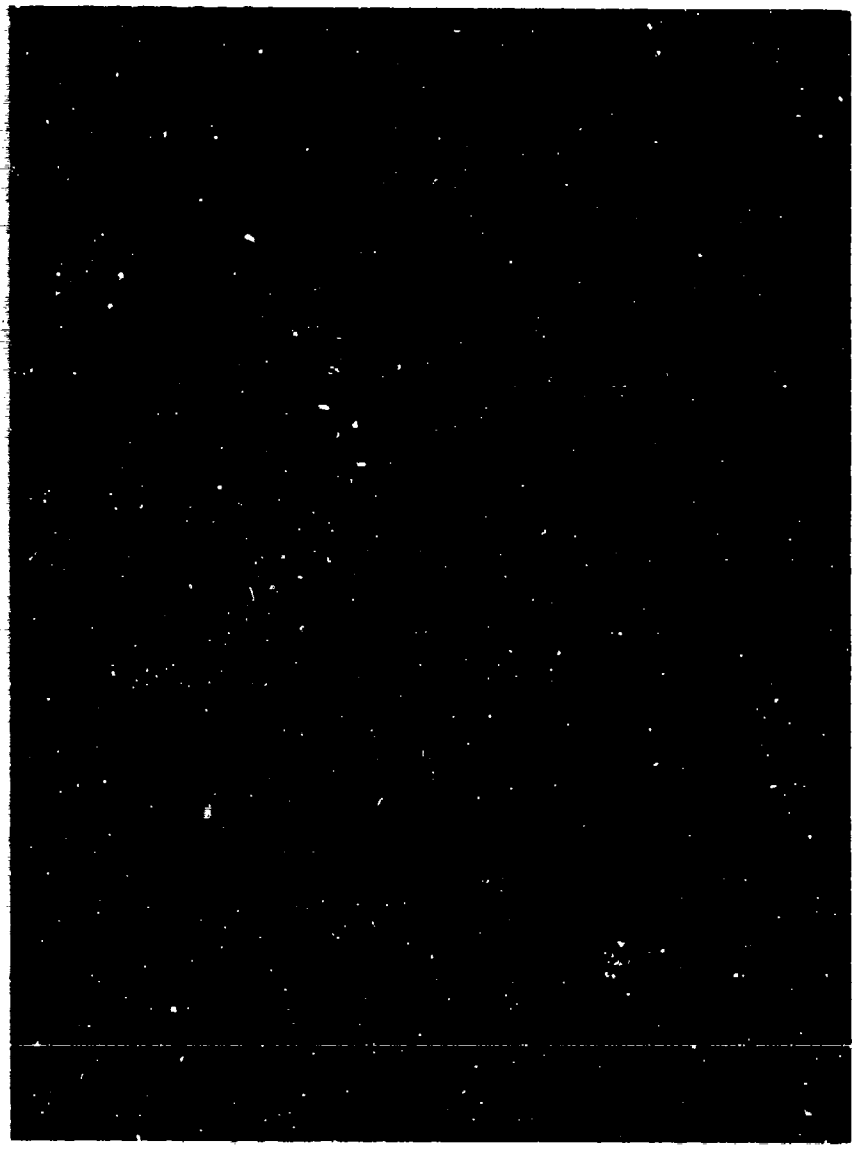


Figure 5

Snellen vision test chart photographed through image intensifying goggles

Figure 6

Single tube image intensifying goggles

DISCUSSION

CHEVALERAUD: Concerning the hypothesis of the destruction of the macula by the fireball, you say that it is possible to fly with paramacular vision? Is this only a hypothesis, or have you done any experimentation yourselves?

BRENNAN: We have not worked with this problem ourselves but consider the views of Vos to be correct.

CHISUM: In connection with this, I might point out that during the early to mid-sixties, there were some tests conducted by people at the USAF School of Aerospace Medicine--Richey and his coworkers--in which they indicated that practically all of the flying activities could be conducted with parafoveal vision. Perhaps some of the very fine instrument reading functions would be lost but most of the activities necessary to bring an aircraft back could be conducted with parafoveal vision.

GLICK: In reference to laser attenuation, we are concerned about the same thing. I agree that reflection from a man's own laser is probably minimal, but more and more we see numerous uses for lasers--target spotting and range detection from both ground-to-air and ground-to-ground and all combinations of the various lasers that you mentioned. Do you have any specific plans for attenuating these at the pilot's eye? That is the first question, and the second one: I noticed you did not use a cover on your dual visor (I guess you could go on to a five-visor system). Do you have some sort of cover?

BRENNAN: Yes, we have a soft fabric cover which is taken off on entry into the aircraft. As for protection against lasers, we would only consider protection if a man was being ranged upon. An example that comes to mind is the laser-guided gun. Obviously, if the man is acting as a target for a laser-guided gun, he will wear protection. But at the moment, we are not advocating protection for people who are using only their own lasers, although I must admit that it is an emotive issue and no matter what one says to certain people, they would still wear laser protective visors because they say they are not going to run any risk at all, however small.

TREDICI: May I ask one question? On your dual visor, the chap in the slide was not wearing any spectacle correction. Do you have any problem integrating corrective spectacles with the dual visor since they would take up more space?

BRENNAN: No, there is adequate space for all flying spectacles.

TREDICI: So the visor is mounted a little further out?

BRENNAN: That is correct. The only trouble that we are having with our dual visor system is in the quality of the polycarbonate. We find it very difficult to get optical grade polycarbonate. We are forced to use commercial grade polycarbonate, which has a very high rejection rate. Ultimately we will probably go to an injection molding process as the only way of getting the high optical quality which we demand.

IRELAND: Have you developed the fabrication capability for PLZT in the UK? And if so, how large are the units that can be made in your industrial process?

BRENNAN: No, not to my knowledge. This was brought to mind by the Sandia people.

WILEY: Do you think that the optical density between 1 and 2 for your photochromics is sufficient protection for nuclear flash protection?

BRENNAN: As you know, the optical density required depends upon your weapon characteristics and the type of aircraft, and the role in which you are using it. I will leave it at that. I will say that we think that an optical density of approaching 2--whether it is sufficient or not, I do not know.

WILEY: What is the reaction time of the photochromic?

BRENNAN: It follows the time course of the ultraviolet. But, we have in the audience Mr Resmond, from the Atomic Weapons Research Establishment at Wildermaster, and he perhaps can answer this question better than I can.

RESMOND: The reaction time for all intent and purposes is instantaneous--10^{-8} of the second.

BRENNAN: So it follows the time course of the ultraviolet--the more ultraviolet you have, the greater the density.

HARRIS: A question on the reaction times. You say it is 10^{-8} of a second. It begins reacting then--at what time does it reach this optical density of 2? In other words, are you down to an optical density of 1 or 2 in 10^{-8} of the second?

RESMOND: The time at which you would reach a given optical density is the function of the amount of ultraviolet which is put on to the photochromic. The 10^{-8} of the second is the basic time constant of the reaction of the photochromic, but, in fact, since you are always limited by the rate at which you are supplying the UV, in a particular case of providing adequate protection it may turn out that the photochromic has no reason to go to a density of 2. This depends upon weapon characteristics and the distance that you are

away from the weapon as well as on general ambient conditions.

TREDICI: I have one more question. I noticed that on all your windscreen failures (birdstrikes), the windscreens were acrylic. Are any newer windscreens being fabricated with polycarbonates?

BRENNAN: No, at the moment we do have windscreens which are laminated, but pure polycarbonates, No.

INTEGRATION OF AVIATOR'S EYE PROTECTION AND VISUAL AIDS

by
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SUMMARY

The basic function of the aviator's helmet and visor assembly is to provide protection for the head and eyes. Recent technological developments have resulted in additional functions being assigned to the helmet and visor. The additional functions range from static aids for distant vision to dynamic displays of information for use in weapon control and guidance, and aircraft management and situational information. Basic requirements for the protective equipment have been established. The expanded functions for the protective equipment require that modifications be made in the equipment configuration. The modifications must be accomplished without sacrificing the basic functions of protection. Accomplishment of these two goals requires cooperation between the display designers and crew equipment specialists.

BACKGROUND

The aviator's helmet assembly provides eye protection, sound attenuation and protection for the wearer's head during in-flight buffeting, seat ejection, bail out, crash landing, bird strikes or other impact threats. The helmet is designed to distribute impact forces over the head and to absorb those forces so that a minimum amount of any impact reaches the wearer's head. The basic helmet currently in the U.S. Navy fleet use for attack and fighter pilots is the APH-6 helmet. The outer shell of this helmet is molded from fiber glass and polyester resins, and gives impact and penetration protection. The edge of the shell is covered with a rubber edge roll which protects the wearer from the helmet edges. The inner foam liner of the helmet consists of three cellular polystyrene sheets which are molded to fit the inside contour of the outer shell. The liner absorbs and dissipates impact forces. Sizing liners which are readily inserted and removed, permit the helmet to be fitted to the aircrewman's head to afford protection, stability and comfort. Nape and chin straps insure helmet retention. The helmet shell and liners are produced in small, medium and large sizes.

The helmet visor assembly provides protection for the eyes from glare, dust, windblast, foreign particles, flash fires and flying debris from windscreen shatters. Standard visors are clear and neutral gray. The helmet sonic earcup assembly consists of an earphone housing and a foam rubber ear cushion. The earcup assemply attenuates ambient noises and thus improves reception of auditory signals from the earphones.

The aircrewman also wears an oxygen mask which is supported by a mask suspension system attached to the helmet at retaining tracks.

Minimum requirements for the aircrewman's personal equipment have been established and are published as specifications. The helmet shell, liners and visors are the equipments which have been most significantly affected by advanced visual aids. The basic requirements for the helmet shell and liner are shown in Table I. The critical requirements for the visors are shown in Table II. The standards which have been set are essentially feasible goals in light of state-of-the-art manufacturing capability and in some cases poorest tolerable quality in terms of the user performance. As will be seen significant changes in helmets and visors have been prompted by helmet mounted sight and display developments.

TABLE I

Helmet Basic Performance Specifications

Characteristic	Test	Performance
Piercing Resistance	16 oz. pointed plumbob dropped from 3.048 M (10 ft.) height	Maximum penetration 3.18 mm (1/8 in.)
Impact	7.39 kg weight dropped from 186.69 cm in a standard impact test apparatus	Maximum acceleration 400 g; No evidence of "bottoming"

TABLE II

Visor Critical Performance Specifications

Characteristic	Specification
Visible transmittance	
clear visor	Not less than 87%
neutral gray visor	12% ± 4%
Neutrality	
neutral gray visor	Less than 12% deviation from neutral
Chromaticity	
neutral gray visor	X & Y chromaticity coordinates within standard limits
Diffuse transmittance	Less than 5% of total visible
Ultraviolet transmittance	Less than 5% between 290 & 320 nanometers
Abrasion resistance	No major abrasion when subjected to standard test
Coating adhesion	No loosening or removal of coating in standard test
Vertical prismatic deviation	Less than 0.25 diopters difference for right and left critical areas. No abrupt changes in prism
Horizontal prismatic deviation	Less than 0.75 diopters total for right and left; less than 0.18 diopters difference between right and left
Spherical power	Less than 0.125 diopters
Critical area distortion	Within standard tolerance limits
Crack propagation	Within specified limits under standard test
Wind blast resistance	Visor shall not rise, loosen, tear away or break in standard test (blast-520 mph; rise time -60 msec.)

INTEGRATION

Efforts have been underway for more than fifteen years to develop helmet mounted sight and display systems. The only system which has reached even a limited operational stage is the Visual Target Acquisition System (VTAS) which is produced by Honeywell, Inc. VTAS is a target sight system in which a reticle and discrete signal lights are presented to a pilot.

The earliest version of the VTAS helmet made use of a small, retractable beam splitter which came to be called a "granny glass". The beam splitter could be positioned so that the signals were presented monocularly to the right eye of the pilot. The second generation of the helmet portion of the VTAS system utilizes the visor as the beam splitter. The projection and additional optics are mounted on the visor and the pilot sees the reticle and signal lights reflected from the paraboloid portion of the visor beam splitter.

Other efforts are or have been underway to develop helmet mounted display systems in which dynamic and/or selectable information can be displayed to a pilot while he observes the environment external to the cockpit. These efforts have included holographic techniques in which holographic lenses are mounted on the visor and cathode ray tubes (CRTs) or some other technique such as light emitting diodes are used to generate the signals to be displayed to the pilot; helmet mounted CRTs with mating optics to relay the CRT images to one eye while the other eye views the outside environment; and helmet mounted CRTs with fiber optic probes to relay the images to a projection point and monocular or binocular beam splitters or reflectors. Most of the helmet mounted sight and display systems require that the line of sight of the pilot be detected and relayed to a computer for use in either weapon system or display management. In some cases, the position of the helmet, or head, is sensed. In other cases, both head position and eye position are sensed. In either case, some type of electronic units are mounted on the helmet as part of the helmet/eye position sensing scheme.

Prior to the development of the VTAS system, crew equipment personnel monitored, with interest, developments in helmet mounted sights and displays, but there was little meaningful interaction between personal equipment specialists and the display designers. The equipment specialists were keenly aware of deficiencies in the comfort of the aviator's helmet, and efforts were underway to improve the fit, stability, balance, weight and thermal comfort of the helmet and the quality and durability of the visor. The advent of VTAS aggravated many of the helmet problems and accelerated efforts to improve the helmet.

Because VTAS is a sight system, movement of the helmet on the aviator's head introduces sizeable guidance errors into the system. Movement of the APH-6 helmet is likely to occur even when the pilot's head is completely dry. Movement is even more likely if there is moisture from perspiration. Addition of the VTAS projector and sensing electronics to the helmet changed the weight and balance of the helmet which further aggravated the helmet slippage problem. The response to these very serious problems was to find an interim method of providing aviators assigned to VTAS equipped squadrons with form-fit helmet liners. This was initially accomplished by making a mold of each aviator's head. The mold was sent to a helmet manufacturer where a liner was made, complete with padding for his helmet. The unit was then returned to the aviator. The process was an extremely time consuming one, and obviously not very satisfactory. Other efforts were underway to find more satisfactory alternatives. Some of the alternatives tried were various field foam-in-place methods of making the helmet liners. Several proved promising. One is the Thread-Rite system which the U.S. Air Force adopted, and which the U.S. Navy is using on an interim basis. It is a foam-in-place system which uses a mold positioned on the pilot's head. The foam components are mixed, poured into the mold and allowed to set. The liner must then be removed from the mold, trimmed, fitted with a comfort liner and a leather liner and then mounted into the pilot's shell. A newer system currently in operational evaluation by the U.S. Navy is the V-TEC system which is an improvement over the Thread-Rite system and uses a helmet outer shell as the mold. When the foaming process is complete the liner is complete, and must then be removed from the mold shell, placed in the pilot's personal shell and the whole process can be completed within approximately 15 minutes. The weight of the helmet has been reduced and is expected to be reduced even further by use of newer light-weight materials.

Still another development in the helmet improvement program which has proven significant for the helmet mounted display developments is a new, low profile light weight foam-in-place helmet assembly which is still in a developmental stage. The basic concept in this development has been that of an integrated approach to the development of head-mounted personal protection equipment. Naval Air Development Center Crew Equipment personnel have addressed the entire spectrum of head-mounted personal protective equipment including visors, communications and oxygen as well as the helmet shell. The VTAS program is being interfaced with the integrated light weight helmet low profile foam-in-place helmet program through the cooperative efforts of the Crew Equipment engineers, the VTAS Project engineers and contractors in both areas. The result is the VTAS III helmet in which the helmet position sensor units are molded into the shell, thus providing better weight and balance while maintaining the penetration and impact protection required for the helmet. Table III shows comparative values for the various generations of helmets, before and after VTAS.

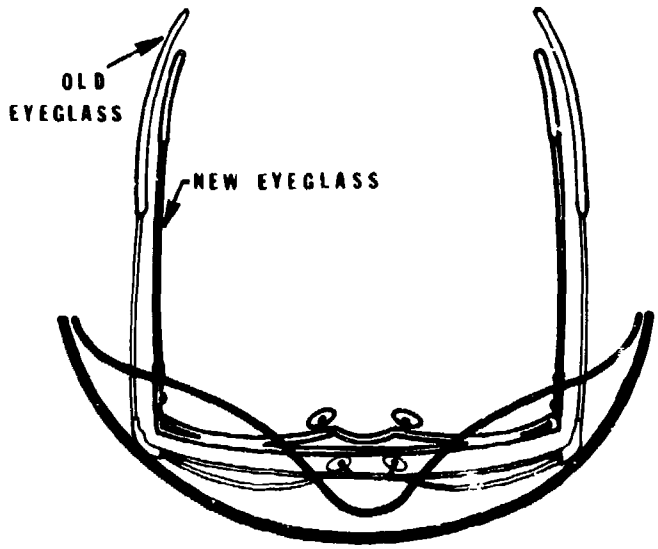
TABLE III

Helmet Weights

Helmet	Weight (kg)
APH-6/A13-A	2.61
HGU-33P/A13-A	1.86
HGU-35/P	1.81
VTAS I/A13-A	2.77
VTAS II(APH-6/A13-A)	3.4
VTAS II(PRU-37/P, A13-A)	2.68
VTAS III(HGU-35/P)	2.13

The visor requires special attention. An aviator should always fly with a protective visor in place. Even a small accident such as being struck in the eye by cockpit debris could be extremely expensive in terms of the individual aviator's career and in terms of the investment in training. In addition, such an accident could conceivably precipitate a larger accident resulting in loss of a crew and aircraft. Everything that a pilot sees, then, while operating an aircraft is seen through the visor. Blurring and distortions of the visual field are unacceptable. Inadequate visor performance can result from two classes of conditions. The first is poor optical quality in the visor, the second is visor surface damage. The optical quality of the visor is determined in the manufacturing process. The basic visor is a section of a sphere and is manufactured by either molding or vacuum forming. It is relatively easy to construct such a visor which conforms to the optical specifications for visors shown in Table II. In order to increase the durability of the visor, "Abcite" coated polycarbonate material is being used. The visors for some of the advanced displays require that special optical characteristics be built into the visor. For example, the VTAS visor is parabolic in the reflecting area. At least one of the proposed helmet mounted display visors is a dual parabolic shape in the reflecting area. Such a visor is much more difficult to manufacture to conform with the spherical and prismatic power specification. The irregular shapes of the visors also raise the problem of mechanical integrity of the visor. The basic strength and durability of the visor must be maintained intact. The experience with the development of the VTAS parabolic visor illustrates the way in which Crew Equipment Specialists - in this case optical specialists - interface with the display manufacturers in a cooperative effort to achieve the desired endpoint - a visor of good optical quality. The result of the efforts of the Honeywell, Inc. personnel who were responsible for the development of the visor was a parabolic visor which conforms with all of the optical requirements of the visor specification.

The transmittance of the visor has always created a dilemma. Since the visor must be used in both day and night operations, a single visor density is inadequate. During daytime operations the tinted visor of 12% ±4% transmittance is used; during night operations the clear visor which has a transmittance of at least 87% is used. Several alternatives are available to accommodate these incompatible transmittance requirements. The least attractive alternative for a pilot is to change the visor assembly on the helmet, another unattractive alternative is for the aviator to have one helmet for day operations and another for night operations. In either of those cases, a mission which included both day and night operations would present a problem. In order to provide for such cases, a dual visor kit which contains both a clear and a tinted visor was prepared and has been in fleet use for some time. The dual visor kit enlarges the profile of the helmet, adds weight and has never been accepted very well in the fighter and attack pilot community. More recent developments in eyeglasses have provided some relief, though not a completely satisfactory solution to this problem. Aviators are now permitted to remain on flying status with visual acuity of 20/50 or better and must wear lenses to correct the acuity to 20/20. In order to accommodate more comfortably, those pilots who require correction, a new eyeglass frame is being developed. The new profile, which is shown in Figure 1, can be worn behind the visor.[1] With the new frame, a pilot can use a helmet fitted with a clear visor and wear sunglasses in the daytime. Those who require correction can wear clear prescription eyeglasses at night and tinted prescription eyeglasses during the day. This solution is a significant improvement in ordinary operations, but it is less than optimum in use with sight systems such as VTAS and is incompatible with the optics of other display systems. The ideal solution would be a variable density visor which developed adequate density for daytime operations and becomes essentially clear in low light levels. Efforts are currently underway to develop techniques for providing such a visor. Because of the nature of the materials which can be adapted for the purpose, the solution will probably be to coat a clear visor with a removable variable density film.



COMPARISON OF NEW/OLD EYEGLASS CLEARANCE UNDER VISOR
FIGURE-1

The oxygen system is another area in which the personnel protective equipment must interface with the helmet mounted sight and display systems. Fighter and attack pilots must be provided with oxygen for breathing. A mask is the most usual way of providing the oxygen. Helmet mounted optical systems must be compatible with the oxygen system. The integrated personnel protection program has included improvements in the oxygen system as well. Complaints about the old oxygen system were directed at the blockage of vision by the profile of the mask, the restriction of head movement caused by the hose which hung from the front of the mask and the uncomfortable weight and balance of the mask. The mask for the new head protection system will have a lower profile, no hose on the front and will provide more comfort because of the improved weight and balance of the total head protection system. Integration with the display visor will be accomplished at the squadron level by trimming the visor to fit the mask contours and position as worn by each pilot. Guides and patterns will be provided for achieving the proper mating.

The electrical and mechanical connections required for the display systems are another area of integration and interface in which crew equipment personnel and display designers must cooperate. For any system which requires connection of an aviator to the aircraft there must also be provision for emergency separation of the two. In addition, the cables which link the pilot and aircraft must not restrict the activity of the pilot to the extent that the ability to perform the mission is impared. Fighter and attack pilots require good cockpit mobility and visibility. If the display system requires that voltage be brought to the helmet, the connections used must have good electrical integrity and insulation, and must be quick disconnect connectors which will not become a threat to the pilot on ejection.

Safety of use is an important consideration. In addition to the maintenance of the integrity of the basic protection afforded by the helmet assembly, and electrical safety, safety during ejection, catapult and arrest must be assessed. The threat on ejection is of damage from wind blast, damage to the head, neck and shoulders caused by imbalance of the head mounted equipment and damage from flailing solid objects such as connectors. The usual method of assessing ejection safety is to first test eject anthropomorphic instrumented manikins outfitted with the equipment being evaluated and then test eject live subjects, on an ejection test tower. The threat on catapult and arrest is of physical damage to the pilot caused by poor balance and/or mechanical integrity of the helmet mounted system. Assessment of these threats is accomplished on a horizontal accelerator with first a manikin and then live subjects.

In addition to equipment integration, another important area of concern is use of the displays, or the man-machine interface. Several considerations are pertinent and should be addressed early in the design of any display. They include type of information required, type of reading operations required, and operator display management. The considerations relevant to the information, optical and visual characteristics, have been dealt with in detail elsewhere.[2] It will suffice for our purposes here to enumerate some of the areas in which design decisions must be made. The type of information to be displayed may be simple static sighting type information with "lock-on" indication as for a radar or missile aiming function, it may be dynamic sight type information such as a hot-line for a gun sight, dynamic display to present "launch envelope" type information or more visually complex signals to provide aircraft position and condition information. There are in general, two types of display reading operations. The first is accurate reading in which precise position, location or alpha-numerics are to be discriminated, the second is monitoring type operations in which relatively gross visual functions are performed. The design decisions relative to these areas will influence choices of symbology, color, brightness, visor transmittance, visor coatings, display signal generators, permissible signal instabilities and system optical requirements. The types of technical personnel who must be involved in reaching these design decisions are, in addition to the display engineers, human factors engineers and vision specialists.

The experiences of Crew Systems personnel at the Naval Air Development Center indicate that the earlier in the design process the appropriate personnel start to interact, the smoother the transitions through the research and development process are accomplished.

REFERENCES

(1) Craig S. Jencks; U.S. Navy Development of Helmet Compatible Eyeglasses; SAFE Twelfth Annual Conference and Trade Exhibit Proceedings; September 8-12, 1974.

(2) Gloria T. Chisum, PhD; Crew Systems Dept., Naval Air Development Center, Warminster, Pennsylvania, 18974; U.S.A.; Head Coupled Display Visual Design Considerations; March 20, 1975; NADC-75013-40.

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DISCUSSION

BRENNAN: What luminances do you use in your displays for day and night time use? That is one question, and the other question is: When wearing sunglasses under your clear polycarbonate visor, how do aircrew manage to don and doff the sunglasses rapidly when going from rapidly changing illumination, such as from low level through clouds to the high levels of luminance?

CHISUM: Well, they don't--that is one problem with using spectacles. One thing that I did not mention in response to the second part of your question. First, the spectacles also present something of a bit of a problem with some of the displays. The optics in the display must be integrated with the optics in the spectacles. If there is power in the spectacles, that is a problem. And in order to solve that problem, a variable density visor would be the ideal visor. There are some efforts underway to develop a variable density visor, but those efforts are really somewhat inadequate. The brightness of the display is a problem. At present, with VTAS--VTAS is only a daytime system, and I do not recall the exact brightness but it seems to me there is some control over the intensities of the VTAS energies and the maximum, I believe, is Delta I of around a tengh of the increase in the background. There apparently have been no problems with the VTAS images. The difficulties will come providing bright enough display images since now the images are being picked up from a cathode ray tube or some other kind of image generating device and transmitted in some way to the visor so that there will be tremendous light loss. The rule of thumg for brightness on the cathode ray tube that has been requested is around 100 ft. lambert rightness at the screen but that number has been used for the helmet-mounted cathode ray tube where either a 100% reflecting mirror is used to reflect the images to the pilot's eye--in some cases, a 90% reflecting beam splitter, a small beam splitter. In attempting to move the cathode ray tube from the helmet to the aircraft in order to reduce the weight on the helmet, it means using a fiber optics probe with 10% per ft. transmittance loss through the fiber optics so the brightness will be a problem. And I suspect that some techniques, such as reflective coatings on the visor, may be used to take advantage of every bit of light that can be reflected--reflected coatings on the inside of the visor which match the phosphorous of the cathode ray tube or whatever other devices may be used to generate the images.

BRENNAN: Just one more question. Where did you get the polycarbonate? Do you inject mold the polycarbonate that you use on the visor?

CHISUM: No, they are vacuum formed, I believe.

BRENNAN: From cheap materials?

CHISUM: Yes, I don't believe that any of them are injection molded.

BRENNAN: Do you happen to know where they get the cheap material?

CHISUM: No, but I will find out. They do conform with the neutrality required for the visors.

TREDICI: You can acquire the polycarbonate from the General Electric, GE; its trade name is Lexan.

WILEY: Just a comment. The Army uses injection molded polycarbonates from the Gentex Corporation.

WILEY: The VTAS is a daytime system only, but can you use it on a clear visor? Do you get enough Delta I on a clear visor, or must it be a tinted visor to see the images?

CHISUM: The tinted visor uses VTAS. This is the first place that the problem of the visor transmittance was really tackled. The visor used with VTAS, the tinted visor, is not a 12% plus or minus 4% transmitting visor. The transmittance is a little higher, but a good deal of the density of the visor is achieved by the coating inside the visor to enhance the reflection.

WILEY: So it has not been tried with a clear visor yet?

CHISUM: It has been tried with a visor, I think, as high as about 60% transmittance.

KUCHNER: I have a question in connection with the new spectacle frames fitting under the helmet with the dual visors. How is the compatability of these frame eyeglass? According to the sketch you presented, are the ends of the great side of the visor precisely placed between the external ear and the region of the curve? This, however, may cause heavy discomfort if the spectacles concerned are worn for longer periods, and, moreover, have you considered reduction of the spectacle frame itself? What about the aperture of the spectacle glasses and the width of the so-called bridge? There you need the possibility of some shifting in respect to the corresponding parts of the nose and the interpupillary distance

CHISUM: This spectacle frame is not in operational use.

TREDICI: But the Navy has been working on a new frame. The Navy is using exactly the same one as I am wearing and which I will describe in the next 20 minutes in detail. All they have done is taken the hinge which in the American Optical frame sits out laterally and bent it 90 degrees so that it now comes straight back, reducing the total width of the frame about 5 mm. That is all that has been done right now. It is too complicated to go into producing a special pair of glasses for one service since these are utilized throughout

the services--Army, Navy, Air Force, etc. But that is what it is right now, a temporary fix.

PERDRIEL: Do you have standards which allow you to measure the optimum radius of curvature for the visor?

CHISUM: The basic visor is a section of the sphere, and there are standards for the permissible power, the prismatic power possible which is acceptable in a visor. With the special display visor, the curvature is not a sphere. With VTAS, the visor in the reflecting portion is a parabolic visor of, I think, possible 2 or 3 in focal length. I do not remember exactly. And the problem of achieving the power required in the reflecting portion of the visor without adding power to the transmitting property of the visor was a problem. The spherical power was not a problem; that was easy to deal with, but the prismatic power was a problem. Just because as the visor was formed, as it was stretched, the center stretched more than the edges, producing a higher prismatic power in the visor than was acceptable; but with a great deal of effort, the techniques in forming of the visor were achieved so that the visor could be formed without the introduction of the additional prismatic power so that now this is not a problem. We do have instruments for measuring the optical characteristics of the visor, and that is not a problem.

THORNE: Have you had any reaction from aircrew to the introduction of the form-fit helmet? We have only had the experience of the test pilots who objected on terms of comfort, thermal comfort, but they may wear their hat on it.

CHISUM: There are several things that pilots have traditionally complained about with the helmet--the weight, the balance of the helmet. The form-fit helmet has been used in the fleet and the fighter squadrons which have VTAS. The pilots liked the form-fit helmet, even though it is hot--it is very hot. They wear little cotton knit pieces under the helmet to try to cut down on the moisture under the helmet a little bit, but they like the form-fit helmet very much. If we were able to develop a form-fit air-conditioned helmet, I am sure they would like that too, but the only complaint has been about the heat--that the helmet is hot. That may be a bit of a biased opinion since that is used for the squadrons using VTAS and the fighter pilots like the VTAS so much that they probably would tolerate more than some of the pilots who are not using VTAS with the form-fit helmet--it probably would give more discomfort but it does help to increase the stability of the helmet. There are still problems, I am sure, based on some of the comments that I have heard from Dr Ewing the other day. I am sure that there are still under high Gs some deformation of the energy absorbing liner and perhaps the stability will not be ideal, but it does increase the stability of the helmet.

GRABBARER: Do you intend to allow contact lenses combined with the helmets? I could imagine it is very interesting and very necessary for pilots to use the same visual aids they usually use.

CHISUM: I guess there is some consideration for the use of contact lenses. As far as I know they are not in use. I suppose that the soft contact lens may receive more acceptance, but many people find it difficult in adjusting to contact lenses, so that I do not know whether they will be using them or not. Are you planning to talk about this, Dr Tredici?

TREDICI: We are going to discuss that in the Round Table, and it probably will get boring once the ophthalmologists begin attacking the contact lens problems; but right now in the military, the US Armed Forces, contact lenses are only used as a last resort for treating medical conditions and we have not utilized them as replacements for spectacles.

PROTECTION FROM RETINAL BURNS AND FLASHBLINDNESS DUE TO ATOMIC FLASH

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SUMMARY

Since the advent of nuclear weaponry, a requirement has existed for eye protection from weapon effects which may produce permanent retinal burn and flashblindness.* (The term "dazzle" is sometimes used to mean flashblindness; however, this usage is not preferred because the meaning is unclear.) Present protection to prevent retinal burns and flashblindness is limited to two passive devices: Gold-plated goggles for daylight use and an opaque eye patch worn over one eye during night use.

Even though a nuclear confrontation is unlikely, the U. S. Air Force has a requirement to protect the aircrew against temporary flashblindness and permanent retinal burn effects that result from exposure to nuclear detonations. The search for such a fast-operating shutter device has been elusive and beyond the state of the art. Increase aircraft weight, field of view, open state transmissivity, cost, and aircraft modification are additional constraints that have slowed the solution to the problem.

A new transparent ferroelectric ceramic material, lead lanthanum zirconate titanate (PLZT), has enabled the development of large-aperture electrooptic shutters in goggle or window-type formats which provide sufficiently rapid decrease in transmitted light intensity to prevent flashblindness and permanent retinal burn from ultraviolet, visible and infrared radiation encountered in nuclear explosions.

PLZT is a spin-off development of the lead zirconate titanate class of ceramic materials utilized in a number of transducer applications by Sandia Laboratories, Albuquerque, New Mexico.

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* A thermal/flash protective device (TFPD) is one which will protect an observer from permanent retinal burns (lesions) and temporary visual impairment, or flashblindness, which would otherwise result from exposure to the brilliant flash of a nuclear detonation. Flashblindness protection is defined by the U. S. Air Force to be achieved if the specified visual function of reading flight instruments is restored within 10 seconds after exposure to the flash. Sufficient thermal/flash protection must be provided by the TFPD device to allow the aircrew to function to the maximum nuclear environment that the aircraft can tolerate. The USAF has found that devices which darken to a luminous density of 3 (0.1% photopic transmissivity) within 150 microseconds of flash onset, and remain in the protective mode throughout the threat duration, meet the TFPD requirement.

A. INTRODUCTION

Lead zirconate-titanate (PZT) ceramic materials have been investigated and utilized in nuclear weapon transducer applications by Sandia Laboratories for approximately 20 years. As part of the development program for manufacturing high-density PZT ceramic bodies of acceptable mechanical quality, the hot pressing procedure was widely exploited. Ceramic materials prepared by hot pressing are subjected not only to the usual high firing temperatures, but also to high pressure. A disc or cylindrical slug is the typical configuration in which the PZT ceramic bodies are formed. PZT materials used in weapons transducer applications are usually doped with other elements to provide certain desirable electronic properties. While investigating some of these doped materials prepared by advanced hot pressing methods at Sandia Laboratories, optical translucence was observed by G. H. Haertling.[1] Exploring further, he found in 1970 that optical transparency could be achieved by substantial additions of the element lanthanum.[2] The optical transparency is substantially improved by using chemical coprecipitation techniques in the batch formulation process and conducting the hot pressing operation with the slug in an oxygen atmosphere.[3-5] The lanthanum-modified PZT materials are designated by PLZT.

Early measurements of the electrooptic properties of these materials were conducted

primarily by C. E. Land.[6] In 1971, J. T. Cutchen and J. O. Harris began to explore PLZT material characteristics for device applications. The primary emphasis in their work was on room-temperature cubic-phase materials, typically X/65/35 with X≥9. (Note: In this notation, X is the atomic percent of lanthanum substituted for lead in a material containing 65% lead zirconate ($PbZrO_3$) and 35% lead titanate ($PbTiO_3$).) Early work by Cutchen and Harris culminated in a USAEC patent (#3,737,211, "Ferroelectric-Type Optical Filter") covering electrooptic variable-density optical filters, light control devices and shuttering devices. The work included an evaluation of the device in a goggle configuration for thermal/flash protection for industrial and military applications.[7] Developments in this and related areas have been reported by Cutchen, Harris, and G. R. Laguna in later publications.[8-11] The exploratory work in PLZT thermal/flash protective devices (TFPD) was conducted at Sandia Laboratories using USAEC funds. Subsequently, the U. S. Army Natick Laboratories and the USAF Aerospace Medical Division (AFSC/AMD) initiated reimbursable programs with Sandia Laboratories. The primary objective of the program with AFSC/AMD was to produce a scale-up in PLZT manufacturing procedures so that 127mm diameter slugs could be successfully fabricated. From these slugs, 76 x 102mm rectangular wafers were procured for use in a prototype four-segment 152 x 203mm heat shield window. The window was considered for mounting directly behind the windscreen of selected aircraft. The work required to accomplish this engineering materials task was significant, and was primarily accomplished by R. H. Dungan, and G. S. Snow, also of Sandia Laboratories.[12] An operational 152 x 203mm window prototype using four of the 76 x 102mm PLZT segments was demonstrated in July 1974.

The devices, accomplishments, and significance of these PLZT programs were evaluated in 1974 by a special AFSC Flashblindness Protection Study Team chaired by the Life Support SPO of Aeronautical Systems Division. The team also evaluated other systems which were under development at the time. As a result of the team recommendations, the Life Support SPO initiated a 24-month reimbursable program with the United States Energy Research and Development Administration (USERDA) to establish a lead lanthanum zirconate titanate/thermal flashblindness protective devices (PLZT/TFPD) goggle production capability. USERDA authorized Sandia Laboratories to proceed on this program in February 1975.

B. PLZT/TFPD Operation

The functional schematic of the PLZT/TFPD is shown in Fig. 1. The device operates exactly as the well-known Kerr cell. The electrooptic wafer is sandwiched between two polarizers, and oriented so that its optic axis is at 45° to the polarizer axes. In the closed-state -- or "off" -- condition, there is no voltage difference between the elements of the interdigital electrode array on the surface of the ceramic wafer. Under these conditions the wafer is optically isotropic and does not affect the light which passes through it. The light is consequently blocked by the polarizer pair, as shown in Fig. 1A. In the open-state -- or "on" -- condition, a voltage difference is applied to the electrodes to create birefringence in the wafer. In this case the wafer becomes optically anisotropic, and retards a component of the polarized light. As a result, the light leaves the wafer in a state of elliptical polarization, which enables some transmission by the second polarizer. When the correct voltage is applied, the wafer acts as a broadband half-wave plate, and the light which leaves the wafer is linearly polarized but rotated by 90°. This is the maximum-transmissivity condition for the assembly, and is shown in Fig. 1B. The level of transmissivity may be continuously varied between the two extremes represented in Fig. 1 by controlling the amount of applied voltage, creating an electrically controlled variable density optical filter. A substraction-color filter can be generated by using the device with a white-light source at voltages higher than the broadband half-wave voltage.

For the TFPD application, the device is typically operated in the fully-open state until a light threat is detected by suitable sensors in the control circuit. When this occurs, the PLZT wafers are rapidly discharged by a silicon-controlled rectifier (SCR), and the goggles revert to the closed state. When the threat is removed, the wafers are re-energized and the open state is recovered. In practice, the hazardous light threat may decay very gradually. In this case, the wafer can be recharged in a gradual fashion to maintain a continuous safe level of light transmission through the lenses. Since the linear polarizers are only effective in the visible spectrum, additional absorption filters are required to block infrared (IR) radiation. Typical IR absorption filters are KG-1 and KG-3 glass. The ultraviolet radiation is blocked by both the polarizers and the PLZT material.

C. The USAF Program

The purpose of the endeavor is to support a research and development program to develop prototype PLZT thermal/flash window segment protective devices and to establish a production capability for PLZT thermal/flash protective goggle devices. Device emphasis in R&D is 70% for a helmet-mounted goggle, 20% for a headset (nonhelmet) version, and 10% for a mosaic window device. Production emphasis is to be 100% on the helmet-mounted goggle. A headset version will be phased into production later. Two variants in goggle design are undergoing evaluation. In one case, a four-lens approach is being considered (2 large front lenses with 2 side windows, all active). For the other, a unit with only two circular front lenses is being considered. The design goal is that the entire goggle assembly and self-contained electronic controller not exceed 1 pound (454 grams) in weight.

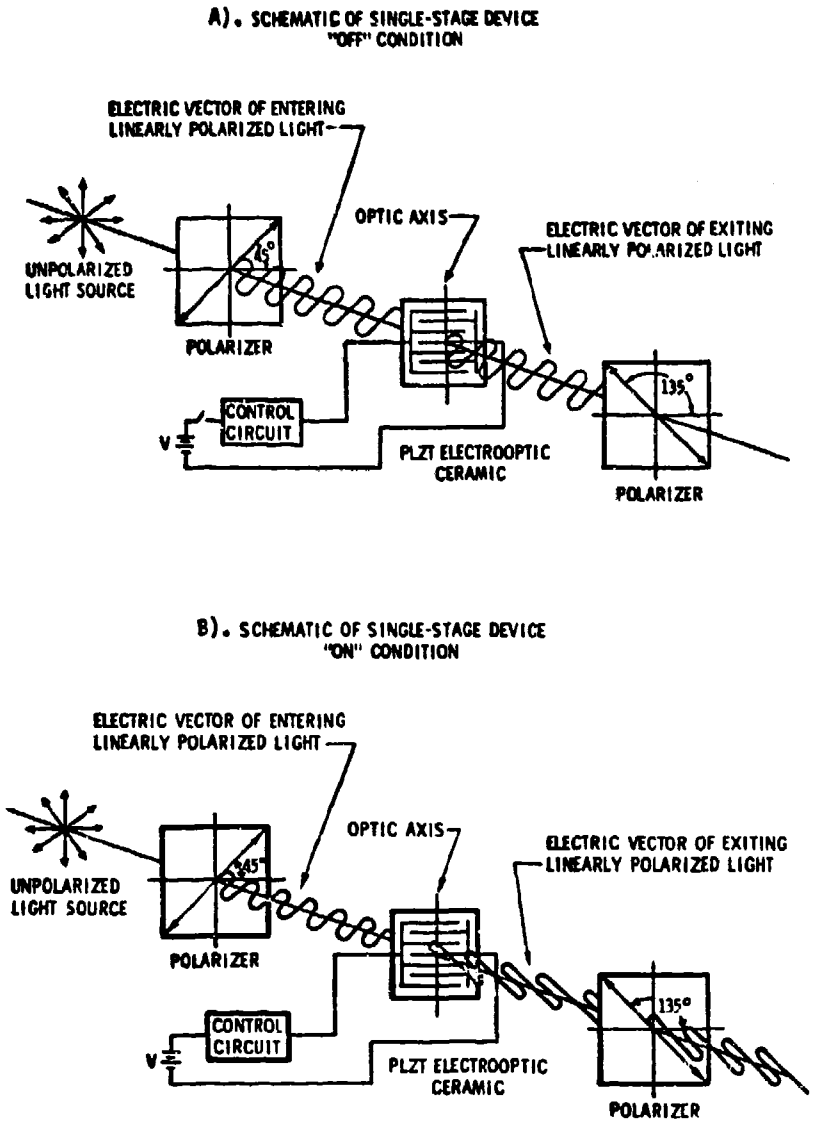

Fig. 1. Schematic operation of the PLZT single-stage device in (a) the closed state and (b) the fully-open state.

Operational goals of the device are: (1) Operating temperature range is 55 ± 45°F (13 ± 25°C); (2) Ultimate luminous density in the protection mode at least 3.0 over the entire operating temperature range; (3) The luminous density of 3 must be achieved within 150 microseconds after flash onset for the upper temperature range of 55° to 100°F (13° to 38°C).

The electronic controller for the PLZT/TFPD goggle will be manufactured using hybrid microcircuit techniques in order to minimize weight and allow packaging within the goggle frame. The unit will be powered by a battery pack and/or 28 VDC from the aircraft. It will be designed to take advantage of the light-control capabilities of PLZT lenses; i.e., to permit transmission of any level of light between the fully-closed (maximum opacity) and fully-open state. Consequently, the electronic controller will possess the following features:

1. Manual control and override of the maximum possible voltage output to PLZT element. This feature will allow the maximum permitted open-state transmissivity.

2. Automatic servo and tracking of the light transmitted through the lenses. The light throughput will be continuously monitored behind the lenses. If the throughput exceeds a pre-set value the servo system will automatically decrease the voltage at the PLZT element to restore the pre-set transmissivity level -- and vice versa.

3. When the behind-the-lens monitor detects an increase in light intensity which exceeds the pre-set tolerable limit and rises faster than the servo can control, the protection mode will be triggered. Under these conditions, the lenses close to maximum opacity

4. In the protected state the servo will control the re-opening of the lenses. That is after the lenses have reached maximum opacity and the external light has begun to diminish, the lenses will be re-opened in a controlled manner so as to maintain the transmissivity at the pre-set level. Under these conditions, the wearer will be continuously provided an external vision capability.

The front and rear polarizing elements in the PLZT lens assembly control both the opacity and the maximum possible open-state transmission. An optimized lens assembly which uses presently-available sheet polarizers (Polaroid Type HN-32) has an ultimate luminous density of about 4.3 (0.005% transmission) in the closed state, and an open-state photopic transmission of about 19% (with KG-3 filters). Obviously, if transmissivity gains are to be realized in the open state the polarizer capabilities must be improved. With ideal polarizers and no other losses in a system, the maximum open-state transmissivity of a lens would be 50%. It appears that some gains can indeed be realized, and one goal of the development effort is to procure more efficient polarizers from Polaroid Corporation.

The following helmet-mounted goggle prototypes have been or will be delivered:

Group	Delivery Date	Quantity	Comments
I	November 1975	8	Passive units - DT&E*
II	March 1977	25	Active units and battery packs - IOT&E**
III	June 1977	30	Active units and battery packs - OT&E***
IV	September 1977	25	Preproduction units

*Development Test and Evaluation
**Initial Operation and Test and Evaluation
***Operational Test and Evaluation

Production delivery is scheduled to begin in October 1977 at 165 - 200 units per month to continue until approximately 6100 goggles are manufactured for the U. S. Air Force.

REFERENCES

1. G. H. Haertling and C. E. Land, "Hot-Pressed Ferroelectric Ceramics for Electrooptic Applications," Bull. Am. Ceram. Soc., Vol. 49, p 411, April 1970.

2. G. H. Haertling and C. E. Land, "Hot Pressed (Pb, La) (Zr, Ti)O_3 Ferroelectric Ceramics for Electrooptic Applications," J. Am. Ceram. Soc., Vol. 54, pp 1-11, January 1971.

3. G. H. Haertling, "Improved Hot-Pressed Electrooptic Ceramics in the (Pb, La) (Zr, Ti)O_3 System," J. Am. Ceram. Soc., Vol. 54, pp 303-309, June 1971.

4. G. H. Haertling and C. E. Land, "Recent Improvements in the Optical and Electrooptic Properties of PLZT Ceramics," Ferroelectrics, Vol. 3, pp 269-280, February 1972, and IEEE Trans. on Sonics and Ultrasonics, Vol. SU-19, pp 269-280, 1972.

5. G. H. Haertling, "Electrooptic Ceramic Materials," 1971 WESCON Convention Record, Paper 31.1.

6. C. E. Land and P. D. Thacher, "Electrooptic Properties of Ba, Sn, and La Modified Lead Zirconate Titanate Ceramics," in Physics of Opto-Electronic Materials, pp 169-196, W. A. Albers, Jr., Ed., Plenum Publishing Co., New York, 1971.

7. J. O. Harris, Jr. and J. T. Cutchen, "Electrooptic Variable Density Optical Filter," International Symposium, Soc. for Info. Display, Digest of Technical Papers, Vol. III, pp 16-17, June 1972.

8. J. Thomas Cutchen, J. O. Harris, Jr., and G. R. Laguna, "Electrooptic Devices Utilizing Quadratic PLZT Ceramic Elements," 1973 WESCON Convention Record, Paper 30.2.

9. James O. Harris, Jr., George R. Laguna, and J. Thomas Cutchen, "Practical Applications of the Quadratic Electrooptic Effect in PLZT Ceramic Materials," Bull. Am. Ceram. Soc., Vol. 53, p. 606, 1974.

10. James O. Harris, Jr. and J. Thomas Cutchen, "Compositional Dependence of Electrical and Electrooptic Characteristics of X/65/35 PLZT Ceramics for X from 8.0 to 10.0", presented at 1975 IEEE Symposium on Applications of Ferroelectrics, Paper 9.2, Albuquerque, N.M., June 9-11, 1975. (Proceedings to be published in Ferroelectrics).

11. J. Thomas Cutchen, James O. Harris, Jr., and George R. Laguna, "PLZT Electrooptic Shutters: Applications," Applied Optics, Vol. 14, pp 1866-1873, August 1975.

12. R. H. Dungan and G. S. Snow, "Hot Pressing of Large PLZT Slugs for Electrooptic Windows," 77th Annual Meeting, Amer. Ceram. Soc., Washington, D.C., May 3-8, 1975.

DISCUSSION

McARTHUR: What is the unit cost?

PFOFF: The projected cost in FY 76 dollars for this four-window model with the power supply is estimated to be about $1250 per copy. Since we will be in production in FY 78 we have assumed possibly a 10% per year inflation rate--we hope it is less than that--but that would make the FY 78 cost when we go into production right at $1500 per copy.

BRENNAN: Two questions--what thermal load would the polarizer stand? And the second question, have you tried any more objective tests of people scoring themselves?

PFOFF: To the first question--the polarizers if they are glass laminated will take just in excess of 40 calories per sq. cm. We also tested plastic polarizers and they will go about 9 calories per sq. cm. So, of course, we will be using the glass laminated polarizers which we have in this device. I might also mention that it does increase the weight and obviously that is a very important consideration. This first prototype weighs about 410 grams--that includes the KG3 and the glass laminated polarizers, so we do plan on keeping this under one pound or under 450 grams.

HARRIS: I will take care of the operational tests. In the 90 some units that we will be getting that are operational units, Dr Brennan, in those extensive OT&E (Operational Test and Evaluation) those will be subjective and objective tests--the full range of qualifying type tests, and, of course, we would make that information available in our exchange program to you when it becomes available.

TREDICI: Did you mean laboratory stereopsis visual acuities?

BRENNAN: I was slightly concerned that people are scoring themselves--I would be more interested in somebody scoring them.

TREDICI: Yes, as they perform.

BRENNAN: That is correct, yes.

HARRIS: The one advantage of having people to score themselves is that I have found out that most pilots, if they cannot fly with it, they will fail it or if they don't like it, they will fail it. That is a risky one also, so we have been very pleased with the acceptability of the crew members in the operational wings, and in case that point was not made, these were operational crew members in the operational wing, and these were normal training flights. We just simply piggy-backed on to their normal flight schedule. There was no flight scheduled just for our test purposes, strictly the normal routine flying of the operational wing.

TREDICI: I have a question, still on that line. There is only one aberrant square up there and that is the 135 tanker pilot who had nearly 5, and all the rest are down to about 2's and 3's. Was there anything peculiar about that group?

HARRIS: Yes, the thing that caused that one score to drop to about a 5--that was a first lieutenant pilot, a 135 on his solo aircraft commander's ride, with a brand new copilot, 2nd Lt, and a brand new navigator, 2nd Lt, that landed in the fog, in the dark, strictly on instruments. He rated it a 6 so that pulled it down to that 4.

LIDSTONE: What is the overall thickness of the elements, of the system?

HARRIS: The ceramic itself is about .015 of an inch thick or .38 mm. The glass laminated polarizers, the KG3 glass, is 2 mm. thick, and we plan to laminate the first polarizer to the KG3 glass, if the loading levels are not too high--that is what we will do; otherwise, the glass laminated polarizers will be approximately .040 thick each. You will have a sheet of glass, then the polarizer in the ceramics and the polarizer in the glass--there will be only two pieces of glass.

PERDRIEL: Will there be any alteration in the color vision and a possible disturbance of the depth perception in the normal open state of these protective goggles?

HARRIS: We have not noticed any problems. If you remember, the first viewgraph which we showed you say the flat spectral response throughout the visible portion. If you look at the ceramic in the slug form before it is sliced it does have a slight yellow tinge; however, when you polish the wafer you cannot see the color. I have some samples here that I can show you. We have not had any reports on problems with depth perception. We also did build one of these to be used in protecting Vidicon tubes, and one Navy group did run some tests on changes in the number of line pairs per millimeter that they could distinguish and they saw essentially no change in the center of the ceramics to the outer edge. We also had some questions initially asked about the grid lines farther from the pilot or the viewer, and, of course, that has not been the case if they are not in the focal plane.

PFOFF: I could go a little further on that one--in reference to the flight test if it did anything to the colors as far as flight instrumentation or anything of that nature. It did not have any effect. We did notice some slight effects in some of the older B-52 windscreens that had some slight marring or scratching or chipping. You could get some slight scattering, but that could be looked around, and we can work with it. It is not perfect but it is workable.

STONE: Not being an ophthalmologist, I am very curious about what sort of resonance frequency your PLZT has? In the radial mode.

HARRIS: I believe that it is about in the vicinity of 30 to 50 kilocycles. It is compositional dependent--it does depend on the lanthanum and as to how we mount it, as to what damping you do have. You noticed on the viewgraph where we had the rapid oscillations. I think it is about 35 kilocycles.

STONE: What about the axial mode resonance of that material?

HARRIS: I do not know.

STONE: The reason I ask, I think you quoted a figure of 125 microamps of current to supply and it is roughly a thousand volts. That is a power output that could be up around 1 to 10 milliwatts. It depends on the wavelength--that is a pretty good power output.

HARRIS: We have not noticed any problems in that regard. We should mention with regards to power that although we are operating in voltages between 500 and 1200 volts, the ceramic has a higher leakage resistance so the leakage current is extremely small so that we are dealing with very small currents generally with regards to safety.

USAF AVIATOR GLASSES - HGU-4/P
(HISTORY AND PRESENT STATE OF DEVELOPMENT)

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SUMMARY

For whatever reasons, one of the most sought-after items of US Air Force issue is the aviator goggle HGU-4/P. Besides this allure, it has an important fundamental role--that of enhancing and protecting the vision of US Air Force aviators. The historical development of this model spectacle frame and lenses is interesting in itself. The spectrum of presently available lenses will be reviewed. Studies done at the USAF School of Aerospace Medicine to improve the product will be detailed--in particular, the impact tests, both drop ball and ballistic, of glass (heat treated and chemical ion exchange) and plastic (CR-39 and polycarbonate). The practical tests of plastic versus glass lenses used in the field will be reviewed. The serendipitous observation of noting that all plastic lenses inserted in the aviator frame warped led to the present issuance of only glass lenses for aviator duties. The culmination of this research has resulted in the presently available product, one that is felt to be the best that the state-of-the-art can presently produce.

INTRODUCTION

Most of the information necessary to accomplish the flying task is gathered by the visual sense. US Air Force flyers are selected with good visual capabilities. It is important to maintain their vision at peak efficiency. A thorough eye examination and visual standards screen out most ocular pathology and visual problems felt to be incompatible with flying (1). However, the refractive status of the eye may change as one matures. Presbyopia is inevitable. Acquired infections and unrecognized genetic factors all take their toll on the visual apparatus. Ocular trauma and the effects of electromagnetic energy on the eye are of more immediate concern. Aviator spectacles are most helpful to manage these latter two conditions as well as for the correction of refractive errors.

Spectacles and goggles have been used by the aviator to protect against wind, fire, foreign particles, glare, excessive electromagnetic energy, and for the correction of refractive errors and presbyopia. Crown glass and various plastic materials can protect and enhance vision (2). Improvements in these materials, such as heat or chemical treatment of spectacle lenses, thus making them impact resistant, and the use of CR-39 and Lexan plastics have advanced the state-of-the-art. The substitution of filters for clear glass and plastic protects against abiotic electromagnetic energy and glare.

Sunlight falling on the earth is composed of 58% infrared energy (700-2100 nanometers (nm)), 40% is in the visible part of the spectrum (400-700 nm), and only 2% in the ultraviolet (290-400 nm) (3). At high altitudes, ultraviolet may reach as high as 5% or 6%, and in space, ultraviolet comprises 10% of the solar energy spectrum (4).

Contributing directly to the problem of glare is the intensity of solar radiation on earth. On a clear, cloudless day with the sun at its zenith, the illuminance is 10,000 ft. candles (108,000 lux); at 10,000 ft.(3050 meters) altitude, it is 12,000 ft. candles (129,600 lux), and in space and on the moon the illuminance is 13,600 ft. candles (146,880 lux) (5). Fortunately for man, the earth's atmosphere attenuates the visible infrared and ultraviolet parts of the spectrum. At ground level glare is only a problem on clear days, but for the aviator it is ever present above the clouds. Water vapor absorbs considerable amounts of the infrared energy. Ultraviolet is largely absorbed by ozone and molecular oxygen so that practically all the ultraviolet radiation shorter than 295 nm is absorbed by the earth's atmosphere (4).

Light energy above a certain threshold will adversely affect various ocular tissues. Ultraviolet energy between 295 nm and 315 nm is absorbed by the cornea and conjunctiva, producing photokeratitis. Ultraviolet radiation effects are additive for 24 hours. Recovery from keratoconjunctivitis is usually complete in 24 hours. The tremendous amount of ultraviolet energy present outside the earth's atmosphere would be a most important factor in extravehicular and moon operations. With no filter protection (100% transmission), a threshold dose producing keratoconjunctivitis would be acquired in outer space in three seconds (4). The visible and near infrared energy when absorbed in sufficient quantities by the retinal pigment epithelium will cause a chorioretinal burn. This may occur while looking at the sun during an eclipse or viewing a nuclear detonation. Further, infrared energy is absorbed by the lens. If this occurs, over a long period of time, a cataract may be produced. Finally, microwave (radar) energy of sufficient intensity has produced cataracts in experimental animals (3).

The ideal aviator spectacle then should:

a) correct refractive error and presbyopia,
b) protect against physical energy--wind, fire, and foreign objects,
c) reduce the light intensity (glare),
d) transmit all the visible energy but attenuate the ultraviolet and infrared,
e) not distort colors,
f) not interfere with stereopsis (depth perception),
g) be compatible with headgear and flying equipment, and
h) be rugged, inexpensive and need minimum care.

HISTORY AND BACKGROUND

During World War II the Army Air Corps used what was known as the B-8 goggle. It was rubber-framed and held in place by an elastic band. A series of plastic inserts of various absorptive properties were used (6). Sunglasses for glare protection had green lenses with a transmission of 52% in the visible spectrum, not sufficiently dense for the purpose intended. These lenses were therefore replaced by rose-smoke lenses which were an improvement (7). The rose-smoke lenses reduced the daylight transmission to 15% and limited erythemal ultraviolet radiation to 1%, with transmission of the infrared limited to less than 15%. In 1949, Rose and Schmidt (8) studied the effects of ophthalmic filters on color vision. Their work showed that the neutral lenses caused no increase in color errors whereas lenses deviating from neutrality caused errors according to the amount of deviation. The transmission of the neutral (N-15) lens in the near infrared and ultraviolet was well below the threshold of ocular pathology. Pilot acceptance tests comparing the rose-smoke with the neutral sunglasses were conducted. These tests showed a decided preference by the pilots for the neutral lenses.

At first, frames for the lenses were whatever was commercially available. In 1952, the F-2 and G-2 sunglasses were standardized: Specification MIL-G-6250B. The F-2 sunglasses had a plastic frame and 15% transmitting neutral lenses designed primarily for Arctic wear. The G-2 sunglasses had a metal frame with similar lenses designed for wear in all other regions (6). (See Figure 1.)

Figure 1. G-2 Aviator Sunglasses

Figure 2. HGU-4/P Aviator Sunglasses

Certain features of the F-2 and G-2 sunglasses were found to be unsatisfactory. The lenses were large (59 mm) and heavy (40 Gm). On long missions the weight of the glass and pressure on the nose caused discomfort. The cable temples had to be individually and correctly fitted. Other poor features were the difficulties encountered in removing or donning the frames while wearing a helmet or headset and the inability to integrate with the oxygen mask. The G-2 metal frame at times tarnished when in contact with the skin. Optical problems revolved around the overly large sized lens blanks needed to properly center the finished lenses. Secondly, there was the variability in density of the sunglass lenses as the power of the prescription increased.

Because of the dissatisfaction with the F-2 and G-2 frames and lenses, a search for an improved design was initiated. In 1956, a meeting was held at the Aeromedical Laboratory, at Wright-Patterson Air Force Base, Ohio. Besides the problems discussed above, other items were addressed. Among these were possible relaxation of the ultraviolet transmission requirements, the possible use of plastic lenses or the feasibility of case-hardening the glass lenses. As a result of this conference, a sunglass frame designed by the American Optical Company was selected for service testing (6).

The original design was altered and improved as a result of this service testing. Finally, on 13 November 1957, MIL-G-25948 replaced MIL-G-6250B for Air Force procurement, and the new sunglasses were given the nomenclature HGU-4/P (6). (See Figure 2.) Except for changes in the lens materials, this design concept has remained unchanged to the present day. The HGU-4/P solved most of the problems that had made the F-2 and G-2 spectacles unsatisfactory. The weight is reduced by nearly 25%; they are much more comfortable to wear; and the spatula temple allows rapid and easy donning and removing, even while wearing headgear or earphones. The one-tenth 12K gold-filled frames have reduced the number of dermal reactions noted. Integration problems with the oxygen mask and visor have been greatly reduced. Adjustable nosepads and straight spatula temples have almost eliminated adjustment problems. Finally, the right and left temples are interchangeagle and the same-size screw is used throughout the frame, greatly reducing the number of items to be stocked.

NEW DEVELOPMENTS

The HGU-4/P frame and lenses have remained relatively unchanged since 1958. The wisdom of not tinkering too much with a good design has been proved since there have been relatively few complaints concerning these spectacles. In this time span they have even been used in space and moon exploration. The original and continuing specification called for unhardened glass lenses to be used. This decision was largely based on the work of Rose and Stewart (9). In 1957, they reported that ballistic missiles of small size (1 mm) traveling at high speed fractured hardened glass lenses more easily than unhardened glass. In the late 1960's the US Food and Drug Administration and the National Society for the Prevention

of Blindness began investigating the feasibility of having all spectacles used in the United States be made impact resistant. This culminated in a 1972 Food and Drug Administration regulation making it mandatory to use only impact resistant or plastic lenses in all spectacles sold and used in the United States (10). Anticipating this ruling, the staff of the Ophthalmology Branch at the USAF School of Aerospace Medicine carried out a replacement and durability study of glass versus plastic lenses. This study evaluated the replacement rate of glass and plastic (CR-39) lenses and compared the durability of glass and plastic lenses in the Air Force environment. One thousand pairs of spectacles having one glass and one plastic lens were dispensed to military personnel at four Air Force bases of different climates. Replacement of plastic or glass lenses was made on the basis of subject response during inspection visits. Comparative durability was assessed on the basis of hazemeter readings and visual inspection. A significantly higher plastic lens replacement rate was found (3.6 to 1) (11). Perhaps even more significant was a serendipitous finding that all of the plastic lenses warped. These lenses had been inserted in both metal and plastic frames. The lensometer did not discern this alteration but the Geneva Lens Measure did, registering an equal change in both convex and concave surfaces, thus leaving the lens power unchanged. This warpage would, however, have to be considered significant in lenses with corrected curves and might also affect spatial perception, especially in an aviator (12).

To seek improved lens materials for the aviator spectacle, further testing was done. Ballistic impact testing of scratched and unscratched ophthalmic lenses was done by Ophthalmology Branch personnel. This work was reported in the American Journal of Optometry and Physiologic Optics in May 1974 (13). The impact performance of plano and prescription ophthalmic lenses was determined by the ballistic technique. The 720 test lenses included nontreated, heat-treated, and chemical-treated glasses as well as plastic (CR-39) lenses. Half of the test lenses in each category were abraded on the front surface prior to impacting with a 4.76 mm (3/16 in.) spherical steel projectile. The lenses were mounted in a metal frame and positioned on an anthropomorphic head during testing. Results showed the plastic lenses to have the greatest impact resistance while nontreated glass lenses have the least. Heat-treated and chemical-treated glass lenses rank second or third and have similar impact performance characteristics. All four types of lenses were found to lose impact strength after being scratched on the front surface. (See Figure 3.)

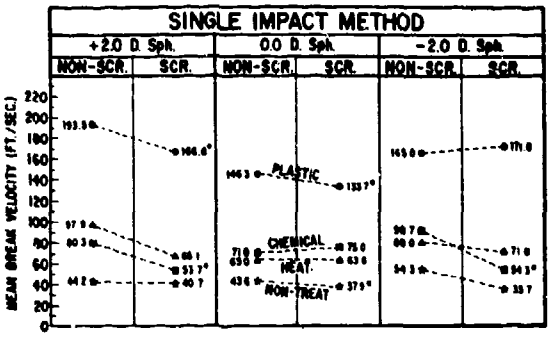

Figure 3. Mean break velocity using the single impact method. Each symbol represents the mean break velocity required to fracture 30 lenses.

The result of the above-reported research is reflected in the present issuance of heat-treated or chemical-treated glass lenses only in the US Air Force aviator spectacles. However, frame modifications are being considered and the ideal lens continues to be sought. A coated, plastic lens with better resistance to warpage might be the ideal replacement for the present heat-treated glass lens.

Aviator spectacles HGU-4/P, therefore, are presently available with clear, heat-treated glass lenses in single vision, bifocal, and trifocal configurations for the correction of refractive errors and presbyopia. These lenses transmit 92% in the visible spectrum. (See Figure 4.) They are also available with a clear coating of magnesium fluoride (MgF) to reduce multiple images (ghost images). These lenses transmit 96% of the visible spectrum. Corrections up to ±5.50 diopters are available. The sunglasses are neutral 15% (N-15) transmission gray up to ±1.50 diopters of hyperopia or -2.75 diopters of myopia. Beyond this range, up to ±5.50 diopters, clear glass lenses coated with a 15% gray tint are substituted. (See Figure 5.) A recently added option is the substitution of 31% (N-31) neutral transmitting glass if the correction is greater than ±1.50 or -2.75 diopters but not greater than +4.00 or -5.50 diopters. The neutral density lenses should not transmit more than 15% of the infrared, 0.2% of the erythemal ultraviolet, and a minimum of 12% to a maximum of 10% of the visible energy. The frames are made of 1/10 12K gold-filled over a base of 14% to 16% nickel-silver.

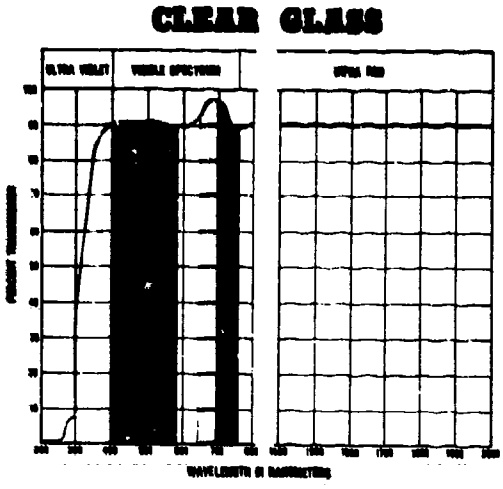

Figure 4. Transmission Curve of Clear Lenses

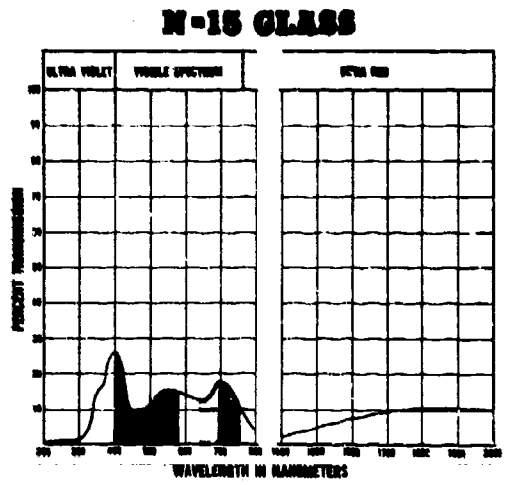

Figure 5. Transmission Curve of N-15 Lenses

Further, all lenses must withstand the drop ball test for impact resistance (14). A 5/8-inch diameter steel ball is dropped on the lens from a 50-inch distance. The lens must withstand the impact energy and not crack, chip, or fracture to be accepted. These lenses have been "hardened" by heating to a temperature of 1180°F and then quenched with a jet of cold air. This strengthens the glass by compressing its surface. The newer ion exchange method of "hardening" glass is slower, taking many hours. The finished lenses are placed on a hot molten salt bath of KNO_3 at 660°F to 920°F. The large monovalent ions of potassium are exchanged for the smaller monovalent ions of sodium. This exchange of larger for smaller ions causes an increased surface compression similar to but better controlled than the heat process (15).

FUTURE CONSIDERATIONS

The aviator spectacle HGU/4-P remains unchanged after nearly two decades of satisfactory service. However, changes in the mission, availability of materials, and new technological developments herald possible future changes in both the frame and lenses. The marked increased cost of gold will necessitate an evaluation of other materials that might possibly be used for the frame, such as rhodium, steel, aluminum, plastic, etc. The plastic polycarbonate (Lexan) should be examined for lens use. This material was used for the APOLLO space helmet and visors, and is presently used by the US Air Force in aircraft windscreens (16). It is several orders of magnitude more resistant to breakage and penetration than any lens material presently available. Its largest disadvantage is poor scratch-resistance and the present nonavailability of prescription lenses. The new photochromic (light valve) lenses, when further improved, may allow a single lens to serve as both clear lens and sunglass. The present photochromic lenses (Sunsensor) do not satisfy those criteria as yet, being either too dark in the clear state or not dark enough in their darkest state. (See Figure 6.) A special trifocal design, exclusively for the aviator, is in its final testing stage at the USAF School of Aerospace Medicine. Finally, not mentioned to this point but obviously of significance, is that further advancements in contact lens fitting, materials, and technology could reduce markedly the future need for aviator spectacles of any kind.

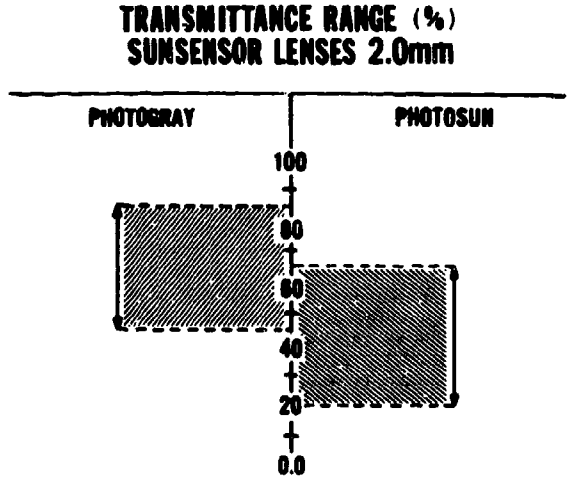

Figure 6. Range of Transmission of Photochromic Lenses

REFERENCES

1. Department of the Air Force, Headquarters USAF, Medical Examination and Medical Standards, April 1971, Air Force Manual 160-1.

2. Wilmer, W. H., and C. Berens, Jr. Aviation Medicine in the AEF, Chapter VI, Department of Ophthalmology, Washington DC, Government Printing Office, 1920, pp. 167-193.

3. Duke-Elder, Sir Stewart. Injuries, Vol. XIV, Part 2, Nonmechanical Injuries, London, Henry Kimpton, 1972, p. 844.

4. Pitts, Donald G. et al. USAF School of Aerospace Medicine, Brooks AFB, Texas, The Effects of Ultraviolet Radiation on the Eye, February 1969, SAM-TR 69-10, p. 5

5. Byrnes, Victor A. Ophthalmic Filters, 1956, Course No. 11, American Academy of Ophthalmology and Otolaryngology, p. 2.

6. Hirsch, J. A. Wright Air Development Center, USAF, Wright-Patterson AFB, Ohio, Development of an Improved Air Force Sunglass, August 1958, WADC Technical Report 58-278.

7. Kay, M. E. Headquarters, Air Material Command, Wright-Patterson AFB, Ohio, Factors to be Considered in the Selection of Rose Smoke or Neutral Glass to be Used in the USAF Standard Flying Sun Glasses, 9 August 1950, Memorandum Report on MCREXD-690-1D.

8. Rose, H. W., and E. Schmidt. USAF School of Aviation Medicine, Randolph Field, Texas, Physiological Effects of Reflective, Colored, and Polarizing Ophthalmic Filters, September 1949, Project No. 21-02-040, Report No. 2.

9. Rose, H. W., and G. M. Stewart. Eye Protection Against Small High Speed Missiles, Trans. Amer. Acad. Ophthalmol. & Otolaryngol., May-June 1957, p. 408.

10. Federal Register, Rules and Regulations, May 15, 1971, Vol. 36, No. 95, pp. 8939-8941.

11. Targove, B. D., et al. Glass Versus Plastic Lenses - An Air Force Replacement and Durability Study, American J. Optom. & Arch. American Acad. Optom., Vol. 49, No. 4, April 1972, p. 326.

12. Kislin, Benjamin, et al. USAF School of Aerospace Medicine, Brooks AFB, Texas, Warpage of CR-39 Plastic Lenses, July 1972, SAM-TR 72-4.

13. Welsh, K. W., et al. Ballistic Testing of Scratched and Unscratched Ophthalmic Lenses, Amer. J. Optom. & Physiol. Optics, Vol. 51, No. 5, May 1974.

14. Sunglasses HGU-4/P (With Case). Military Specification MIL-S-25948F, 14 December 1972, Department of Defense, Washington D.C., Government Printing Office.

15. Renaldo, D. P., A. H. Keeney, D. H. Lyle, Jr. Ion Exchange Tempering of Glass Ophthalmic Lenses, Amer. J. Ophthal., Vol. 80, No. 2, August 1975, p. 294.

16. Provines, W. F., and B. Kislin. Visual Performance through a Sample Windshield Segment of the B-1 Aircraft. Amer. J. Optom. & Physiol. Optics, Vol. 52, January 1975, p. 52.

DISCUSSION

FORGIE: You mentioned the problem with warping of the plastic lenses. You also mentioned that it did not cause any alteration of the power but it caused some spatial distortion problems. Could you amplify that and tell us how significant this was from a practical point of view?

TREDICI: Perhaps not too significant. I must agree it did cause some distortion due to magnification effect. We do have a paper (authored by Col Kislin) that did show there is the possibility of extreme variations if you went from the maximum on one end to the minimum on the opposite axis and added is the variability that was possible between the two lenses. One of the problems being that when the lenses are placed in the frames there is nothing to tell you how much you should tighten the frame. You can keep tightening it until you can have all kinds of distortion. The plastic frames were a little better, and things are improving in the newer generations of CR-39 plastics. We will probably alter our regulation on supplying glass lenses only, in the very near future.

BRENNAN: A comment and a question. Perhaps the reason for the popularity of those sunglasses--if your Air Force is anything like ours--is the fact that they are free! Do you find that a luminous transmittance of 10 to 15% is sufficient in the high light levels which you quote are existent in Texas. I say this because I once read that submarine commanders in the last war working at very high light levels preferred luminance transmittances down to as low as 3%.

TREDICI: It is, I think, a good compromise that we are not willing to change right at this time, but, I think 5 or 6% would be better up at high altitudes; 15% is not too bad around Texas but I agree with you.

GLICK: More of a comment. You were mentioning going to N-31 or 31% transmission to eliminate the bull's eye and "mexican hat" effect. Don't you mean though that this is a uniform coating of that percentage rather than a through-and-through tint?

TREDICI: No, it is a through-and-through tint. We have had coatings of 15% before and their life is so short that we have given up on these coatings. We had a coating on glass and a dipping of the plastic to get it down to whatever transmission we wanted although that was kind of hit and miss. We have given up on the glass coating. We just went to the 31%; it just alters the overall percentage and we can accept that.

GLICK: But the effect is still there?

TREDICI: Yes, but less evident.

A PROPOS DU VOL ET DE LA CORRECTION DES PRESBYTES.

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1 - INTRODUCTION

Même s'ils ne sont plus affectés dans des unités opérationnelles, les membres du Personnel Navigant âgés de plus de 40 ans continuent à piloter. Ils se trouvent alors confrontés dans l'avion à un problème de vision différent de celui qui est le leur au sol, dans leur bureau.

Pour recueillir les informations nécessaires au pilotage, fournies essentiellement par la fonction visuelle, le pilote doit réaliser un certain nombre de taches. Ces taches exigent :

- une bonne vision à distance pour l'observation de la piste ou de l'espace aérien,
- une bonne vision intermédiaire pour la lecture des instruments du tableau de bord et des instruments situés au-dessus de la tête du pilote,
- une bonne vision de près pour la lecture des plans de vol, des cartes de navigation, des procèdures etc ...

Les distances pour les visions intermédiaires et de près varient d'ailleurs selon le type d'appareil, selon la morphologie des pilotes et selon leurs habitudes.

Une enquête a été menée il y a quelques années auprès des navigants civils expertisés dans notre Centre, et âgés de plus de 40 ans. Elle nous avait montré que 22 % d'entre eux portaient en vol une correction optique entre 40 et 45 ans. Ce pourcentage s'élevait à 56,5 % chez les sujets âgés de 46 à 50 ans et à 92 % au-delà de 51 ans.

Cette enquête nous avait montré également que les lunettes étaient portées plus précocement en vol de nuit.

Enfin, nous avions pu remarquer qu'aucun système de correction utilisé par ces navigants ne leur donnait entière satisfaction ; ceci s'expliquait, au moins partiellement, par le fait que la prescription n'avait pas été étudiée pour le travail aérien. Les lunettes servaient aussi bien au sol qu'en vol.

Nous ne pouvons rapporter les résultats d'une enquête identique chez les navigants militaires. Les résultats ne seraient d'ailleurs pas concordants, puisque la plupart des appareils militaires sont différents et que les critères de sélection des pilotes le sont également. Pour les pilotes militaires, il est tenu compte, non seulement de l'acuité sans correction, mais également de la valeur de la réfraction après cycloplégie (afin d'éliminer toutes les myopies latentes et les hypermétropies supérieures à 2 dioptries).

2 - LE PROBLEME DE L'ACCOMMODATION

2.1 - Dans des conditions normales, en fonction de son âge, un sujet peut faire varier sa distance focale, de façon que les objets éloignés comme les objets rapprochés puissent être vus nettement.

L'ensemble des phénomènes, qui permettent à l'oeil de produire une image nette, constitue le phénomène de l'accommodation, dont le mécanisme est essentiellement cristallinien. Il est caractérisé par une modification des rayons de courbure antérieur et postérieur du cristallin et aussi par un léger déplacement en avant de la lentille, chez le sujet debout. Il s'ajoute également un phénomène intracristallinien, lié à une modification de l'indice de réfraction, sans doute par tassement des fibres à la partie centrale.

Ce phénomène d'accommodation, dont le mécanisme est d'origine corticale, dépend de la mise en jeu du muscle ciliaire. Il est accompagné de deux autres phénomènes qui se révèlent indépendants ; la convergence et la contraction pupillaire avec décentrement en dehors. Ces deux derniers phénomènes sont, par contre, liés l'un à l'autre.

2.2. - L'accommodation comporte des limites, entre lesquelles elle s'effectue. C'est tout d'abord le punctum remotum (P.R) qui représente le point où doit se trouver un objet éloigné pour que son image se forme nette sur la rétine, sans que l'oeil accommode. Pour un oeil emmétrope, ce point est situé au delà de 6 mètres. Le point le plus proche vu encore distinctement par mise en jeu de l'accommodation est le puntum proximum (P.P). En avant de lui, l'image ne peut plus se former nettement sur la rétine.

La distance entre PP et PR est le parcours d'accommodation ($a = r - p$), tandis que la différence entre l'oeil accommodé P et l'oeil au repos R représente l'amplitude d'accommodation ($A = P - R$).

Chez l'emmétrope jeune $A = P = 14$ dioptries, tandis que chez l'hypermétrope $A = P + R$ et chez le myope $A = P - R$.

2.3. - L'accommodation subit des variations physiologiques et pathologiques. L'âge est le facteur principal entraînant une diminution. La fatigue générale, tout comme la fatigue visuelle, intervient de la même façon : on remarque, en effet, à partir de la 15ème minute d'un travail de près, un recul du PP, ce qui représente un bon test de fatigue. De même les hétérophories, les amplitudes de fusion médiocres perturbent l'accommodation. Les anomalies de réfraction, non corrigées,

agissent dans le même sens.

Certaines thérapeutiques locales ou générales modifient l'accommodation : collyres à la néosynéphrine par exemple ou médicaments utilisés dans le traitement des affections digestives.

Enfin, les conditions aéronautiques elles-mêmes peuvent intervenir, telles l'anoxie, les accélérations et le stress.

Pour que l'acte accommodatif s'effectue confortablement pendant une longue période, on admet que le sujet ne doit utiliser que les 2/3 ou la 1/2 de son pouvoir d'accommodation. On peut ainsi définir une accommodation maximale et une accommodation efficace.

3 - LA PRESBYTIE

On dit qu'un sujet est presbyte lorsque ayant une vision de loin normale, corrigée ou non, il éprouve des difficultés à avoir une vision précise et soutenue à une distance de 33 centimètres.

En réalité, cette définition est très empirique, car la sclérose cristallinienne est très progressive et on ne peut que préciser une zone de rupture d'équilibre.

L'âge de début est variable chez le sujet emmétrope ; il se situe habituellement vers 45 ans. Certains facteurs déclenchent ou accentuent souvent ce phénomène : une fatigue importante, un accident, un choc psychologique, une intervention chirurgicale sous anesthésie générale.

Chez le sujet hypermétrope non corrigé, la presbytie apparaît plus tôt, d'autant plus que l'hypermétropie est plus importante.

Chez le myope, la presbytie est identique, mais la lecture de près demeurant possible, elle pourrait passer inaperçue chez un sujet non corrigé.

4 - MESURE DE L'ACCOMMODATION

Nous utilisons deux méthodes : la première clinique, simple mais imprécise, la seconde plus fidèle mettant en jeu le proximètre.

4.1 - En faisant lire l'échelle d'acuité de PARINAUD, on recherche le point rapproché à partir duquel la lecture devient impossible.

4.2.- Le Proximètre, réalisé par les services techniques du Centre d'Etudes et de Recherches de Médecine Aéronautique en 1958 (PERDRIEL, COLIN et BRICE), est utilisé pour mesurer le punctum proximum de convergence et le punctum proximum d'accommodation. Cet appareil est composé essentiellement :

- d'un appui menton/front permettant d'amener les yeux dans le plan du test,
- d'un dispositif optique simple qui permet de repérer le sommet des cornées et de placer le zéro de la règle graduée servant à la mesure sur un plan normal au centre de la cornée,
- d'un anneau de Landolt noir sur fond blanc, mobile et orientable.

La distance, mesurée en centimètres, à laquelle le sujet peut encore situer correctement l'orientation de la brisure de l'anneau, représente le punctum proximum d'accommodation.

5 - CORRECTION DE LA PRESBYTIE

5.1 - On pourrait, en fonction de l'âge et de la valeur de l'accommodation, prescrire une correction, mais il faut également tenir compte de la distance de travail et des conditions dans lequel il s'effectue pour proposer une correction valable.

Ainsi, si un pilote doit focaliser à 75 centimètres, dans l'hypothèse assez rare où il est emmétrope, l'accommodation nécessaire sera donc égale à :

$$\frac{1}{0,75} = 1,33 \text{ dioptries.}$$

S'il est hypermétrope de 0,50 dioptrie, ce qui est par contre très fréquent, l'accommodation nécessaire sera de 1,33 + 0,5 = 1,83 dioptries. En vol de nuit, où la valeur de l'hypermétropie augmente d'environ 0,60 dioptries en éclairage rouge d'après PADZIKHOSKI, l'accommodation nécessaire sera donc de l'ordre de 2,5 dioptries. En supposant que notre pilote, choisi pour exemple, ne puisse utiliser que les 2/3 de son accommodation pendant une longue période, il faudrait qu'il dispose de près de 4 dioptries pour être certain qu'aucun facteur environnant ne l'empêchera d'accomplir les taches visuelles qui lui incombent. Si l'on retient, comme certains auteurs, l'utilisation de la moitié de l'accommodation, il lui faudrait alors 5 dioptries.

Les courbes établies d'après DUANE situent ces valeurs entre 42 et 44 ans.

5.2.- Les solutions utilisées pour corriger les presbytes sont nombreuses et tiennent compte du type d'appareil, de la valeur de la vision de loin et de l'âge.

Lorsque le parcours d'accommodation se révèle être inférieur à quatre dioptries, la première correction sera le plus souvent prescrite.

Elle se fera en tenant compte de l'hypermétropie préexistante. Si l'acuité visuelle de loin est normale, il suffira, très souvent, de la corriger pour améliorer d'une façon permanente la vision intermédiaire et la vision de près.

Certains sujets préfèrent ne pas modifier leurs habitudes et se contentent d'une demi-lunette à monture étroite qui leur permet l'addition qui soulage leur accommodation.

D'autres sujets préfèrent avoir recours à un monocle, utilisé seulement et à la demande

pour la vision de près.

Si l'acuité visuelle de loin est diminuée et si la puissance d'accommodation est supérieure à 2 dioptries, il faut envisager l'usage de verres bifocaux. La vision de loin et la vision intermédiaire se fera avec le foyer supérieur, tandis qu'un petit foyer inférieur permettra la lecture de près.

Lorsque le parcours d'accommodation devient inférieur à deux dioptries, la vision intermédiaire deviendra impossible et il faudra envisager un verre trifocal. Pour réaliser celui-ci, il est souhaitable de placer la correction pour la vision intermédiaire en haut du verre et la correction pour la vision de près le plus bas possible et n'occupant qu'une petite surface. La surface intermédiaire la plus grande possible servira à la vision de loin.

Pour tous ces types de lunettes, il faut insister sur un parfait réglage. En effet, une mauvaise inclinaison des verres comme un mauvais centrage peuvent entraîner des effets prismatiques importants. Il faut également veiller à la distance entre sommet de la cornée et face postérieure du verre, toute augmentation de cette distance augmentant la puissance effective.

Nous avons maintenant à notre disposition des verres à foyer progressif qui semblent devoir remplacer les verres multifocaux lorsque le pilote n'a pas besoin d'une correction intermédiaire pour lire les cadrans placés au-dessus de lui. Les premiers verres progressifs mis à notre disposition avaient été abandonnés. La vision au centre du verre était, en effet, satisfaisante mais, latéralement, s'accompagnait d'aberrations à l'origine d'images floues. Il était donc impossible d'atterrir avec ce type de correction. En vol, pour éliminer les images floues, le pilote était obligé d'effectuer des mouvements de rotation de la tête qui pouvaient créer des illusions sensorielles du type des phénomènes de balancement et de roulis.

Actuellement, les verres progressifs présentent une valeur optique pratiquement équivalente dans tous les secteurs du verre, ce qui permet de les prescrire avec profit. Il demeure nécessaire de veiller à la bonne réalisation de ces lunettes, qui doit être confiée à un opticien compétent et entraîné au montage de ces verres.

L'utilisation de deux paires de lunettes demeure exclue ; pour des pilotes qui ne sauraient s'habituer aux verres progressifs, nous prescrivons parfois des "lunettes à monture basculante". Il s'agit d'une lunette normale avec des verres bifocaux, sur laquelle est articulée une monture additionnelle dans laquelle on peut placer des verres bi ou trifocaux. Il est donc possible de jouer avec les puissances en les additionnant ou en les soustrayant, ce qui permet de faire face à toutes les conditions de vision imposées par le pilotage. La manoeuvre peut s'effectuer si rapidement qu'elle ne gêne pas le travail aérien. On prescrit le plus souvent dans la monture fixe la correction de loin placée dans un petit segment de la partie supérieure du verre, la partie médiane et inférieure étant utilisées pour la correction de la vision intermédiaire. La monture mobile porte une correction qui permet lorsqu'elle est en service de lire les instruments avec la partie supérieure du verre et les textes imprimés ou les cartes avec la partie inférieure.

Les pilotes d'avions de transport, pour lesquels nous avons fait une telle prescription, en sont satisfaits.

6 - CONCLUSIONS

Pour obtenir de bons résultats dans la correction des pilotes devenus presbytes, il est bien sûr nécessaire de mesurer lors des visites révisionnelles la réserve d'accommodation. On se heurte le plus souvent à des réticences et on peut se demander si les lunettes sont réellement portées. L'utilisation assez fréquente du monocle qui se révèle discret, mais assez peu efficace, paraît un excellent exemple.

Il faut aussi admettre qu'aucune des solutions optiques proposées n'est réellement satisfaisante.

Il faut enfin insister sur la nécessité de faire réaliser pour le vol des lunettes qui seraient différentes de celles utilisées au sol, puisqu'elles doivent prendre en considération un certain nombre de paramètres particuliers.

BIBLIOGRAPHIE

I - ARTICLES :

1 - CHEVALERAUD (J.P.), BOUVERY (P)
A propos de la vision de près et de la vision intermédiaire chez les navigants civils
S F P M A C - 19 juin 1970 -

2 - CHEVALERAUD (J.P.), PERDRIEL (J)
La mesure de l'accommodation par le proximètre
Soc. Fr. Optique Physiologique, déc. 1968

3 - DREYER (V)
Problèmes visuels chez le personnel navigant âgé.
Congrès de Médecine Aéronautique - Nice Sept. 1972
Revue de Médecine Aéronautique et Spatiale n) 45/1973

4 - MANENT (P.J.)
Contribution à l'étude de la fatigue oculaire et accommodative de l'opérateur de détection électro-magnétique.
Thèse Paris 1958

5 - PERDRIEL (G), HEYNEMANN (L.D.), CHEVALERAUD (J.P.)
Fatigue accommodative et éclairage des tableaux de bord des aéronefs.
Soc. Fr. Optique Physiologique, déc. 1968.

II - OUVRAGES GENERAUX :

1 - Optique Médicale Pratique
SARAUX, ROUSSELIE, COSCAS
Edition DOIN, 1968.

2 - Manuel de Médecine Aéronautique Civile
O A C I - 1974 -

DISCUSSION

GLICK: Does the variable focus lens also go by the name of Varilux as did the original lens?

CHEVALERAUD: Yes, this lens is identified now as the Varilux II.

BRENNAN: Do you find you have to take into account aviators who are flying with red cockpit lighting and require an extra accommodative effort?

CHEVALERAUD: Yes, since we are aware of the additional plus lens necessary to correct the presbyopia under red lighting. This extra amount is tested for and given in the correction.

TREDICI: Do you still use red cockpit lighting?

CHEVALERAUD: We use it in combat aircraft.

KUCHNER: How compatible is the spectacle with the head gear and with the protective helmet?

CHEVALERAUD: There is no significant problem as to why the spectacle frames cannot be worn under the visor. The glasses are compatible with and can be worn with the helmet.

APTITUDE AU VOL ET LENTILLES DE CONTACT SOUPLES.

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" Il est évident que la fabrication d'une armure de chevalier du Moyen Age est bien différente de la confection d'un costume de Tergal ... ".

C'est en utilisant ces termes que WICHTERLE comparait les lentilles classiques avec les lentilles souples hydrophiles, lors d'une conférence à ROYAUMONT (France), en avril 1964.

1 - LES LENTILLES RIGIDES ("hard")

En 1947, voici donc près de 30 ans, dans leur remarquable rapport à la Société d'Ophtalmologie de Paris, MERCIER et DUGUET avaient rappelé les avantages et les inconvénients des verres de contact en aéronautique. Il s'agissait alors de verres à appui scléral. Ils concluaient à la compatibilité probable de ces prothèses avec le vol en altitude, à la possibilité de les admettre dans les mêmes conditions que les verres de lunettes classiques, sous réserve d'un contrôle éventuel au caisson à dépression et d'une tolérance parfaite pendant au moins dix heures.

Malgré cet espoir,en France du moins, les membres du personnel navigant militaire, porteurs de lentilles de contact, sont très peu nombreux. Encore s'agit il toujours de sujets possédant une expérience aéronautique, victimes d'accidents ayant entraîné, dans presque tous les cas, une aphaquie unilatérale.

En effet, malgré les cas favorables enregistrés pendant la dernière guerre mondiale avec ce type de prothèse, on a su très rapidement que 50 % à peine des pilotes équipés supportaient ces prothèses (CROSS, 1949 - NEELY, 1953).

Les lentilles précornéennes rigides ("hard contact lenses"),plus légères et n'entravant pas la circulation limbique, ont fait naître un nouvel espoir.

Cependant, de nombreux auteurs,en expérimentant au caisson à dépression, ont mis en évidence la libération de nombreuses petites bulles gazeuses ayant tendance à se grouper au centre de la cornée, à partir de 3500 mètres. En France, l'un d'entre nous, (Perdriel, 1958), a confirmé ce phénomène décrit précédemment avec des verres à appui scléral par DUGUET et DUMONT. Cette manifestation a également été décrite par d'autres auteurs, en particulier par Mac CULLOCH (1962), BERTENYI (1962), LEHWESS et LITZMAN (1964).

Les bulles de gaz qui apparaissent, et qui se révèlent être de l'azote, agissent de différentes façons :

- métaboliques en gênant la respiration cornéenne, ce qui entraîne un oedème, générateur d'une baisse de l'acuité et d'une augmentation de la sensibilité à l'éblouissement (MILLER, WOLF, GEER et VASSALLO),

- mécaniques; en se groupant au centre de la cornée, les bulles créent une sensation de brouillard diminuant l'acuité. Elles creusent en plus de petites fossettes juxtaposées, dans l'épithélium cornéen. Lors du retour vers le sol, les bulles disparaissent ou, au contraire, persistent.

Une instillation de fluoresceine permet de visualiser les petites fossettes constatées en altitude. Ces lésions retiennent le colorant vital, affirmant l'altération de l'épithélium cornéen. Le parenchyme, par contre, demeure le plus souvent normal. Après cicatrisation sans séquelle, l'acuité redevient normale.

Le risque de complication paraît avoir été l'argument le plus important pour refuser le port des lentilles cornéennes.

Le deuxième argument était le risque de voir un corps étranger se glisser entre la cornée et la lentille pouvant créer une intolérance immédiate ou, au contraire, une lésion importante cicatrisant avec des séquelles.

Le troisième argument était que,lors des accélérations, il existait, du fait du poids des lentilles, un risque non négligeable de les voir glisser en dehors de l'axe visuel.

L'épreuve au caisson à dépression est obligatoire avant une décision de dérogation. Si elle est favorable, le port de lentille peut être autorisé le sujet abandonnant le pilotage d'avions de combat pour celui des avions de liaison ou de transport.

2 - LES LENTILLES SOUPLES HYDROPHILES ("Soft Lenses")

1 - La mise au point en Tchécoslovaquie par WICHTERLE et SIM de lentilles de contact hydrophiles a suscité, en 1960, des espoirs nouveaux et un évènement marquant dans l'évolution de la lentille de contact.

2 - Les lentilles souples sont constituées de gels hydrophiles qui sont presque tous des polymères ou des copolymères de l'Héma (2 Hydroxy-Ethyl-Methamylate).

Les trois propriétés essentielles de ces lentilles sont les suivantes :

- l'hydrophilie : elle dépend du degré de réticulation du matériau. La teneur en eau varie de 40 % à 70 % (pourcentage du poids de l'eau dans la lentille saturée) ;

- la souplesse : elle permet le confort, une adaptation rapide et la possibilité de n'utiliser les lentilles que pendant quelques heures chaque jour, si on le désire ;

- la perméabilité : plus la quantité d'eau absorbée par l'hydrogel est grande, plus sa perméabilité à l'eau, aux molécules solubles dans l'eau et aux ions est importante. Ceci permet d'envisager une meilleure physiologie cornéenne.

On utilise actuellement des lentilles contenant 40 % d'eau.

3 - Les lentilles souples semi sclérales, dont le diamètre est compris entre 13 et 16 mm, sont actuellement les plus utilisées et paraissent convenir à la plupart des cas.

Les lentilles souples cornéennes, dont le diamètre correspond à celui de la cornée, c'est à dire entre 10 et 12 mm, sont d'utilisation plus limitée.

Enfin, les lentilles souples hydrophiles toriques, d'apparition récente, ne peuvent être utilisées que pour corriger une myopie supérieure à 3 dioptries, associée à un astigmatisme compris entre 1 et 4 dioptries. Elles sont actuellement peu utilisées, mais on pense qu'elles pourraient, dans l'avenir, servir à la correction des aphaques.

L'apparition de ces lentilles, beaucoup mieux supportées que les précédentes, a fait envisager leur utilisation en aéronautique.

3 - EXPERIMENTATION

1/ Protocole : Nous avons voulu étudier le comportement de ce type de lentilles au caisson à dépression.

Nous n'avons pu tester que quatre sujets jeunes, non navigants, portant des lentilles à 40 % d'hydrophilie. Dans deux cas, il s'agissait de lentilles semi sclérales, dans les deux autres cas de lentilles cornéennes.

Les sujets de notre expérience étaient équipés depuis plusieurs semaines. L'adaptation avait été précédée d'un examen ophtalmologique comprenant en particulier l'étude de la sensibilité cornéenne avec l'esthésiomètre de COCHET et BONNET, l'étude du tonus oculaire avec le tonomètre à aplanation de Goldmann, l'étude de la perméabilité des voies lacrymales, la mesure de la sécrétion lacrymale avec le test de SCHIRMER et, enfin, l'étude de la vision binoculaire.

La mesure de la sécrétion lacrymale avait été particulièrement précise car l'hypo-sécrétion nous paraît être la première contre-indication à l'équipement en lentilles souples hydrophiles. Quelques hôtesses de l'air, qui utilisent leur lentille à bord d'avions commerciaux, souffrent souvent d'irritation conjonctivale chronique liée à la sècheresse de l'atmosphère. Pour éviter la chute des lentilles qui se produit parfois, elles doivent instiller, à intervalle régulier, lors des vols de longue durée, des larmes artificielles (BOISSIN).

Le protocole d'examen a été le suivant : montée à 3500 ou 4000 mètres avec une vitesse ascensionnelle de 10 mètres/seconde, sans inhalateur. L'altitude étant atteinte, on observait un palier de 15 minutes, puis la descente s'effectuait avec une vitesse de 10 mètres/seconde. Un examen biomicroscopique était pratiqué dans le caisson avant la mise en route des pompes, puis tous les 1000 mètres pendant l'ascension et la descente. Au cours du palier, les cornées étaient examinées toutes les cinq minutes.

Dans les cinq minutes suivant le retour au sol, l'acuité visuelle était mesurée, puis les lentilles étaient retirées. Une mesure de la sécrétion lacrymale et un lavage au sérum après instillation de fluorescéine étaient pratiqués.

2/ Résultats :

- Les sujets équipés ne se sont jamais plaint de sensations désagréables lors de ce vol simulé.

- Aucun dégagement gazeux n'a été constaté.

- Après le retour au sol, l'acuité était la même que celle mesurée avant l'entrée dans le caisson.

- La sécrétion lacrymale demeurait inchangée, la longueur du papier humidifié dans le test de SCHIRMER étant identique.

- Enfin, la cornée ne retenait pas le colorant, ce qui prouvait l'intégrité de l'épithélium cornéen.

4-CONCLUSIONS

Les conclusions de notre expérimentation rejoignent exactement celles de POLISHUK et RAZ, qui précisent de plus la stabilité des lentilles pour des accélérations de 6 G, et également celles de CROSLEY et Coll.

Nous pensons donc que nous devons nous orienter vers des lentilles de ce type chaque fois qu'il s'avère nécessaire d'envisager une correction par contact. Ces cas doivent demeurer exceptionnels et se limiter à des sujets expérimentés et victimes d'accidents.

Dans l'aviation militaire française, il ne paraît pas souhaitable d'envisager

la multiplication de ces prothèses. Les normes d'aptitude actuellement en vigueur excluent d'ailleurs les sujets amétropes qui devraient avoir recours à des verres correcteurs. Le port de lentilles ne se justifie donc pas.

BIBLIOGRAPHIE

I - BARBARA (G) - Progrès en lentilles souples hydrophiles.
4ème Congrès Français d'Optique de Contact - PARIS Nov. 1974.

2 - BERTENYI (A) - Le comportement des verres de contact et des verres cornéens aux grandes altitudes - Szemeszet, 99, 2, juin 1962, P 121 - 122.

3 - CROSLEY (J.K.), BRAUN (E.G.), BAILEY (R.W.) -
Soft (hydrophilic) contact lenses in U.S. army aviation. An investigation study of the Baush and Lomb Soflens.
U.S. Army Aeromedical Research Laboratory (Fort Rucker, Alabama).

4 - MAC CULLOCH (C) -
The acceptance of contact lenses in military personnel - Visual Problems in aviation Medecine (AGARD), Pergamon Press (Oxford), 1962, 26-33.

5 - GIORDAN (P), NOGER (A) -
Au sujet des verres de contact
Rev. Med. aeron., 1951, vol 6, 47-72.

6 - KREIS-GOSSELIN (F) -
La prescription et l'adaptation des lentilles souples dansles cas optiques en ophtalmologie
Con. d'opt. medicale n° 27, 1975 - 2.

7 - LEHWESS, LITZMANN -
Wearing of contact lenses by airplane pilots.
Aviation Medicine Translations, Janv. 66, AM 66-2, Cote 47 R, p. 5 - 6.

8 - MERCIER (A) - DUGUET (J). -
Physiopathologie oculaire de l'aviation.
Rap. Soc. Oph. Paris, nov. 1947.

9 - PERDRIEL (G) -
Tolérance des lentilles précornéennes en altitude
Soc. Med. Mil. française - mars 1958 -

10 - POLISHUK (A), RAZ (D) -
Soft hydrophilic contact lenses in civil and military aviation.
Aviation, Space and Environmental Medicine, Sept 1975, Vol 46 n° 9, 1188 - 1190

11 - POULIQUEN (Y), BONNET-BOUTIER (M), KREISS-GOSSELIN (F) ROGER (J) -
Lentilles de contact souples.
Rapport de la Soc. opht. de Paris - 1974.

DISCUSSION

DREYER: I work very much with contact lenses; this is another activity of our clinic. I cannot share with Dr Chevaleraud his optimism on the soft lenses because the main complaint of persons fitted with soft lenses is the very high degree of shifting of the visual acuity. This has been the complaint of my patients, who are not aviators, so that I am not sure that all aviators can pass the visual requirements. Another thing with the soft lenses is that they need a very high degree of care. I should like to hear Dr Chevaleraud's comments on that.

CHEVALERAUD: In my experience with studies done in the altitude chamber there has been no decrease in the visual acuity while wearing the soft contact lenses. Dr Dreyer, are you referring to soft lenses, hydrophilic soft lenses, that contain 40% water, or to certain others that I am acquainted with that have 60 or even 70% water? My experience with those containing only 40% water has been that we have not found any changes.

TREDICI: I see you have 36% humidity in the chamber and in the airplane. Many times in Texas we do not have that much humidity at ground level so we are already starting with well below this level. In our planes the humidity is less than half of that once they are at altitude. It may not be possible to produce enough tears and the visual acuity in a few subjects has been observed to drop several lines. And secondly, unfortunately for us, in the states we can only clean these lenses by again FDA-approved methods, which necessitate hauling a large amount of paraphernalia around--baby bottle warners, salt solutions, etc. Right now we can only boil them, we cannot use any kind of chemicals and so with all of these drawbacks we are not using them for aviators as yet. The only question I have is about the humidity. I felt the humidity was less than 36% at altitude, less than the experimental conditions of the chamber, which would then accentuate the problem of lens drying and changes in acuity.

CHEVALERAUD: I agree with you except that the basic conditions of humidity are as they are and cannot be altered

VISION WITH THE AN/PVS-5 NIGHT VISION GOGGLE

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This paper presents the results from a series of experiments in which visual performance using the AN/PVS-5 night vision goggle was measured. Visual modulation transfer functions of the man-goggle system were determined and compared to results obtained with unaided viewing. It was found that the man-goggle system performance was superior to unaided visual performance at average target luminances equivalent to 5% and 25% moon illuminances. At a target luminance equivalent to a full moon illuminance, unaided visual performance was superior at higher spatial frequencies, while remaining poorer at the lower spatial frequencies. Using a modified Howard-Dolman apparatus, it was determined that the stereoscopic threshold was degraded with the man-goggle system. Field measurements of relative depth discrimination using all available visual cues showed that performance of the man-goggle system was statistically equivalent to unaided photopic visual performance at intermediate viewing distances, but was inferior to unaided viewing at distances of 500 feet or greater. While use of the night vision goggle reduces the ambient light level necessary for military rotary wing support, use of the goggle does not allow the operator to perform with photopic visual efficiency.

INTRODUCTION

Recent military experiences and modern tactical considerations have dictated the requirement for placing emphasis on sustained operations with future military deployment. Such sustained operations imply continuous activity by military units during periods of darkness as well as daylight. The requirement for operating during periods of reduced illumination will place new perceptual demands and physiological stress upon the individual soldier. Since vision is the principal sensory modality with which man gathers information from the external world about him in order to function effectively, major military operations historically have been conducted during periods of good illumination.

The eye and related neural structures comprise an extremely effective information processing system. The visual system has a total dynamic range in response to light stimulation much greater than any other known photodetection system. In order to achieve this large dynamic range, several physiological adaptations and compromises have been accomplished. The duplicity arrangement of the retina represents one of the most effective adaptations. At moderate to high light levels, the cone or photopic system is operational and processes visual information with remarkable resolution along several dimensions (color, spatial, temporal). At lower light levels, down to the order of several photons, the rod or scotopic system is operational. In order to be capable of functioning at low light levels, some severe visual compromises have been made. For example, the scotopic system integrates light over relatively large retinal areas so spatial resolution is considerably reduced. No color information is processed, and temporal processing is reduced. The limited information provided by the scotopic visual system restricts the capability of the soldier to effectively perform his military duty.

In recognition of the requirement for sustained military operations, two avenues have been pursued to reduce the impact of the basic limitations of the scotopic visual system on military operations during periods of darkness. The first approach has been to increase the amount of time devoted to operational training at night. It is felt that this will reduce the stress and increase the perceptual proficiency of individuals during night military operations. However, the anatomy and physiology of the human visual system are relatively immutable and certain tasks, such as nap-of-the-earth (NOE) rotary wing flight, require more visual information than the scotopic system can provide. To fulfill this need for low light level visual information, major technological advances in light amplification and infra-red systems have been developed in recent years.

The AN/PVS-5 Night Vision Goggle (NVG), developed by the U.S. Army Night Vision Laboratory, is considered an effective interim solution to allow U.S. Army aviators to conduct rotary wing operations at night. While the NVG performs admirably in light amplification, use of the NVG has presented new problems and questions for those of us concerned with the human in this man-machine loop. For the past several years, personnel at the U.S. Army Aeromedical Research Laboratory have been conducting experiments designed to determine the present and potential impact of the NVG on aviators during rotary wing flight. A previous AGARD Conference report[1] reviewed studies conducted by other laboratories on the NVG, and these will not be further detailed here. However, several reports have more immediate pertinence to the present conference and should be discussed briefly.

As with any new device, there has been some concern about possible damage to the eyes while using the NVG. Several military agencies reported that their personnel were complaining of a so-called "brown eye syndrome" after using the NVG. This problem was investigated and found to be simply a color afterimage which should be expected after viewing the narrowband output of the P20 phosphor used in the goggle[2]. In addition, the persistence of the afterimage lasted only a brief period of time. However, the P20 phosphor output has caused another problem of some significance. This is the loss of color information while using the NVG. Because of the reduced resolution and narrowband output of the goggle, standard navigation maps cannot be used. Recently, the U.S. Defense Mapping Agency has developed an experimental map consisting of a reversed contrast display. It has been determined that adequate information can be obtained from these black background maps using either the goggle or with the naked eye and aviation red illumination[3].

The NVG is powered by a 2.7 volts wafer battery. Since goggle failure occurs due to low battery output without prior warning, it is of some importance to know the state of adaptation of the eye upon removal of the NVG. With normal viewing conditions, luminance output of the goggle display is between 0.7 foot lambert and 1.5 foot lamberts. It was found[4] after allowing subjects to fully dark adapt followed by a 5-minute period of viewing with the goggle that visual sensitivity had degraded to that level normally found at approximately 10 minutes into the course of dark adaptation. However, the average recovery time (i.e. time to return to 30 minute level of sensitity) was 2 minutes.

This report presents results from experiments designed to determine the effects of the goggle on a user's ability to make relative depth discriminations under both field and laboratory conditions. Data are also presented on the visual modulation tranfer function of the man-goggle system.

METHODS and RESULTS

(1) Laboratory Measures of Relative Depth Discrimination

A modified Howard-Dolman apparatus was used for the laboratory measures of relative depth discrimination. Modifications to the basic instrument consisted of driving the variable vertical rod by a motor which was controlled by a radiofrequency receiver. The observers held a radiofrequency transmitter and moved a toggle switch in a fore and aft direction to elicit rod movement and effect alignment with the fixed comparison rod. When an observer indicated alignment of the two rods, displacement readings to the nearest 0.1 mm were taken with a digital voltmeter which read the voltage across a linear potentiometer attached to the variable rod. Except for a 0.75° X 1.75° viewing window in the front of the instrument, the apparatus was completely enclosed and illuminated with electroluminescent panels lining the sides and top of the case. The luminance levels used were 6.70 foot lamberts for the naked eye observations and 0.012 foot lambert for the observations using the NVG.

Six experienced aviators were used as observers. A modified method of adjustment was used, and during each testing period, an observer would make 10 readings under each of four different viewing conditions: unaided monocular, unaided binocular, monocular with NVG, binocular with NVG. To eliminate an order effect, the viewing conditions were alternated after each observation. All observations were made at a viewing distance of 6 meters from the fixed rod.

Hirsch and Weymouth[5] first discussed the theoretical implications of measures of depth discrimination thresholds, and their suggestion of using the standard deviation of the linear displacement scores has been adopted by other investigators in subsequent reports. Accordingly, our threshold measure was the standard deviation of the displacement scores from the 10 observations made by each observer under the different viewing conditions. Table 1 shows the average thresholds obtained from the six observers with the four viewing conditions. It can be seen in this table

Table 1. Relative Depth Threshold with Howard-Dolman Apparatus

	Linear Threshold (Centimeters)	Angular Threshold (Seconds of Arc)
Binocular	1.34	5.0
Monocular	5.19	19.3
Binocular/NVG	4.80	17.9
Monocular/NVG	7.04	26.2

that unaided binocular viewing yielded results superior to any of the remaining three conditions. Binocular viewing with the NVG was slightly better than unaided monocular viewing, while monocular viewing with the NVG gave the poorest results. Scheffe's S multiple comparison method was used to statistically evaluate these data. There was a significant difference ($p<.01$) between the results obtained with unaided binocular viewing and those found with the other three viewing conditions. However, no statistically significant difference ($p<.01$) was indicated between the thresholds with unaided monocular viewing, binocular-NVG viewing, and monocular-NVG viewing.

Thresholds in terms of angular disparities are also shown in Table 1. These were determined using the following equation[5]:

$$\eta = \frac{a\,(\Delta d)}{d^2} \cdot 206{,}280$$

where

η = angular threshold in seconds of arc

a = interpupillary distance

Δd = linear displacement of the variable rod from the fixed rod

d = observation distance

A binocular threshold of approximately 5 seconds of arc is of the same order of magnitude as those which have been presented in previous investigations[5,6].

(2) Field Measures of Relative Depth Discrimination.

The six observers used in the laboratory study were also used for the field measures of relative depth discrimination. Again, a modified method of adjustment was used and the observer's task was to indicate when two targets, one fixed and one variable, were judged to be at the same distance from him. However, several procedural changes were made. Only three viewing conditions were used: monocular viewing during the day, binocular viewing during the day, binocular viewing with the NVG at night. Only one viewing condition was tested during each observation period, and two aviators, alternately responding, were tested during the same period. Full moon no overcast conditions prevailed during the night testing periods with photometric measures of moon illuminance averaging 1.7×10^{-2} foot candles.

The aviator subjects were seated in the cockpit of a UH-1H helicopter and viewed target pairs (one fixed and one variable) placed at distances ranging from 200 feet to 2000 feet from the helicopter along an inactive runway at Shell Army Airfield, Fort Rucker, Alabama.

The targets consisted of white cloth stretched over metal framework. The larger variable targets were mounted on wheels to allow easier movement. The actual sizes of the targets, as shown in Table 2, were established so that each of the five target pairs would subtend a visual angle of 10' x 30' at their respective testing distances. Lateral angular separation between the two targets of each pair was maintained at 1.5° for all testing distances.

Table 2. Actual Size of the Target Pairs

Testing Distance (Feet)	Target Size (Feet)
200	0.58 x 1.75
500	1.46 x 4.37
1000	2.91 x 8.73
1500	4.37 x 13.09
2000	5.82 x 17.46

Figure 1 shows the resultant thresholds for the three viewing conditions at all testing distances. As with the laboratory study, the measure of threshold was the standard deviation of 10 observations at each distance for all conditions. The average threshold for all six observers is shown in Figure 1. It can be seen that while the monocular and binocular results were similar, the depth discrimination performance with the night vision goggle was clearly inferior at most of the testing distances. Again, Scheffe's S multiple comparison method was used to statistically evaluate these data. Results indicate that there is a statistically significant difference ($p<0.01$) between the unaided daylight monocular and binocular thresholds only at the 2000 feet testing distance. However, NVG performance was significantly different

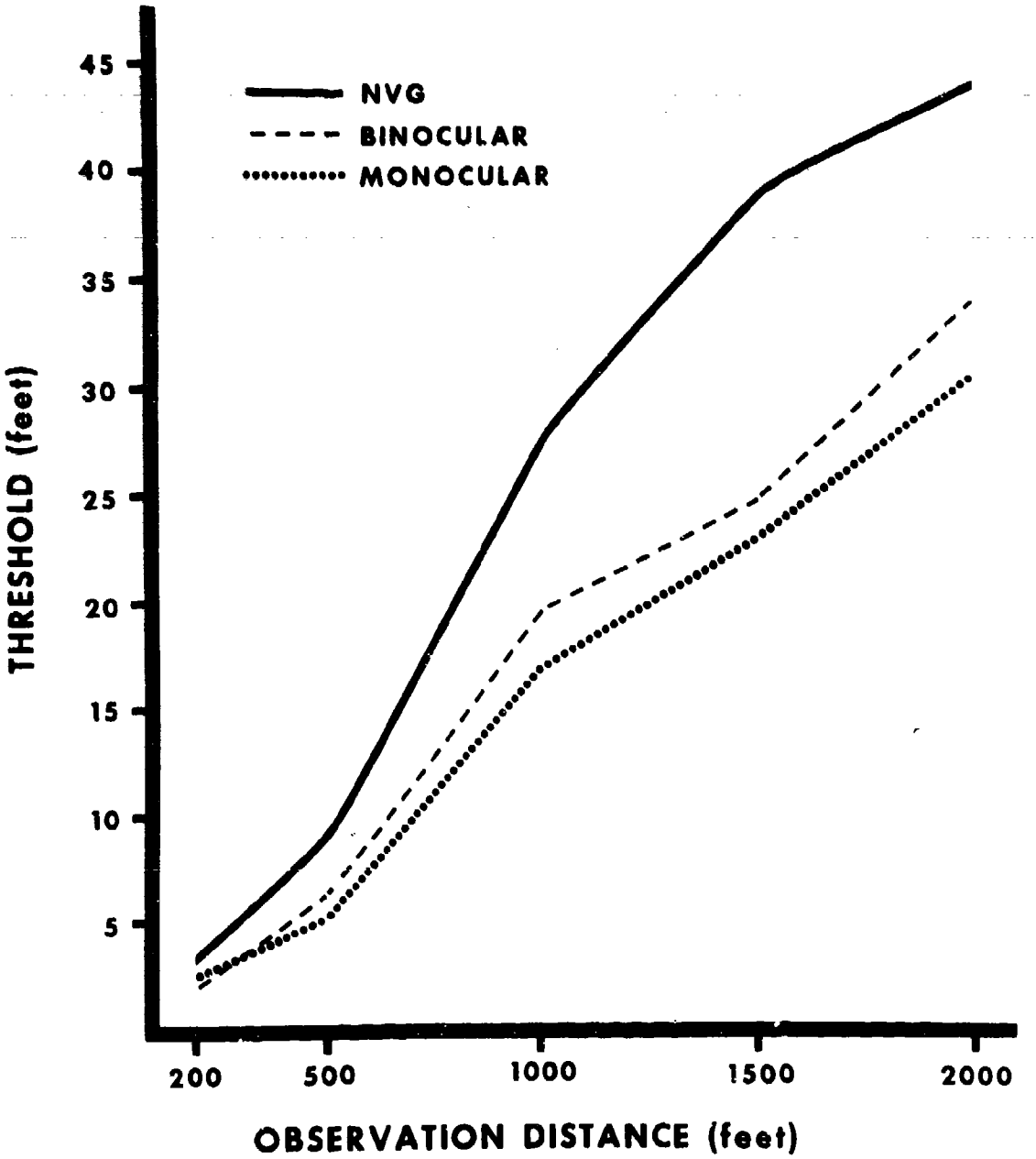

FIGURE 1 LINEAR THRESHOLDS FOR RELATIVE DISTANCE DISCRIMINATION UNDER THREE VIEWING CONDITIONS. DATA POINTS ARE THE AVERAGE FROM SIX OBSERVERS.

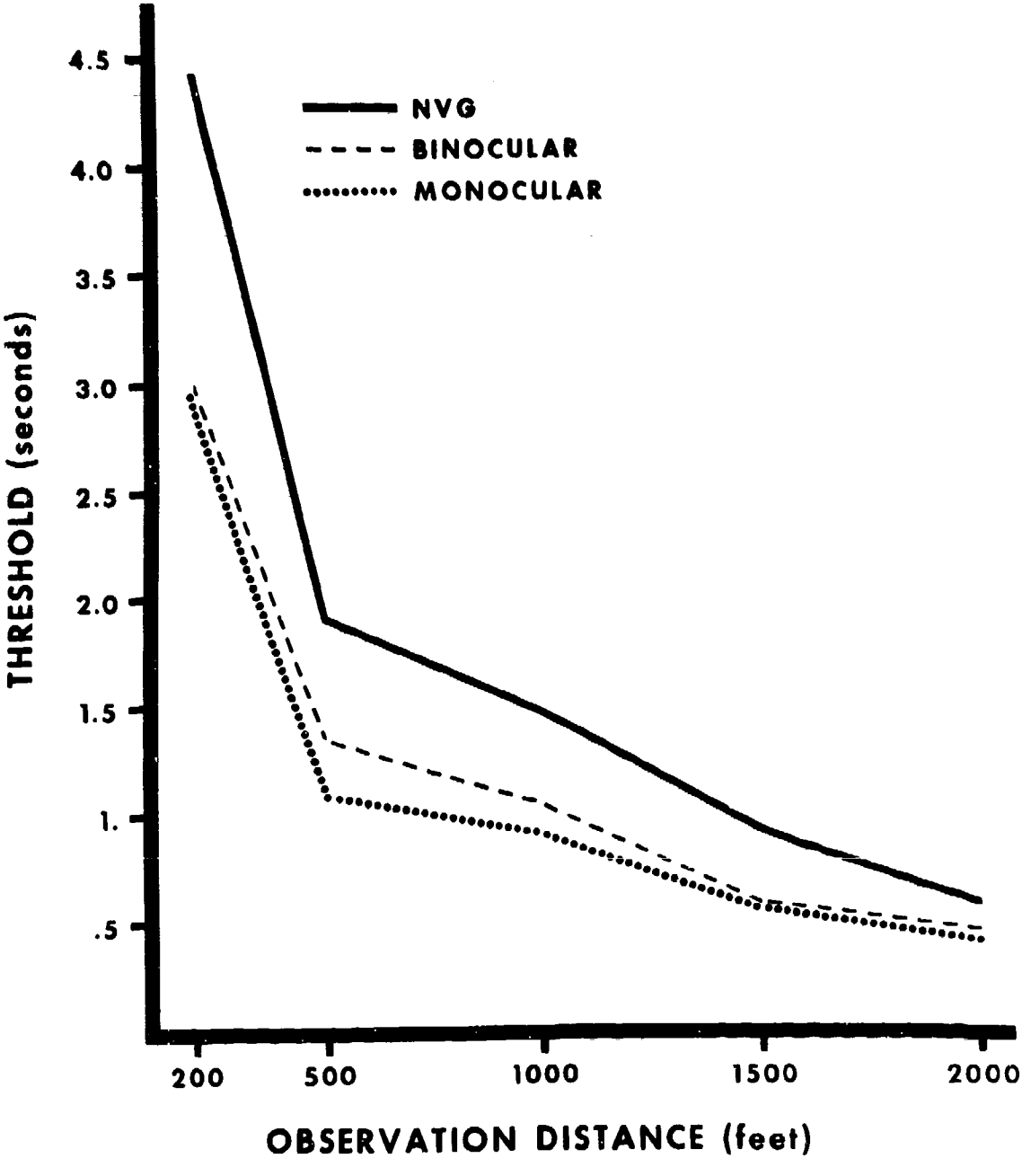

FIGURE 2 ANGULAR THRESHOLDS FOR RELATIVE DISTANCE DISCRIMINATION.

from monocular performance at all distances except 200 feet, and goggle performance was significantly different from binocular performance at all distances except 200 feet and 500 feet.

The results in terms of angular thresholds using the conversion equation discussed earlier are shown in Figure 2. It can be seen, and has been shown previously[7,8,9,10], that the angular threshold for relative depth discrimination decreases with distance. However, these angular thresholds cannot be viewed as stereoscopic disparity thresholds. Clearly, additional monocular cues such as size constancy are operational for these depth discriminations made under field conditions at all of the testing distances.

(3) Visual Modulation Transfer Functions of the Man-NVG System

Using simple clinical measures of visual acuity, it has been determined that Snellen acuity using the goggle is about 20/60, corresponding to a minimum angle of resolution of 3.0 minutes. However, such one-dimensional measures are not completely adequate since angular subtense of the resolution target is the only variable satisfactorily controlled and higher-order factors such as blur interpretation can confound the results. The luminance output and the signal/noise ratio of the goggle do vary with changes in scene luminance. A more quantitative technique to describe man-NVG performance is that offered by the visual modulation transfer function (VMTF) which allows control of such external variables as average scene luminance, contrast, and angular subtense of the resolution target.

The modulation transfer functions obtained in this experiment were determined in the following manner. The subject sat in a darkened room and viewed a television monitor on which was displayed an electronically-generated spatial sine wave grating. The experimenter established and controlled the average luminance on the video display, and the subject controlled the depth of modulation (contrast) of the grating around the average luminance. The subjects were allowed several practice sessions with the equipment prior to the actual data collection periods. Two viewing conditions (unaided and with the NVG) and four average luminance levels were used. The average luminance levels used correspond to the luminance of grass (12% reflection) under a 5%, 25%, and full moon illuminance with no overcast conditions. The fourth level of 25 foot lamberts, considerably above the level with which the NVG would be used, is presented for comparison purposes.

Figure 3 shows the modulation transfer functions at the four average luminance levels for a man wearing the goggle and also when using his unaided vision. The ordinate values of percentage modulation were determined from the relationship,

$\frac{B_{max} - B_{min}}{B_{max} + B_{min}} \times 100$, and are plotted logarithmically as a function of spatial frequency. The data presented in Figure 3 represent the average modulation thresholds obtained from two subjects who were very experienced in making visual psychophysical observations. It can be seen in Figures 3A and 3B that the man-goggle system performs better than unaided vision at the low average luminance levels with a 5% and 25% moon. The depth of modulation (contrast) required to make the grating just visible was less at all spatial frequencies when viewing with the goggle at these levels. However, at a luminance under a full moon (Figure 3C), the observers performed better using unaided vision at high spatial frequencies while performance was better using the goggle at lower frequencies. Figure 3D shows that unaided eye performance is much superior to that achieved with the goggle when the target luminance is sufficiently high to allow the photopic system to operate.

DISCUSSION

Although the MTF's of the man-goggle system have not been published previously, knowledge of the visual modulation transfer functions of the human visual system[11] and of the night vision goggle[12] have been available. However, these separate MTF's are insufficient to predict performance of the man-goggle system. Modulation transfer functions do not cascade between optical components which are directly coupled. When the optical components of a system are separated by diffusers, the overall system MTF can be determined simply by multiplying the individual MTF's. However, when the various components are directly coupled, as is the case when a man views with the night vision goggle, the individual MTF's cannot be multipled to determine the overall system MTF. This is because the aberrations of one component may compensate for the aberrations in another, and thus produce an image quality for the combination which is superior to that of either component. Any "corrected" optical system utilizes this principle.

As noted previously, Figure 3 shows that the quarter moon performance while wearing the goggle is superior to that of the unaided performance at all frequencies while at full moon light levels, the unaided performance is better at the higher frequencies and is slightly poorer than the man-goggle system at the low frequencies. Therefore, under quarter moon illuminance, the resolution limit of the naked eye is lower than that of the man-goggle system whereas under full moon conditions, the

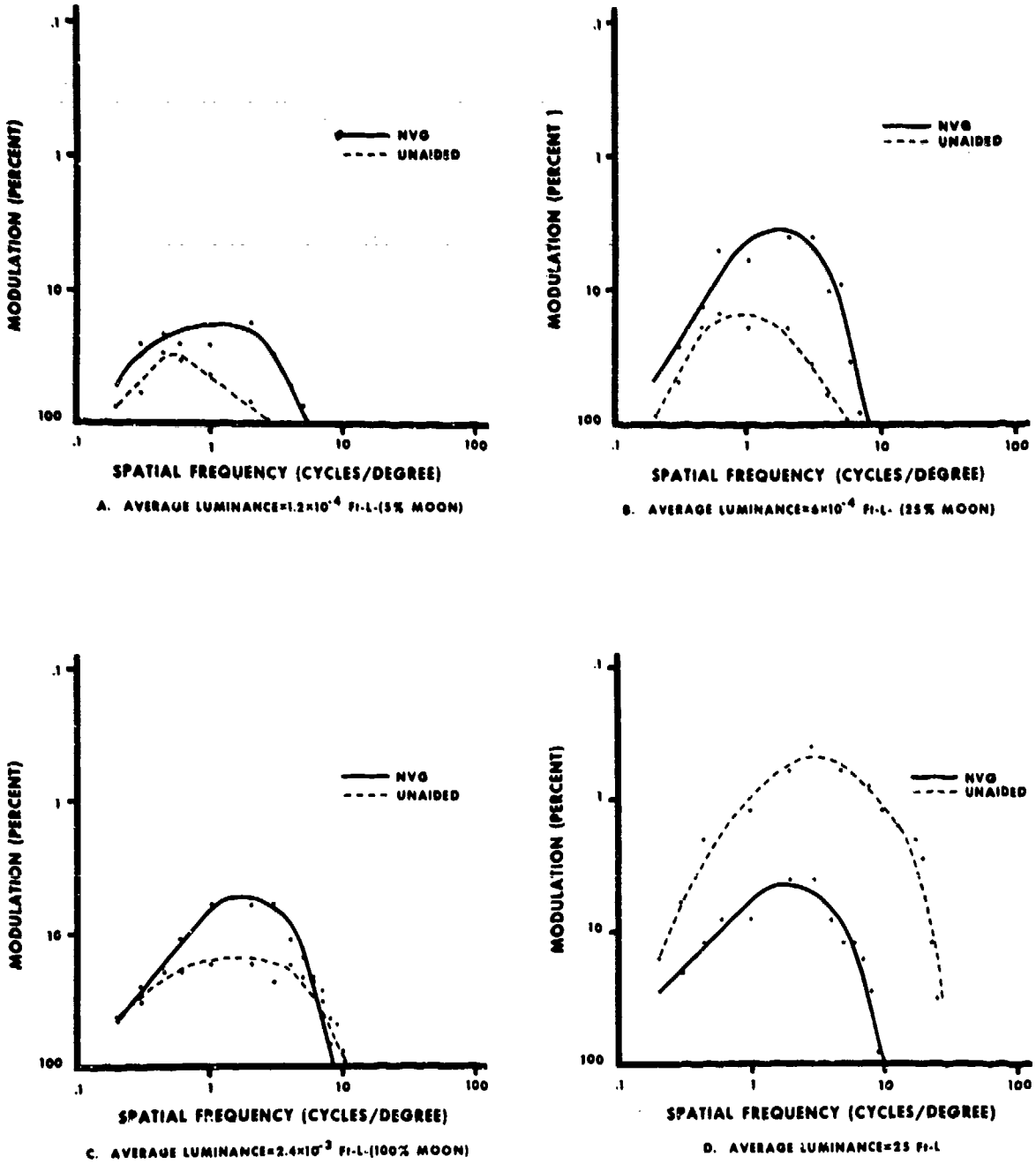

FIGURE 3 MODULATION TRANSFER FUNCTIONS.

resolution of the goggle is the limiting factor and the naked eye performance overtakes that of the man-goggle system. It should be noted that the amount of light provided by a 5% moon is considered insufficient for NOE flight even with the goggle. One effect of the NVG is to increase the luminance levels of the visual stimulus to a range where the discrimination ($\Delta I/I$) threshold for the visual system is less and the visual system is more sensitive to contrast. This is shown in its purest form at the lower frequencies where resolution limits do not confound the effect. While the effect of raising the luminance levels into a $\Delta I/I$ range in which the visual system is more sensitive is probably the main influence on the results with the lower frequencies and lower luminances, we cannot eliminate the possibility that the NVG also provides some contrast enhancement or decrement. A nonlinear goggle output brightness in response to a changing scene brightness would provide either contrast enhancement or decrement depending upon whether the shape of the nonlinear curve was positively or negatively accelerated.

Information obtained from the U.S. Army Night Vision Laboratory indicates that the resolution capability of the NVG is 0.67 line pairs/milliradian. However, this limit was established with a microphotometric measurement of goggle output, and scene luminance was not specified. The limit of 0.67 line pairs/milliradian is approximately equal to 12 cycles/degree. Our data using equivalent moon illuminances (Figures 3A, 3B, 3C) show the cut-off spatial frequency to be between 6 cycles/degree and 8 cycles/degree. The actual resolution capability of the man-goggle system is lower than the physical specifications of the goggle, and it is obvious that the contrast detection of the human visual system is less sensitive than the physical system used to specify goggle output.

The present data are in good agreement with our observation that aviators experienced in flying with the night vision goggle prefer to use the goggle at quarter moon illuminance while at full moon illuminance, these same aviators usually prefer to fly with unaided vision. As shown in Figure 3C, resolution with the unaided eye is higher at the full moon illuminance level. It should be remembered, however, that other factors such as the height of the moon may also enter into consideration. For example, if the aviator is flying along a river bed or other partially shaded area and the moon is low in the sky, his immediate surround may be receiving much less illumination than open areas, and he may choose to use the goggle even with a full moon.

The reduced resolution capability with the NVG has probably influenced the results obtained in the depth discrimination experiments. As shown in Table 1, the results obtained with the Howard-Dolman apparatus indicate that the depth discrimination thresholds with unaided binocular vision were superior to those obtained with binocular viewing thresholds, while thresholds obtained with the NVG and monocular viewing were the poorest. Statistical evaluation indicated that while there was a statistically significant difference ($p<.01$) between the thresholds of binocular viewing and the remaining viewing conditions, there was no significant difference between unaided monocular, binocular-NVG, and monocular-NVG viewing conditions. However, our own observations and comments from every subject used in these experiments indicate that there is a perceptually significant difference between binocular viewing with the NVG and the two monocular viewing conditions. That is, even though the targets are not as clear, depth judgments using binocular viewing with the NVG are more easily made than those using unaided or aided monocular viewing.

An upright image is achieved with the NVG by means of a fiber optics twist contained within the optics of the tube. The fact that adequate spatial information is retained after the fiber optics twist is shown by the readily fused images presented to the eyes by the two tubes in the NVG. One might reasonably expect disparity information to be retained also. Therefore, the decrement in performance while using the goggle from that of unaided binocular viewing is mainly ascribed to the loss in resolution.

The loss of resolution resulting in larger depth discrimination thresholds can also be seen in a comparison between the unaided and aided monocular performances (Table 1). The Howard-Dolman apparatus is usually considered to yield measures of central stereopsis. Relative depth judgments with this instrument are supposedly based upon disparity of the retinal images of the two eyes. However, cues for depth judgment other than image disparity are available to the observer with the Howard-Dolman apparatus. This is true with the instrument used in the present experiment. One cue, proximal image size, was purposely left available for our subjects. Size was probably the major cue used to make the displacement settings when the targets were viewed monocularly. Although the cues available to the observer when viewing the apparatus monocularly with and without the NVG were the same, the degraded image of the targets with the goggle resulted in a threshold which was much greater than that found with unaided monocular viewing.

The field experiment was designed to measure relative depth discrimination thresholds using the goggle and to compare that performance with depth thresholds of daylight unaided vision. With the preponderance of monocular cues, the cue of retinal image disparity was relatively minor, and little difference between monocular and binocular performance was expected. This supposition was supported as shown in Figure 1 in which the monocular and binocular thresholds are statistically equivalent at all testing distances. However, for distances of 500 feet or greater, Figure 1

also shows that depth discrimination performance with the night vision goggle is significantly poorer. As with the results of the laboratory study, the larger thresholds obtained while the observers viewed with the NVG are probably the result of the reduced resolution. That is, while information similar to that used by the observers when viewing the targets during daylight was also available to them when they used the night vision goggle, most of the cues, such as texture, gradients, lighting and shading, and linear perspective, had become sufficiently subtle to result in larger thresholds .

Our results have shown that stereopsis, the appreciation of depth by means of the disparity of the retinal images, is significantly reduced when wearing the night vision goggle. Also, when many monocular cues are available, relative depth discrimination is poorer with the NVG for distances of 500 feet or greater. For lesser distances, performance was statistically equivalent to unaided daylight performance. It should be noted that our results only reflect accuracy and not other qualities such as speed or comfort. The relative advantages of stereopsis in aviation are still somewhat equivocal. Two recent reports[13,14] have shown that landing perormance of pilots deprived of vision in one eye were as accurate as their landings while using both eyes. However, these reports were based on data obtained in fixed wing aircraft. The visual demands of rotary wing flight might be considerably different. Certainly, military flight profiles involving hovering and flight into and out from unprepared areas without benefit of approach and landing aids might reasonably be expected to place greater demands on an aviator's ability to perceive depth, especially at distances of less than 100 feet. The reduced depth discrimination with the goggle should be recognized so that aviators can be properly trained in preparation for flight with the night vision goggle.

As scientists concerned with the visual welfare of our aviators, we are confronted with a paradox. We have assisted in establishing and have supported high visual standards which our aviators must meet. Now we find that aviators are flying with a viewing device with which few of these requirements are met. For example, a resolution capability of 8 cycles/degree, the full moon illuminance cut-off spatial frequency of the man-goggle system, is approximately equivalent to 20/70 Snellen acuity. We have required that our aviators have normal color vision and a full field of vision. Yet, the narrowband output of the goggle eliminates color vision, and the goggle offers only a 40° visual field. The present experimental results have demonstrated that depth discrimination is degraded while using the goggle. Obviously, the NVG does not turn night into day nor does it allow a user to operate with daylight photopic efficiency. However, the night vision goggle does provide sufficient visual information to allow flight under ambient light conditions which was not possible with the unaided scotopic vision system. A previous report[1] has shown that use of the goggle allows a lower flight altitude and more accurate hover capability than with unaided vision. A future generation light intensification device should provide more light intensification with improved imagery to further extend the operational effectiveness of aviation support.

SUMMARY

Comparisons of the visual modulation transfer functions obtained with the man-night vision goggle system and unaided vision show that the performance with the man-goggle system is better when the average target luminances are equivalent to that under 5% and 25% moon illuminance levels. At average target luminance corresponding to a full moon illuminance, performance of the unaided visual system was superior at higher spatial frequencies while the man-goggle system was more sensitive to contrast at the lower frequencies.

Stereopsis thresholds measured with a modified Howard-Dolman apparatus were lower with unaided binocular vision than with the man-goggle system. However, binocular thresholds with the man-goggle system were slightly better than unaided monocular thresholds. Monocular thresholds with the man-goggle system were the largest of any of the four viewing conditions.

Field measures of depth discrimination have shown that relative depth perception with the man-goggle system is inferior to daylight monocular and binocular viewing for distances of 500 feet or greater. For viewing distances less than 500 feet, performance of the man-goggle system was statistically equivalent to unaided viewing.

The following conclusions are supported:

1. The resolution capability of the man-goggle system under full moon illuminance is limited to 8 cycles/degree (approximately equivalent to 20/70 Snellen acuity) or less.

2. Stereopsis, which is based upon retinal image disparity, is degraded with the goggle.

3. Relative depth discrimination with the man-goggle system is statistically equivalent to unaided photopic viewing for intermediate distances, but performance with the man-goggle system is inferior at viewing distances of 500 feet or greater.

4. The AN/PVS-5 night vision goggle does not allow visual performance of daylight efficiency. However, it does provide sufficient visual information to permit rotary wing flight under ambient light conditions which previously prevented flight using only the unaided scotopic visual system.

DISCLAIMER

The findings in this report are not to be construed as an Official Department of the Army position unless so designated by other authorized documents.

REFERENCES

1. Sanders, M.G., Kimball, K.A., Frezell, T.L. and Hofmann, M.A. Helicopter flight performance with the AN/PVS-5, Night Vision Goggles. Paper presented at the Aerospace Medical Panel Meeting, AGARD/NATO, October 1975, Ankara, Turkey.

2. Glick, D.D. and Moser, C.E. Afterimages associated with using the AN/PVS-5, Night Vision Goggle. August 1975, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, USAARL Letter Report-75-1-7-1.

3. Glick, D.D. and Wiley, R.W. A visual comparison of standard and experimental maps using the AN/PVS-5, Night Vision Goggle. March 1975, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, USAARL Letter Report-75-26-7-6.

4. Glick, D.D., Wiley, R.W., Moser, C.E., and Park, C.K. Dark adaptation changes associated with use of the AN/PVS-5, Night Vision Goggle. August 1974, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, USAARL Letter Report-75-2-7-2.

5. Hirsch, M.J. and Weymouth, F.W. Distance discrimination. I. Theoretic considerations. 1948, Archives of Ophthalmology, 39: 210-223.

6. Sloan, L.L. and Altman, A. Factors involved in several tests of binocular depth perception. 1954, Archives of Ophthalmology, 52: 524-544.

7. Hirsch, M.J. and Weymouth, F.W. Distance discrimination. V. Effect of motion and distance of targets on monocular and binocular distance discrimination. 1947, Journal of Aviation Medicine, 18: 594-600.

8. Teichner, W.H., Kobrick, J.L., and Wehrkamp, R.F. Effects of terrain and observation distance on depth discrimination. May 1954, Environmental Protection Division, U.S. Army Quartermaster Research and Development Center, Natick, Massachusetts, Report No. 228.

9. Teichner, W.H., Kobrick, J.L., and Wehrkamp, R.F. The effects of terrain and observation distance on relative depth discrimination. 1955, American Journal of Psychology, 68: 193-208.

10. Teichner, W.H., Kobrick, J.L., and Dusek, E.R. Commonplace viewing and depth discrimination. 1955, Journal of the Optical Society of America, 45: 913-920.

11. Van Nes, Floris L. and Bouman, Maarten A. Spatial modulation transfer in the human eye. 1967, Journal of the Optical Society of America, 57: 401-406.

12. Unpublished data furnished by the U.S. Army Night Vision Laboratory.

13. Lewis, C.E., Jr. and Krier, G.E. Flight Research Program XVI: Landing performance in jet aircraft after the loss of binocular vision. 1969, Aerospace Medicine, 40: 9-11.

14. Lewis, C.E., Jr., Blakeley, W.R., Swaroop, R., Masters, R.L., and McMurty, T.C. Landing performance by low-time private pilots after the sudden loss of binocular vision - Cyclops II. 1973, Aerospace Medicine, 44: 1241-1245.

DISCUSSION

TREDICI: On the IR illuminator, it is very interesting, what is the range? How far will it go?

WILEY: The near infrared illuminator is probably only good for 10, 12 or 15 ft.

TREDICI: If you had a powerful beam of infrared, the goggle would work much better than it does now because more infrared energy would return from the target.

WILEY: There really has not been that much consideration given to using IR illuminators simply because they are so easily detected by other devices. The purpose of the night vision goggle is to allow you to remain "cool bird" and then if you go out and use an IR illuminator, you would probably lose them. Dr Chisum has done some work on IR illuminators too.

CHISUM: Just one observation: If the goggles are considered for aid in search and rescue, then an auxiliary infrared source is useful and certainly significantly improves the operation with the goggles.

TREDICI: But this source must have to be so powerful when we are talking about projecting the beam out at let's say a quarter mile.

CHISUM: I think if you use something like a strobe lamp, this gives an instantaneous but repetitive flash, and it has good range. Unless you have absolutely no moon or starlight, then you would have to have a very powerful source, but with some natural light plus an auxiliary light, this may be useful.

WILEY: This reminds me of something that should be mentioned, and I think Dr Brennan mentioned in his paper--that the nemesis of helicopter pilots is wires, wire strikes. The goggles present new problems there because right now without them maybe they don't know they are going to hit them. With the goggles I believe they are going to be overconfident and get down to the level where they are going to be running into them and we are going to see more wire strikes which they cannot see with the goggles.

KURSCHNER: Can you tell us how sensitive this device is to G forces and the influence of vibration

WILEY: Vibration is a problem. As you could see, they are loosely suspended from the helmet and they are very uncomfortable to wear. You strap them back so that now the whole helmet is vibrating with them, and that is somewhat of a problem although again we have flown with them safely quite a few hours.

KURSCHNER: Then they can be used under low level flight conditions at high speed.

WILEY: They are being used under low level flight conditions. G forces is not that big a problem in helicopters.

WARD: Would you mention the problem they have when there is a sudden flash of light, like a weapons system going off or a nuclear weapon or the strobe light that Dr Chisum just mentioned.

WILEY: That used to be a problem with an earlier generation. That problem was that a sudden flash of light would saturate and you would get a "blooming" of the goggles. This is no longer a problem. They have a damp--it automatically damps down and it is not such a large problem any more. You don't have to do anything. In fact, they provide some bit of major protection.

FUCHS: Referring to your question before, Colonel Tredici, concerned with the distance and your objections. I feel that that is not only an aviation problem, it is also a problem for the Army people, for the ground people, for the armored cars, and my question is what do the Army soldiers do in the same case?

WILEY: They were originally developed for the ground use. There has not been that much experimentation done on the ground with them. I know of one study and only know of it second hand about a mechanized group that just navigated over some known terrain so that they could do it.

TREDICI: In the United States, Dr Berson, of Harvard, who works at their Electrophysiology Laboratory, is using a night vision goggle for retinitis pigmentosa patients. Retinitis pigmentosa robs you of your night vision very quickly. You still can see centrally and in the daytime but very little at night. So, they have had some medical application in that respect.

CHEVALERAUD: Have you run any experiments in helicopters in making precision-type of landings? Don't you believe that a reduction of 40 degrees in the visual field in each eye would interfere with the pilot's vision and performance?

WILEY: Again, I can only repeat that our experiences have been restricted to rotary wing operations and the reduction in the field has not caused any problems; however, very few pilots

have been cleared to use these yet and so when the sky becomes a bit more crowded, then it might become a larger problem. Landing is not a problem.

DRAEGER: Did you try to have an optical magnification besides electrical systems, especially for high speed flying planes? This could be useful for the pilot to diminish his visual field but to increase his magnification. Do you use it like a telescope?

WILEY: No, not with the goggles. There are other light amplification systems that do this, but I don't envision that these goggles will be changed that much to include that. I think they will stay with unity magnification.

TREDICI: There is a very basic problem here. He is already down to 20/70 vision and it is resolution that counts so that magnifying an object that cannot be resolved is like looking at a newspaper photograph which is made up of spots and then putting a magnifying lens on it. You do not see the picture any more, you see black and white dots, and that would be worse.

KNAPP: I don't think anyone should get the idea from this presentation that these night vision goggles now are the cure-all of the problem with night flying. We have to be very careful with this--it is more of an experimental device because it has been decided that it will provide enhancement of night tactical maneuvers for US Army helicopter operations, and the operational people are pushing very hard for this piece of equipment. It has reached about the ultimate in its design capability or close to it. We may be able to cut the weight a little bit, but it probably has reached about as high a degree of refinement as is possible. It will cause some problems, as Dr Wiley mentioned--overconfidence. The pilots may think they can see more than they really can. And it is going to take a lot of care on the part of our medical people and people involved in vision to make sure that we do not create accidents, get ourselves into more problems than we solve by the night vision goggle.

TREDICI: Your graphs and charts prove that most people would not want them when the moon is out or maybe when it is a half moon, but when you get down there to the real scotopic vision you haven't got anything else. You are either going to sit on the ground or you are going to try and use these devices.

KNAPP: There will be one, or two of these devices in every aircraft for every pilot no matter what type of flight operations they are performing, whether they be rescue or whatever that would be. That opens up some questions that yet need to be answered. Can every individual with any type of visual function use them? Use them effectively. Or do they use them with glasses? If a person wears glasses and he is supposed to wear them, does he have to take his glasses off? Is there some special training required? We have not even begun to touch on these.

ETUDE EXPERIMENTALE DE L'EBLOUISSEMENT CHEZ L'ANIMAL

par

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RESUME

Les études concernant l'éblouissement, la mesure des temps de récupération, l'efficacité de systèmes protecteurs conduites chez l'homme interdisent de réaliser des stimulations nociceptives et font généralement appel à des techniques purement psychophysiologiques. Le but de ce travail est la description d'un ensemble de méthodes développées chez l'animal, le lapin et le primate MACACA MULATTA, afin de mettre en évidence les modifications électrophysiologiques et comportementales apportées par un éblouissement ainsi que la mesure des temps de récupération.

L'éblouissement est un déficit temporaire de la perception visuelle chez un sujet soumis à une énergie lumineuse intense, tout au moins plus élevée que celle définissant son niveau d'adaptation. Il comporte des phénomènes électrophysiologiques et biochimiques au niveau de la rétine, des voies et relais du message visuel, des aires de projection primaires et associatives ; le phénomène biochimique et corrélativement électrophysiologique rétinien est le plus important.
Le temps de récupération ou temps de restauration (recovery time), temps mis par le système visuel pour retrouver une fonction partielle ou totale constitue une mesure de l'éblouissement ; habituellement il s'agit du temps mis par le sujet exposé pour retrouver une acuité visuelle donnée. Cette notion est, dans ce travail, étendue à la mesure du temps nécessaire pour que les activités électrophysiologiques du système visuel et plus particulièrement l'électrorétinogramme (ERG) retrouvent les caractères morphologiques et temporels d'activités évoqués par des stimulations supra-liminaires mais de faible valeur, prises comme témoins. Cette étude concerne chez l'animal, lapin ou singe, muni d'électrodes chroniquement implantées l'analyse de la récupération de l'électrorétinogramme et des potentiels évoqués (PE) recueillis au niveau des corps genouillés latéraux et des aires de projection primaires après éblouissement par un flash de forte puissance. Elle comporte l'étude des activités électrophysiologiques évoquées par le stimulus éblouissant, mais surtout, à l'aide de la technique des doubles stimulations, l'analyse de phénomène de restauration d'activités électriques analogues à celles obtenues lors de stimulation témoin. Chez le singe elles associent la mesure de temps mis par le sujet pour percevoir un symbole.

METHODE

1 - PREPARATION NEUROPHYSIOLOGIQUE

Sous anesthésie locale chez le lapin et générale chez le singe après fixation dans un appareil de stéréotaxie, les animaux sont munis d'électrodes mono ou bipolaires. Chez le lapin de la race Fauve de Bourgogne, les électrodes sont réparties sur le cortex moteur, somesthésique et visuel et au niveau de l'hippocampe dorsal, pour la voie visuelle, au niveau du corps genouillé latéral, du colliculus supérieur et des aires visuelles de projection primaire. Chez le Macaque de 3 à 5 kgs, 12 à 27 électrodes se répartissent à la surface du cortex et au niveau du corps genouillé et des aires visuelles de projection primaire et associative. Les électrodes de référence sont placées l'une derrière le globe oculaire, l'autre 2 cm en avant du bregma chez le lapin, sur la mastoïde chez le macaque. Les électrodes sont soudées à un connecteur verrouillable fixé sur le crâne et noyé dans une résine acrylique. Les sujets ne sont utilisés qu'un mois après l'implantation, et entraînés à rester immobiles, sans aucune prémédication dans une boîte à contention ou sur un siège. La tête est fixée sur un support à l'aide de bande Velcro ou pour les singes dans un casque, adapté et réalisé pour chaque sujet.

ERG. L'électrode de mesure est constitué d'un fil d'argent de 5/10 de mm protégé par une gaine de nylon. Sur cette dernière, un fil de cuivre ou d'argent de même diamètre enroulé en spire jointive et relié à la terre permet d'obtenir un conducteur flexible et surtout de minimiser l'artéfact de stimulation. L'ensemble est monté sur un dispositif que l'on fixe avant chaque expérience sur le connecteur d'électrodes de l'animal. L'extrémité de l'électrode de mesure, une boule sphérique de 1 mm ou un anneau de 3 mm de diamètre est amenée alors au contact de la cornée, préalablement anesthésié à l'aide de NOVESINE et protégé par un collyre à la méthylcellulose. Les animaux subissent tous avant toute expérience, un examen du fond de l'oeil, de la chambre antérieure et du cristallin. Les expériences sont toutes réalisées la pupille en mydriase après installation répétée d'homatropine.

2 - ENREGISTREMENT

L'enregistrement est réalisé en dérivations monopolaires. Le signal est amplifié à l'aide d'une chaîne de préamplificateurs, amplificateurs et enregistreurs graphiques de 8 à 16 voies. Il est recueilli à la sortie des préamplificateurs sur bande magnétique analogique à l'aide d'un enregistreur à fréquence porteuse (bande passante DC-5000 Hz). La constante de temps introduite à la sortie de l'étage amplificateur est de 0,7 s pour l'électrorétinogramme, 0,1 pour les activités électriques cérébrales.
Un générateur d'impulsion programmable délivre les impulsions de synchronisation, base de temps et les impulsions de déclenchement des différents générateurs d'éclat survenant chacun après des délais réglables, tout d'abord pour le stimulus éblouissant puis pour les stimulus tests.

3 - ANALYSE DES SIGNAUX

On dispose immédiatement de l'enregistrement graphique mais en fait les mesures sur l'électrorétinogramme et les réponses évoquées sont réalisées après traitement du signal analogique. Ce traitement comporte la conversion analogique numérique des signaux, leur mise en mémoire à l'aide d'un petit calculateur comprenant multiplexeur, convertisseur analogique numérique, mémoire centrale de 16 K de 8 bits et unité de visualisation. Le convertisseur analogique numérique code sur 8 ou 16 bits. La fréquence d'échantillonnage utilisée généralement est de 10 KHz.

La conversion analogique numérique est réalisée en méthode d'extraction signal/bruit, utilisant soit le moyennage, soit le multi échantillonnage lorsque la fonction analysée est stationnaire et ceci sur des moyennes de 5 réponses évoquées ou le plus souvent lorsque la stimulation est importante et que les conditions de stationnarité ne sont pas respectées en fac similé, réponse après réponse.

La précision absolue des mesures de temps est liée à la fréquence d'échantillonnage ; elle est de l'ordre de 0,2 ms. Les mesures des amplitudes des réponses évoquées se font par rapport à la ligne isoélectrique évaluée par calcul sur l'échantillon du signal précédant la stimulation ou pour l'électrorétinogramme par rapport à l'amplitude maximale de l'onde a et pour les potentiels évoqués par rapport à l'amplitude maximale de la première composante. La précision est de l'ordre de 5 %.

Un programme d'analyse numérique permet également de calculer automatiquement ces paramètres et d'effectuer lissage, filtrage des graphes, calcul de la fonction d'auto et d'intercorrélation et spectre de densité de puissance.

4 - PARAMETRES OPTIQUES DE STIMULATION

(a) NIVEAU D'ADAPTATION Les animaux sont placés dans un caisson expérimental dont l'éclairement assuré par des lampes MAZDA lumière du jour, alimentées sous une tension variable varie de 0 à 350 Lux. La mesure de l'éclairement est assurée en routine à l'aide d'une cellule photoélectrique METRIX suivi d'un multimètre ; lors des étalonnages de précision pour les éclairements supérieurs à 3 Lux à l'aide d'un luxmètre CHAUVIN ARNOUX type Polycontrôle 94 et pour les éclairements inférieurs à 3 Lux, à l'aide d'un photomultiplicateur comportant filtre photopique de correction et diffuseur. La précision des mesures est de 2 %.

(b) STIMULATION TEMOIN (S) Le stimulus test a été choisi, pour obtenir chez un sujet adapté à l'obscurité un électrorétinogramme complet c'est-à-dire possédant une onde a, des ondes e et une onde b_2. Il s'agit d'un éclair de lumière blanche, de durée de 0,3 ms, émis sous une puissance de 0,3 joule provoquant au plan de la cornée un éclairement maximum de 1800 Lux survenant 0,1 ms après le déclenchement de l'éclair et une lumination de 5 Lux.s. Les mesures ont été réalisées à l'aide d'un photomultiplicateur IENA comportant un filtre photopique et les impulsions sont visualisées sur oscilloscope à mémoire.

(c) STIMULUS EBLOUISSANT (P) Il est délivré par un flash au Xénon BALCAR T 100 S situé au centre d'un diffuseur. A la base de ce dernier, ayant la forme d'une calotte hémisphérique, il existe une plaque métallique noire dont le centre est équipé à la demande d'un diaphragme d'ouverture variable et de filtres neutres de différentes densités permettant de faire varier à la fois le diamètre du faisceau et la valeur du stimulus.

Il opère à la puissance variable de 150, 300, 600 et 1200 joules. Sa température de couleur est de 5500°K et la durée de l'éclair, variable selon la puissance mesurée à la demi-hauteur de l'impulsion est respectivement de 0,75, 0,87, 1,5 et 2 ms. Les mesures au plan de la cornée des stimulations effectuées sont rassemblées dans le tableau 1.

Les mesures ont été réalisées à l'aide d'un photomultiplicateur IENA équipé d'un filtre photopique et protégé par un filtre neutre de densité 4 et d'un circuit de photodiode.

5 - PROTOCOLE EXPERIMENTAL.

Le nombre de lapins étudié est de 85, de primates de 12.

(a) EXPERIENCES PRELIMINAIRES Il s'agit de l'étude de l'effet de l'adaptation sur l'électrorétinogramme pour 6 niveaux d'éclairement à 0,12, 15, 6,5, 68 et 270 lux. Le stimulus étant un éclair Xénon de 150 joules type A.

TABLEAU 1

STIMULATION	PUISSANCE A L'EMISSION en joules	INSTANT DE L'ECLAIREMENT MAXIMAL en ms	ECLAIREMENT MAXIMAL en Lux au plan de la cornée	LUMINATION en en Lux.s
A	150	0,1	$1,07.10^5$	270
B	300	0,2	2.10^5	540
C	600	0,3	$2,8.10^5$	1070
D	1200	0,4	$3,95.10^5$	1880

-de l'intensité de la stimulation sur l'électrorétinogramme du lapin ou du singe adapté à l'obscurité, le stimulus étant toujours délivré par le flash Xénon, à une puissance A = 150 joules mais dont l'intensité et la lumination variaient par interposition de filtres neutres et de diaphragme entre 300 Lux.s et 0,0075 Lux.s.

(b) EXPERIENCES CONCERNANT L'EBLOUISSEMENT PROPREMENT DIT

Tous les animaux étant adapté à l'obscurité pendant 30 minutes, il a été réalisé :

- L'étude de la récupération de l'ERG évoqué par le flash S à la suite de la stimulation provoquée par le flash S lui-même, l'intervalle de temps séparant les 2 stimulus variant entre 20 ms et 30s.
- L'étude de la récupération de l'ERG évoqué par le flash S à la suite d'un éblouissement important provoqué par le flash P pour les 4 valeurs de stimulation A, B, C, D.

Le protocole comprend alors :

- La délivrance de 10 éclairs S espacés de 30 s, la moyenne des activités recueillies étant pris comme témoin.
- 30 s après le dernier éclair S, l'éblouissement par le flash P.
- L'étude de la récupération par une série d'éclair S survenant 5 s après P et toujours espacé ensuite de 30s, pendant 10 à 15 mn.

- Chez le primate, l'association de l'expérience précédente avec la présentation de symbole. Ce dernier + ou - éclairé en lumière jaune sous une luminance de 0,5 Nit apparait 10 s après le stimulus éblouissant. Le sujet percevant le signal appuie sur un levier, reçoit alors une récompense en arrêtant la séquence de présentation. Le temps de réponse est mesuré.

RESULTAT

1 - EVOLUTION DE L'ELECTRORETINOGRAMME EVOQUE PAR LE STIMULUS TEST S APRES EBLOUISSEMENT PAR CE STIMULUS CHEZ LE LAPIN (graphique n° 1)

- La période réfractaire absolue au cours de laquelle une 2ème stimulation n'évoque aucune activité électrophysiologique est de 52 ms ± 7 ms.

- La réapparition des éléments de l'ERG se fait dans l'ordre b_1, a, b_2 et les périodes réfractaires correspondantes sont de 62 ± 7 92 ± 8 et 142 ± 10 ms.

- Les ondes a, b_1, b_2 augmentent progressivement d'amplitudes jusqu'à ce qu'elles reviennent à la valeur témoin.

La croissance de l'onde b_1 est relativement plus rapide que celle de a et b_2.

On remarque que l'onde b_2 atteint une valeur absolue maximale supérieure à l'amplitude apparente de b_1 et que les amplitudes de b_1 et b_2 sont alors sensiblement égales lorsque l'intervalle entre les 2 stimulations est compris entre 1,750 et 2.000 s.

- Le temps de récupération de b_1, a et b_2 sont respectivement de 2 ± 0,2, 10 s ± 0,3 et 20 ± 0,5.

L'imprécision de ces mesures est essentiellement due au fait que la vitesse de récupérration est plus lente, lorsque l'écart entre les 2 stimulus augmente et ceci surtout à partir de 500 ms.

Au cours des différentes étapes de la récupération de l'ERG, on retrouve les aspects morphologiques de cette activité électrique pour différents niveaux d'éclairement.

L'élévation du niveau d'éclairement d'adaptation diminue l'amplitude de a, b_1 et b_2, mais la sensibilité n'est pas la même pour les divers éléments (graphique n° 2 exprimant chez 10 lapins cette évolution). Pour 0,12 Lux b_1 et b_2 sont à peu près d'égale amplitude, pour 68, 6,5 et 1,5 Lux a et b_2 sont de plus en plus grandes et les ondes sont apparues, pour 270 Lux a et b_2 sont très petites alors que b_1 est pratiquement dépourvue d'ondes e.

2 - EVOLUTION DE L'ERG EN FONCTION DE L'INTENSITE DE LA STIMULATION CHEZ UN ANIMAL ADAPTE A L'OBSCURITE

Les expériences préliminaires chez le lapin et le singe en utilisant un éclair de flash Xénon opérant à 150 joules et en interposant des filtres neutres amenant au plan de la cornée différents éclairements maxima variant entre 200.000 Lux et 0,05 Lux ont permis de préciser des résultats généralement admis. L'évolution est comparable chez le lapin et le singe ; seuls les seuils diffèrent.

(a) MORPHOLOGIE (Illustration graphique n° 4)

Lorsque le stimulus s'élève l'électrorétinogramme passe par plusieurs stades que l'on peut schématiser. L'ERG est constitué uniquement par une onde positive homogène que son aspect, sa durée, sa latence, et le délai de son amplitude maximale permettent d'identifier avec l'onde b_2 (STADE I intensités 2 à 4). Puis l'onde a et b_1 apparaissent mais cette dernière est incomplétement développée et l'onde e_2 est alors très nette (STADE II DE TRANSITION, intens. 4 à 6). Ensuite l'onde a est parfaitement dessinée et l'onde b_1 comporte 3 ondes bien différenciées (STADE III, intens. 7 à 9). L'onde e_3 enfin tend à se fondre dans l'onde b_2 et n'apparait plus que comme un décrochement de la partie ascendante de l'onde b (STADE IV, intens. 9 à 10 et >10). Dans les deux derniers stades, la morphologie de l'onde a évolue pour être asymétrique et pointue puis parfaitement symétrique à sommet arrondi enfin à sommet dédoublé.

(b) AMPLITUDES (graphique n° 3 exprimant l'évolution générale sur 10 animaux)

Les seuils de a et b_1 sont voisins et supérieurs d'environ 3 unités log à celui de b_2.

Les relations amplitude/intensité pour a et b_2 sont d'allure logarithmique. Il n'existe pas dans cette gamme de variation du stimulus de saturation et les variations s'étendent sur environ 6 unités log pour b_2 3 unités log pour a.

- L'onde b_1 se présente immédiatement comme une différenciation de la partie ascendante de l'onde b et son amplitude est dans le seuil, environ la moitié de ce qu'elle sera à l'intensité la plus élevée. Si l'on tient compte de la superposition de la partie initiale de b_2 à l'onde b_1, il semble donc que l'amplitude de cette dernière ne varie pas avec l'intensité de la stimulation.

- Si les variations évoluent d'un animal à l'autre dans le même sens, la dispersion des valeurs absolues obtenues à un stimulus donné est importante, d'un facteur 2 à 3.

(c) EFFETS SUR LES DELAIS

Pour l'onde a le délai varie en fonction inverse de l'intensité de la stimulation depuis le seuil jusqu'à la valeur maximale du stimulus.

Le délai du sommet de b_2 diminue également aux fortes intensités mais pour les faibles intensités et en particulier lorsque a et b_1 n'existent pas, il est moins élevé qu'aux intensités moyennes.

Les délais de e_1 et e_2 diminuent quand l'intensité augmente.

Le comportement de e_3 est plus difficile à systématiser.

3 - EVOLUTION DES ACTIVITES ELECTROPHYSIOLOGIQUES DE LA RETINE POUR LES STIMULUS ELEVES A, B, C, D CHEZ LE LAPIN

(a) EVOLUTION MORPHOLOGIQUE DE L'ERG

La morphologie de l'ERG est dans l'ensemble celle du stade III décrit plus haut. (graphique n° 6)

L'onde a prend une importance relative et absolue considérable et un aspect assez caractéristique à deux sommets. Pour la valeur maximale du stimulus, stimulation C, il apparait dans 15 % des cas chez le lapin et 30 % des cas chez le singe une morphologie particulière de l'ERG constitué presque exclusivement de l'onde a et il semble que la saturation de l'onde a soit effectivement réalisée.

(b) EVOLUTION DYNAMIQUE DE L'ELECTRORETINOGRAMME EVOQUE PAR LE FLASH S APRES EBLOUISSEMENT PAR LE FLASH B

Les tableaux 2, 3 résument la dynamique générale du processus chez le lapin lorsque la stimulation est le stimulus D (nombre de sujets : 85).

TABLEAU 2

EVOLUTION DES AMPLITUDES MOYENNES DE L'ERG TEST EXPRIMEES EN µV ET EN POURCENTAGE DE LA VALEUR TEMOIN

Valeur témoin	ONDE a 60 ± 10	%	ONDE b_1 185 ± 10	%	ONDE b_2 270 ± 15	%
Intervalle de temps en s						
5	30 ± 5	50	130 ± 5	70	80 ± 10	29
20	32 ± 3	53	142 ± 2	76	90 ± 5	33
30	45 ± 5	75	170 ± 4	91	195 ± 7	72
40	48 ± 2	80	175 ± 5	94	200 ± 2	74
60	50 ± 6	83	190 ± 5	102	235 ± 5	87
90	53 ± 7	88	200 ± 10	108	255 ± 6	94
120	55 ± 8	91	180 ± 4	101	260 ± 5	96
150	58 ± 8	96	189 ± 3	102	268 ± 6	99
180	59 ± 9	98	190 ± 7	102	268 ± 3	99
210	60 ± 10	100	185 ± 6	100	268 ± 7	99
240	62 ± 12	103	188 ± 7	101	272 ± 5	100
270	63 ± 10	105	188 ± 8	101	270 ± 7	100
300	60 ± 12	100	190 ± 10	102	270 ± 7	100

TABLEAU 3

EVOLUTION DES DELAIS MOYENS EXPRIMES EN ms

TEMOIN Intervalle de temps en s	a 13,4	e_1 19,5	e_2 25,2	e_3 35,8	b_2 63,8
30	11,5	17	23	32	50
60	12	18	24	34	52
90	13,5	19	25,8	35,1	55
120	13,3	19,2	25,3	35,2	61
180	13,8	19,5	25,2	35,6	62
240	13,4	19,5	25,2	35,6	63,5
270	13,4	19,5	25,2	35,6	63,7

Le tableau 4 résume l'évolution de l'amplitude des ondes a, b_1, b_2 chez le lapin après les stimulations A, B, C, D. L'amplitude est exprimée en pourcentage de la valeur témoin.

TABLEAU 4

INTERVALLE DE TEMPS ENTRE LE STIMULUS EBLOUISSANT ET LE TEST EN S

		5	10	30	60	90	120	150	180
Onde a									
STIMULATION	A	95	95	112	117	110	116	118	115
	B	96	95	110	140	115	110	110	110
	C	60	71	105	120	121	122	130	123
	D	50	51	75	83	88	91	96	98
Onde b_1									
	A	92	103	110	115	106	107	115	112
	B	90	95	105	105	110	116	115	120
	C	85	91	98	102	102	100	108	118
	D	70	78	91	94	108	101	102	102
Onde b_2	A	-	85	96	104	106	106	105	105
	B	-	75	92	100	102	105	111	106
	C	-	58	92	98	110	105	94	108
	D	29	35	72	87	94	96	99	99

On constate que les temps de récupération varient très rapidement avec la valeur de la stimulation et que la restauration complète est souvent plus lente et toujours plus difficile à évaluer qu'une restauration relative à 75 ou 80 % de la valeur témoin initiale.

Le temps de récupération, à la valeur maximale D de la stimulation sera pour une restauration complète, de 1 à 2 mn pour a et b_1 et de 3 mn pour b_2, de l'ordre de 30 s pour a, 10 s pour b_1 et 40 à 50 s pour b_2, si l'on évalue une restauration à 75 % de l'aspect initial. Il apparait également que le retour aux valeurs antérieures n'est effectif que 3 mn après l'éblouissement.

Le tableau 5 résume ces temps de récupération (en s).

TABLEAU 5

VALEUR DE LA STIMULATION EBLOUISSANTE	95 % DE LA VALEUR INITIALE ERG TEMOIN a	b_1	b_2
A	5	5	20
B	10	10	30
C	25	60	50
D	130	90	140

4 - EVOLUTION DE LA RECUPERATION DE L'ERG CHEZ LE MACAQUE CONDITIONNE

L'évolution de la récupération de l'ERG chez le macaque n'est pas fondamentalement différente de l'ERG chez le lapin et la dynamique générale du processus est superposable. Le problème posé est de savoir à quel moment l'animal perçoit sans ambiguïté le symbole lumineux qui lui est présenté.

Les expériences sont actuellement limitées à un nombre restreint de sujets, mais il apparait que pour les valeurs de la stimulation A et D, la perception du symbole coïncide avec une récupération de l'onde a et b_2 au moins égale à 75 % de la valeur initiale (tableau 6).

TABLEAU 6

VALEUR DES ONDES a ET b_2 EXPRIMEES EN % DE LA VALEUR INITIALE

Onde a	INTERVALLE DE TEMPS ECOULE (en s)								
STIMULATION	5	10	20	30	40	60	90	120	180
A	85	92	95	98	100	102	105	102	105
D	46	45	60	75	92	98	100	110	115
Onde b_2									
STIMULATION									
A		60	75	85	98	100	105	110	105
D	10	30	40	60	78	85	95	103	110

TEMPS MIS POUR LA LECTURE DU SYMBOLE

A 18 s ± 5
D 42 s ± 10

(moyennes établies sur l'ensemble des 12 sujets et pour une série de 3 expériences par animal).

DISCUSSION - CONCLUSION

L'ensemble des méthodes décrites et illustrées par quelques exemples a pour but l'évaluation de l'importance d'un éblouissement en s'attachant à décrire les variations des grandeurs reliées de façon suffisamment précise à la sensibilité du système visuel.

Si l'on ne considère que les variations des activités électrophysiologiques évoquées par un stimulus test survenant à intervalle variable après le stimulus éblouissant, on constate que l'ERG est le seul effectivement relié directement à l'état de sensibilité du système visuel, que les activités du corps genouillé sont encore un test acceptable mais qu'il est difficile d'établir une relation simple entre l'évolution des réponses évoquées recueillies au niveau des aires de projection primaire ou associative et la récupération des fonctions visuelles.

Chez le lapin comme chez le primate la mesure précise des différents paramètres du potentiel évoqué, latence du phénomène, amplitudes, délais et durée des différentes composantes conduit à des valeurs dont la dispersion est très importante. Si l'on peut dégager certaines lois d'évolution, lorsque l'on juge à niveau de vigilance égal et lorsqu'on évalue les variations du PEV après un stimulus unique d'intensité croissante, il est beaucoup plus difficile de définir la dynamique de la récupération pour une stimuation test survenant après un stimulus éblouissant important. Il apparait en effet que souvent le message provenant aux aires de projection primaire se traduit par un PE peu modifié, alors que l'ERG ou même l'activité recueillie au niveau du corps genouillé est profondément altéré. Seule la mesure des temps de transfert, à l'aide des fonctions d'intercorrélation semble un paramètre beaucoup plus fidèle.

Comme l'ERG est chez le lapin ou le primate bien défini au cours de l'adaptation à la lumière, l'évolution de sa morphologie et de ses différentes caractéristiques temporelles après un éblouissement apparait parfaitement décrite. Son évolution a de grandes analogies avec celle de l'électrorétinogramme obtenu à intensité constante mais pour des niveaux d'adaptation de plus en plus faible, l'onde b_1 est l'élément qui récupère le plus rapidement et la récupération de a est plus rapide que celle de b_2. Bien que l'on doive garder à l'esprit que l'ERG ne met pas en jeu l'ensemble des phénomènes de la perception visuelle, mais intéresse essentiellement l'aspect périphérique, encore que certains auteurs émettent l'hypothèse d'un contrôle central sur sa récupération, ce phénomène est extrêmement utile pour caractériser et mesurer l'éblouissement.

La combinaison de méthodes électro et psychophysiologiques chez l'animal, délicate à mettre en oeuvre permet de confirmer cette conception. Il semble que chez le primate l'apparition de l'onde a et de l'onde b_1 corresponde dans la récupération après éblouissement, aux seuils de vision proprement dit, tout au moins pour une luminance de la tâche voisine de 0,5 Nit. C'est à ce moment là d'ailleurs seulement qu'à niveau de vigilance égal (éveil attentif), la latence générale du PE primaire comme l'amplitude et le délai de sa 1ère composante sont voisines de celle du PE témoin.

Certains problèmes méthodologiques demeurent :

1 - Le stimulus test qui doit être suffisant pour permettre l'acquisition d'ERG comprenant tous ces éléments provoque lui-même un éblouissement discret mais non négligeable et l'on doit tenir compte de ce fait dans l'interprétation des résultats.

2 - Dans les expériences psycho-neurophysiologiques, la présentation du symbole sous une luminance donnée constitue également une stimulation parasite. Il est souhaitable soit de retarder la présentation symbolique du stimulus test proprement dit, soit de réaliser l'expérience en deux fois en dissociant récupération des activités électrophysiologiques de la lecture du symbole, mais dans les mêmes conditions de stimulation éblouissante. Si la luminance de la tâche visuelle est faible, il n'apparait pas de différence significative entre les temps de réponse mesurés (pour la stimulation A le temps de réponse est de 16 ± 3, pour la stimulation D de 40 s ± 5 contre 18 s ± 5 et 42 s ± 10). Il n'a pas été possible d'obtenir d'ERG reproductible en utilisant la réponse "on" à une présentation d'un symbole prolongé pendant 10 s.

Cet ensemble méthodologique toutefois convient aux préoccupations de recherche appliquée et permet de tester même pour des stimulations élevées nociceptives à la fois le comportement du sujet ébloui, les temps de récupération et l'efficacité du système protecteur.

Il nous a permis également d'approfondir quelques aspects fondamentaux concernant la théorie dualiste de l'ERG et de préciser l'existence d'effet à long terme d'éblouissement important.

On constate en effet que lors de la récupération de l'ERG après un éblouissement, reposant essentiellement dans le cas présent sur la réadaptation à l'obscurité.

- b_1 est bien restauré avant b_2 en accord avec la conception dualiste mais il importe de ne pas assimiler dualité fonctionnelle et dualité morphologique des récepteurs, car chez le lapin la rétine est composé presque exclusivement de bâtonnets.

- Si l'on observe bien un dédoublement du sommet de a pour les stimulus intenses, le comportement de a n'est pas en accord avec certaines conceptions qui relie l'onde a toute entière à l'activité du système photopique. En effet, le dédoublement de a est inconstant, n'apparait que pour des intensités élevées et même en adaptation à l'obscurité l'amplitude de a et de b_1 en fonction de l'éclairement ambiant est nettement différent.

Par ailleurs il a été retrouvé pour des stimulations importantes type C, dans 10 % des cas chez le lapin, 22 % des cas chez le singe une augmentation initiale de b_1 suivie d'une réduction de l'onde b et de l'onde a, une augmentation importante et durable de l'ordre de 1 mois des temps de récupération, accompagnée ou non d'altération morphologique de l'ERG avec la disparition d'une ou plusieurs ondes e. Ce fait tendrait à prouver que sans altération du fond d'oeil il peut exister une altération fonctionnelle réversible de longue durée du système visuel après un éblouissement. Le problème est de savoir si des altérations ultrastructurales sont sous-jacentes.

REFERENCES

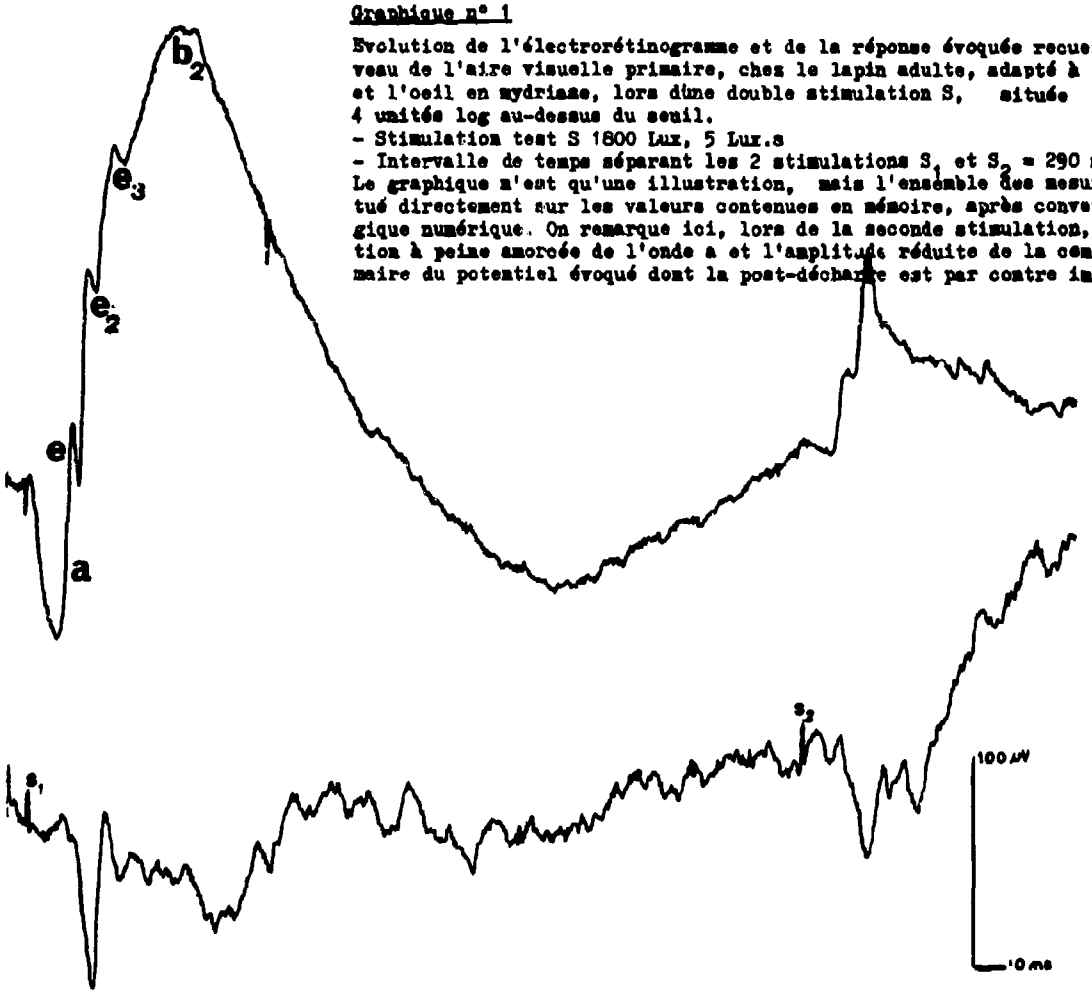
La bibliographie principale est rassemblée dans les rapports ci-dessous :

1 - L'électrorétinogramme du lapin adulte par M. BASIN ; M. CASSAN, L. COURT ; Centre de Recherches du Service de Santé des Armées - Rapport Laboratoire Central de l'Armement et Centre de Recherches du Service de Santé des Armées, Mars 1971.

2 - Evolution de l'électrorétinogramme et des activités évoquées visuelles primaires chez le lapin adulte au cours d'un éblouissement par M. BASIN, M. CASSAN, L. COURT, Centre de Recherches du Service de Santé des Armées. Rapport Laboratoire Central de l'Armement et Centre de Recherches du Service de Santé des Armées, Mai 1971.

REMERCIEMENTS

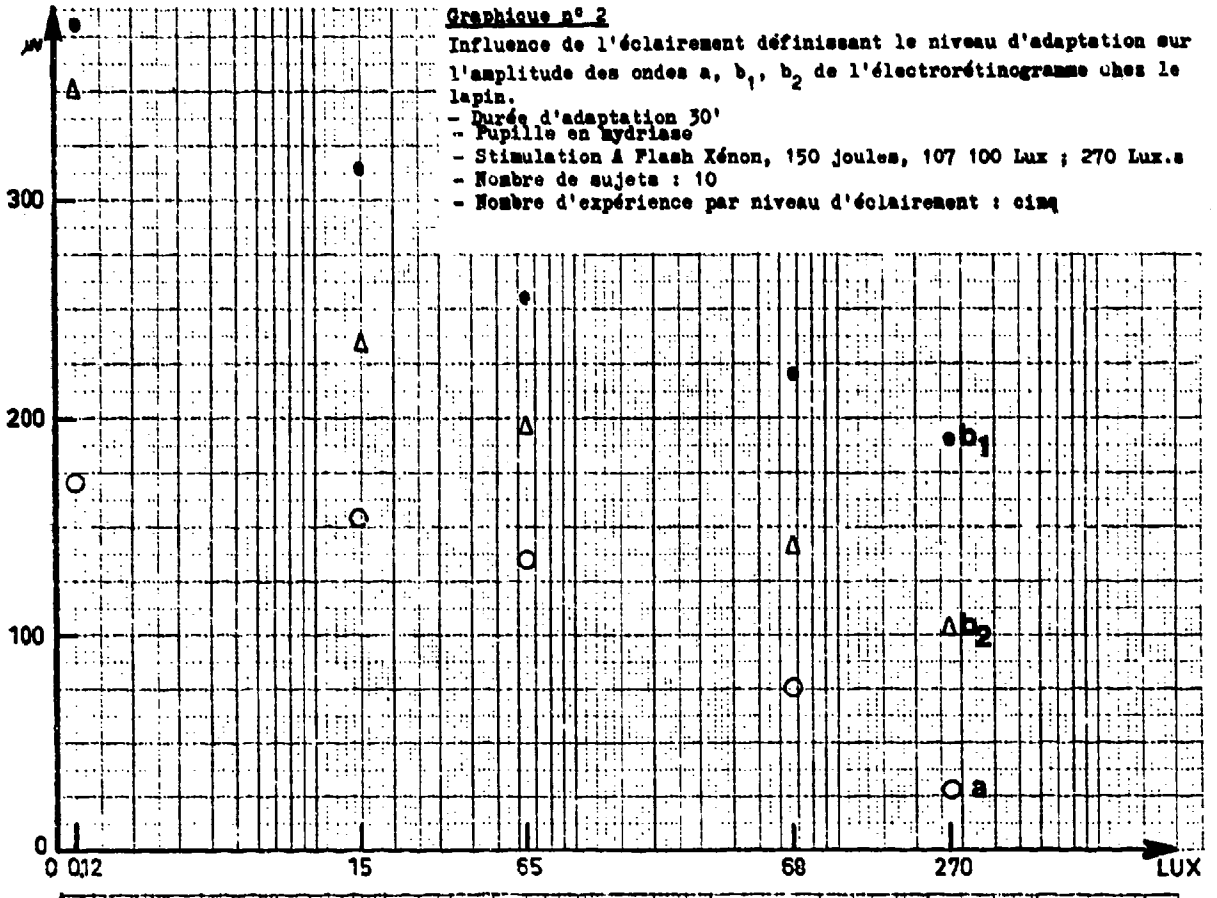
Le montage du dispositif éblouissant et les mesures photométriques sont dus à Monsieur CAMBORDE, Ingénieur, Etablissement Central de l'Armement que nous remercions.



Graphique n° 1

Evolution de l'électrorétinogramme et de la réponse évoquée recueillie au niveau de l'aire visuelle primaire, chez le lapin adulte, adapté à l'obscurité et l'oeil en mydriase, lors dune double stimulation S, située environ 3 à 4 unités log au-dessus du seuil.
- Stimulation test S 1800 Lux, 5 Lux.s
- Intervalle de temps séparant les 2 stimulations S_1 et S_2 = 290 ms.

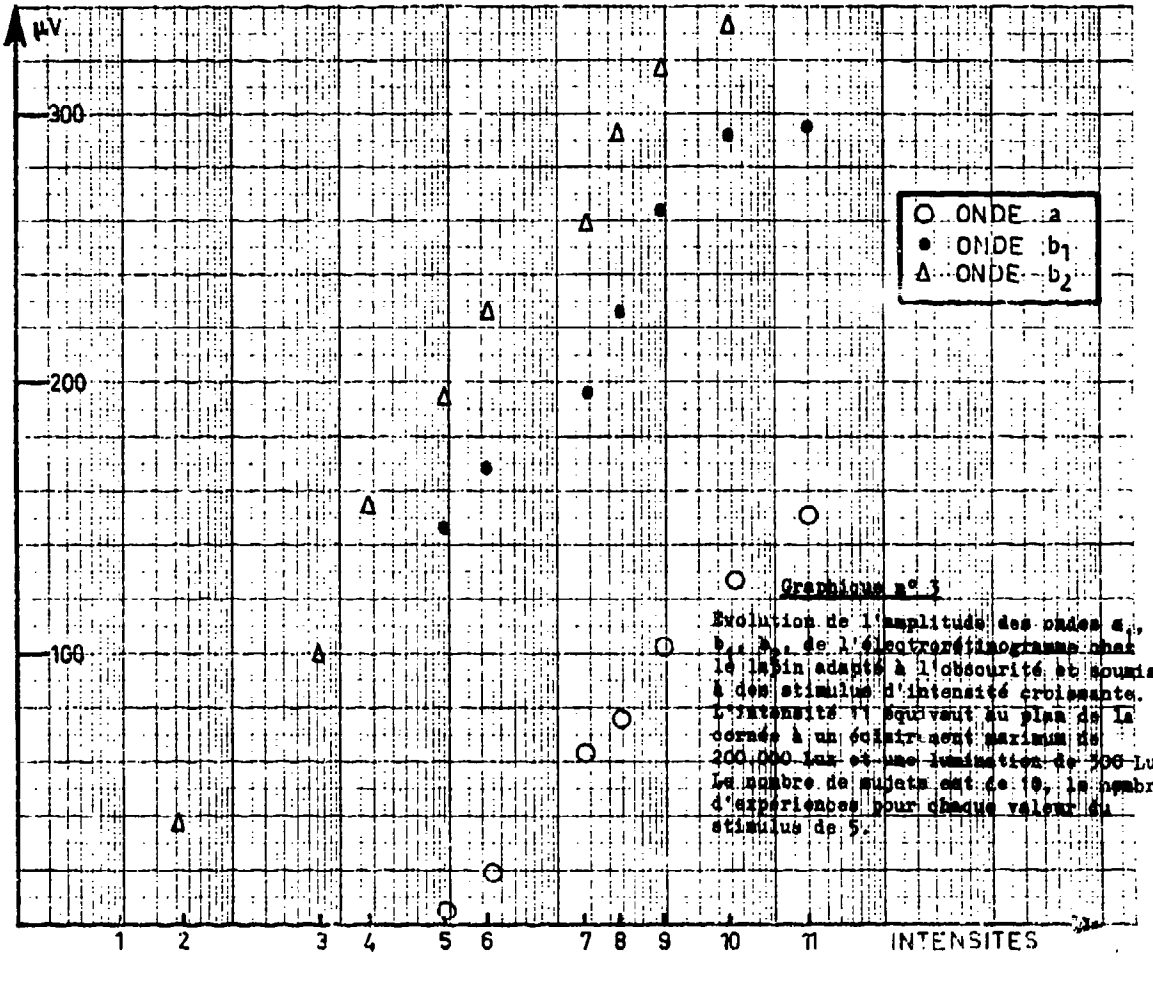
Le graphique n'est qu'une illustration, mais l'ensemble des mesures est effectué directement sur les valeurs contenues en mémoire, après conversion analogique numérique. On remarque ici, lors de la seconde stimulation, la restauration à peine amorcée de l'onde a et l'amplitude réduite de la composante primaire du potentiel évoqué dont la post-décharge est par contre importante.



Graphique n° 2

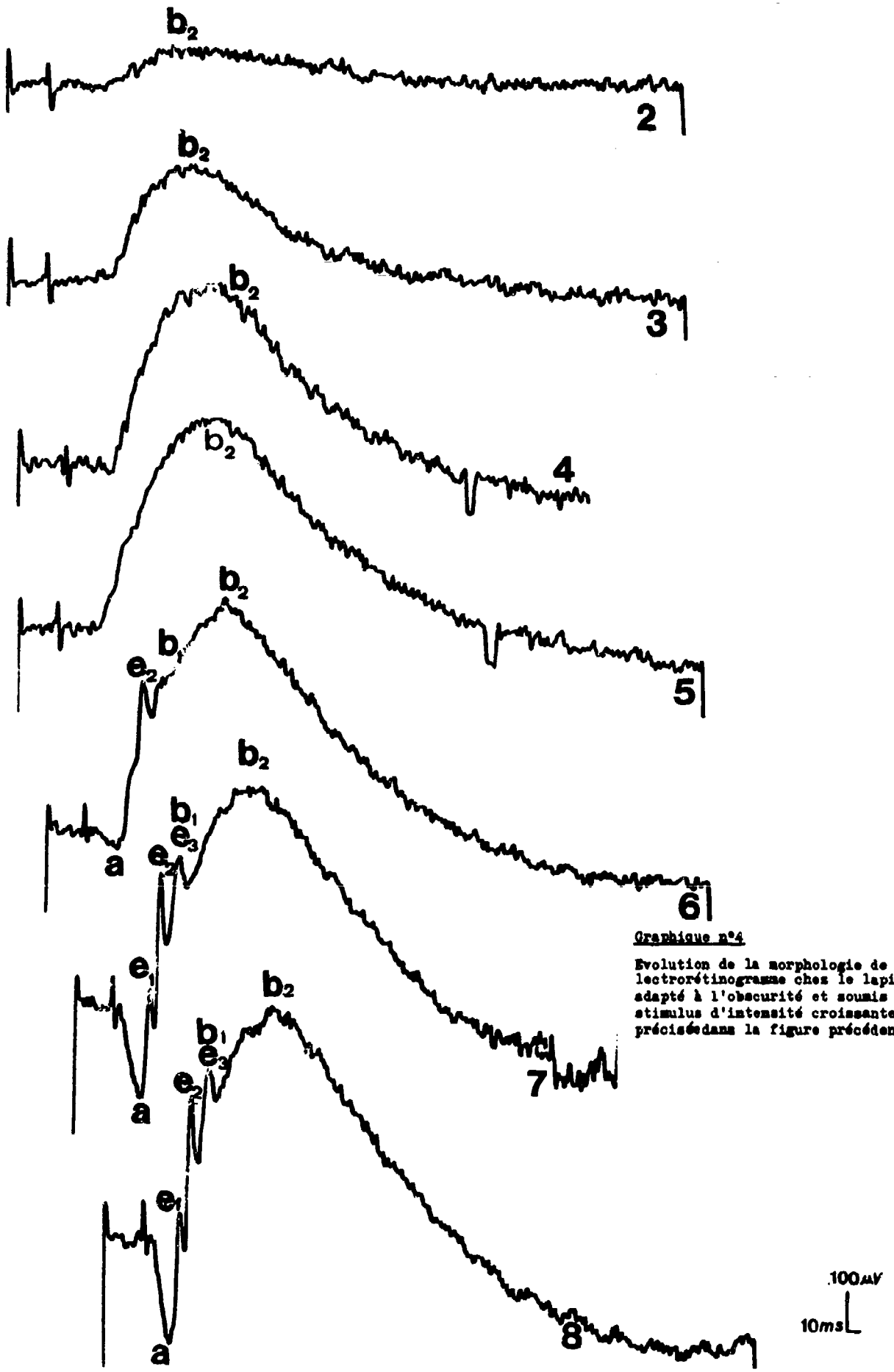
Influence de l'éclairement définissant le niveau d'adaptation sur l'amplitude des ondes a, b_1, b_2 de l'électrorétinogramme chez le lapin.

- Durée d'adaptation 30'
- Pupille en mydriase
- Stimulation à Flash Xénon, 150 joules, 107 100 Lux ; 270 Lux.s
- Nombre de sujets : 10
- Nombre d'expérience par niveau d'éclairement : cinq



Graphique n° 3

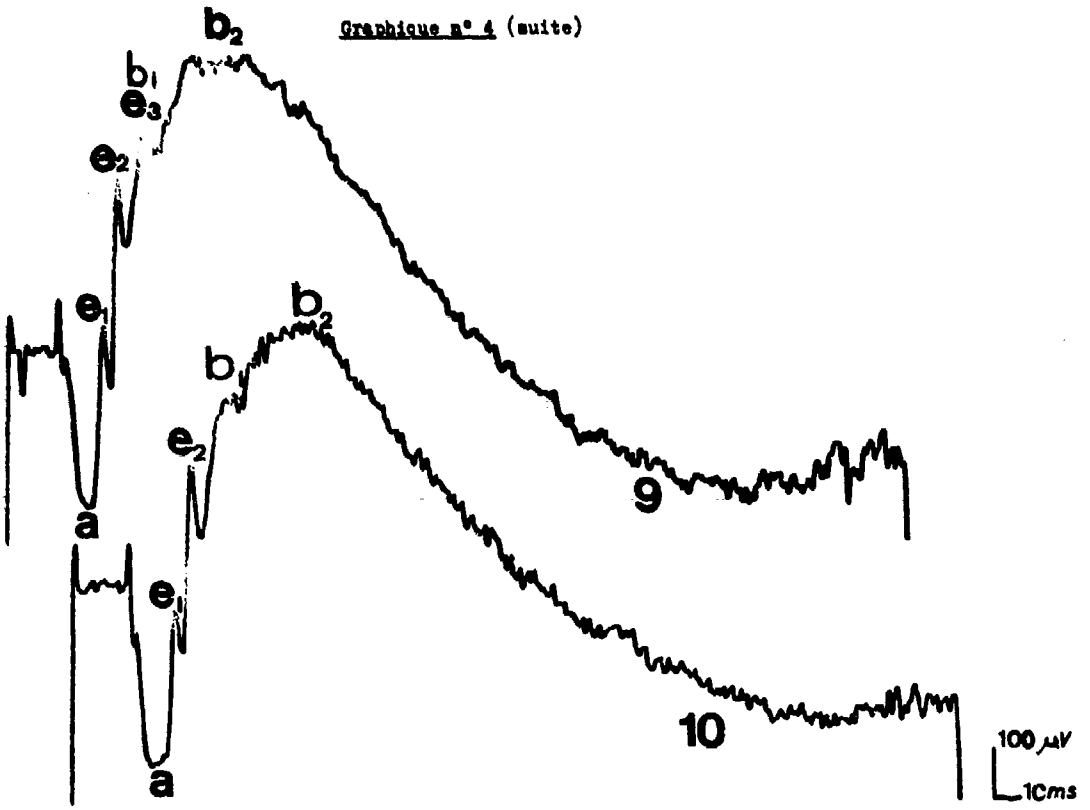
Evolution de l'amplitude des ondes a, b_1, b_2, de l'électrorétinogramme chez le lapin adapté à l'obscurité et soumis à des stimulus d'intensité croissante. L'intensité 11 équivaut au plan de la cornée à un éclairement maximum de 200.000 Lux et une lumination de 300 Lux.s Le nombre de sujets est de 10, le nombre d'expériences pour chaque valeur du stimulus de 5.

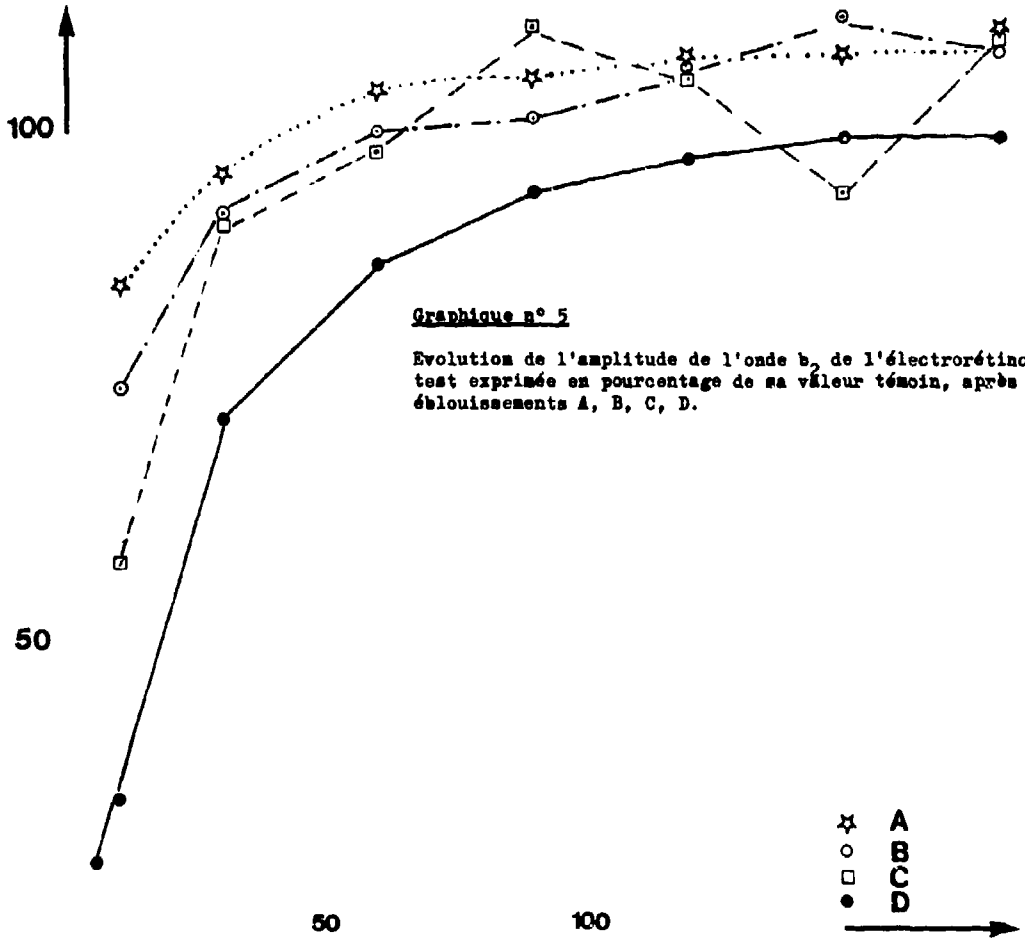


Graphique n°4

Evolution de la morphologie de l'électrorétinogramme chez le lapin adapté à l'obscurité et soumis à stimulus d'intensité croissante, précisédans la figure précédente.

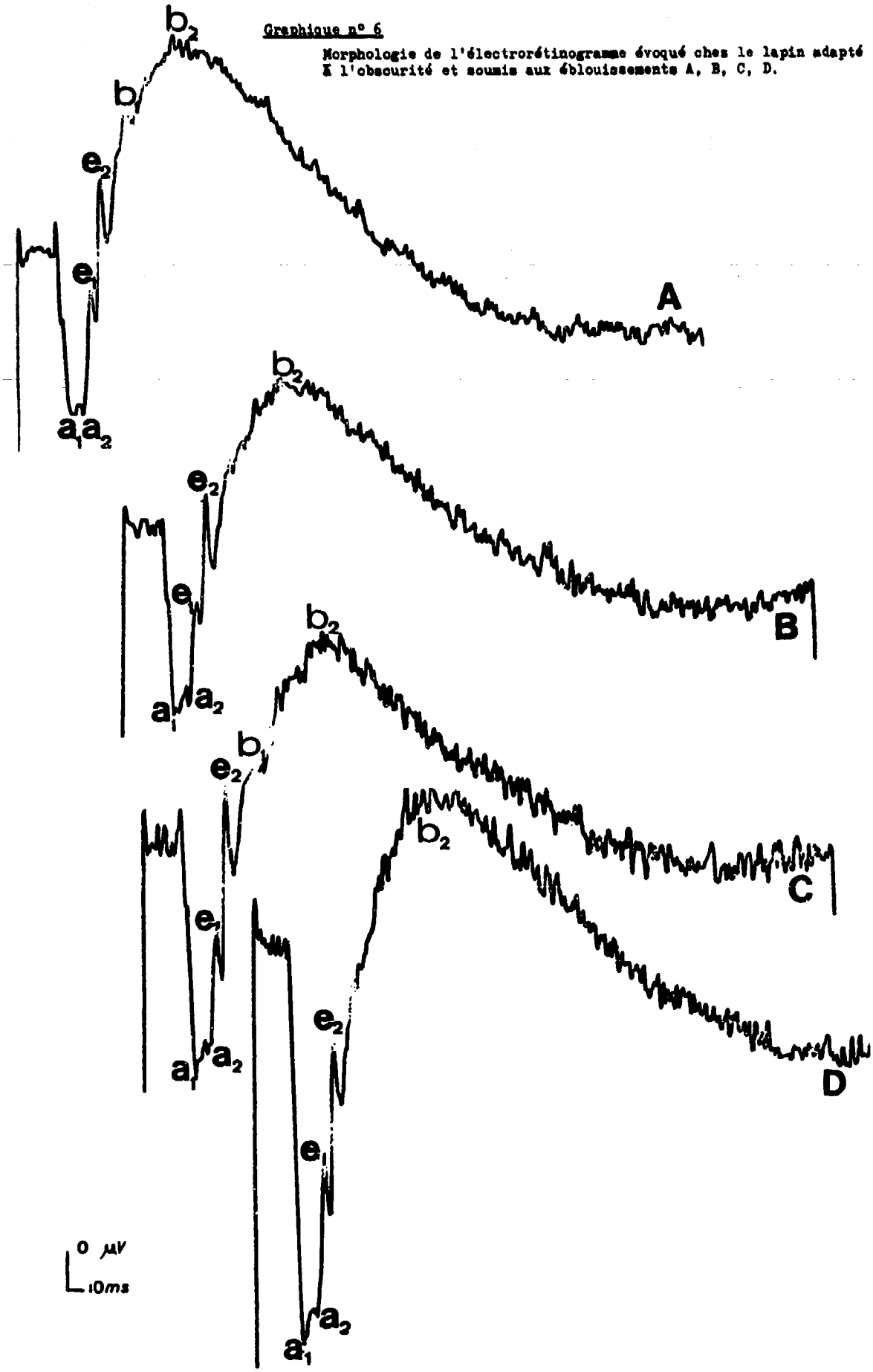
Graphique n° 4 (suite)





Graphique n° 5

Evolution de l'amplitude de l'onde b_2 de l'électrorétinogramme test exprimée en pourcentage de sa valeur témoin, après les éblouissements A, B, C, D.



Graphique n° 6

Morphologie de l'électrorétinogramme évoqué chez le lapin adapté à l'obscurité et soumis aux éblouissements A, B, C, D.

DISCUSSION

WILEY: Probably what I need is some more clarification rather than a question. But, did you say that you felt the ERG was modified by some feedback from the more central portion of the visual system, the nervous system?

CHEVALERAUD: I am basically relating my hypothesis which considers that the ERG which originates at the retinal level may be controlled by chemical substances durinr or for the retro-retinal feedback--that which intervenes in the evolution of the ERG.

WILEY: But are these maintained at the retinal level, or do you feel they are some kind of neuro feedback from higher centers? Are you talking about biochemical control?

CHEVALERAUD: They can be, at the level of the optic nerve. Certain fibers which should be inhibiting fibers of the ERG which then would bring certain changes in the ERG.

WILEY: Such feedback has never been demonstrated anatomically or electrophysiologically, I don't believe, or has it?

CHEVALERAUD: In the primate this has been demonstrated.

COMMENTS

PERDRIEL: It is certain that the thalamus, based on sensory physiology, has been the filter of our sensations and of all the "inputs" reaching it, be they audio, video, or even anesthetic. And one should admit that the divergent (inconsistent) results we have obtained between the cortical responses to evoked occipital potentials and those recorded at the retina are related to this thalamic interference. On the other hand, one knows apparently the effective pathways of this feedback, especially Jacobson who has demonstrated in the dog that certain fibers exist near the optic nerve, sectioning of which has brought about an increase of the electroretinogram (ERG). Moreover, in clinical medicine when an atrophy of the optic nerve is present--namely, when centripetal conduction is absent, one observes, paradoxically, a hyperactivity of the retinal potentials. This would seem to prove that damage to the optic nerve frees the system controlling feedback which, in turn, changes the usual amplitude of the ERG.

IN-FLIGHT EVALUATION OF HAND-HELD OPTICALLY STABILIZED TARGET ACQUISITION DEVICES

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With the arrival of improved optical devices and radar detectors on today's battlefield there exists a need to stand off from the enemy as far as possible and yet still be able to acquire and identify targets at these greater ranges. The target acquisition problems due to this increased range may be reduced through optical magnification. However, the vibrations inherent in helicopters are bothersome to effective use of these devices and increasingly so with magnification. In order to overcome this problem, optical stabilizing systems were incorporated in the viewing devices.

The first part of this report pertains to an in-flight comparison of several devices. Considering size, weight, complexity and performance in an in-flight visual acuity task, one of the devices looked very promising.

In part two, a group of twenty-nine subjects used a single device in a scout helicopter flight scenario. Reports had been received that the device produced motion sickness and the experimental plan was designed to assess this as well as visual acuity in flight. The subjects flew the scenario first with the unaided eye and then with the device in both a stabilized and unstabilized (caged) mode. The latter two flights were counterbalanced across subjects. Following the flight phase, the subjects were given a series of tests to evaluate individual susceptibility to motion sickness. Performance in the visual acuity task was significantly correlated with the airsickness ratings of an on-board experimenter; however, there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged.

INTRODUCTION

The use of improved aircraft detection devices by potential enemies has created a need to increase our stand off distances. However, we still must be able to acquire and identify targets at these greater ranges. Target acquisition problems, due to increased range, may be reduced through optical magnification. However, its effectiveness, when used in conjunction with aerial observation, is degraded because of the inherent vibrations of a helicopter in flight. In order to overcome this problem, stabilizing systems designed to dampen vibrations were incorporated in the viewing devices. The United States Army Aeromedical Research Laboratory was invited to make a comparative evaluation of several such devices. They were:

a. Ken-Labs, Inc. Stabilizer EXFA 28V D.C. (Figure 1)

Manufactured by Ken-Lab. Inc., this is an active hand-held stabilized platform upon which we mounted a pair of 10 X 50 Bushnell binoculars. Electrical power for the stabilizer was obtained from the aircraft.

b. Monocular-R-Mark 1610 - X3 (Figure 2)

Manufactured by the Marks Division of Stabilizer Optics Corporation, this is a 10 power, hand-held, D.C. powered device.

c. Stedi-Eye 3ma Stabilized 8X telescope (Figure 3)

Manufactured by Fraser-Volpe Corporation, this stabilization system can be operated either actively (rechargable batteries) or passively. It is a monocular hand-held device.

d. Stedi-Eye 3p Stabilized 8X telescope (Figure 4)

This unit is also manufactured by Fraser-Volpe and contains the same optics as in the Stedi-Eye 3ma except it is passive, not requiring electrical assist for stabilization.

e. Trans-Lens, D3 (Figure 5)

Manufactured by Dynascience Corporation, this is an electrically powered, 8X magnification, monocular viewing device.

Part I of the report concerns this comparison.

Part II was also an evaluation using a stablized optical viewing device; however, there was only one unit (an XM-76 monocular, stabilized device by Dynascience) and a comparison was made between the subject's performance with the viewer in its stabilized mode, in a caged (non-stabilized) mode, and with the unaided eye. In addition, the flight scenario was more complex simulating an Army scout helicopter profile. An extensive study was made concurrently in order to evaluate the effect of stabilization upon motion sickness. However, we will be primarily concerned in Part II with the visual acuity aspects of this device.

Figure 6 illustrates the target used in both Part I and Part II. In Part I only the largest Landolt "C" was in use.

PART I - METHOD

All observations were made from the front seats of a JUH-1H helicopter flown at the U.S. Army Aeromedical Research Laboratory's (USAARL) instrumented range[1]. The course was 7500 meters in length over moderately flat farmland.

The target consisted of a black Landolt C, 1.745 meters in diameter, on a white 8 ft. by 8 ft. background (86% contrast) as seen on the left side of Figure 6. The standard dimensional ratios of height:stroke width:gap size (5:1:1) were used. The gap in the letter was changed after each run to one of eight positions and the subject's task was to report the correct orientation.

The subject was forced to guess the letter's orientation (eight alternative, forced choice) as soon as the target location was detected. He continued to respond until he positively confirmed the orientation of the target.

The recorded values of interest were:

a. The distance at which the subject first correctly identified the Landolt C orientation followed by a second correct response and no subsequent erroneous answers.

b. The distance at which he positively confirmed his sighting.

Six male subjects were used. The three used on the first day were aircrewmen (two pilots and one crew chief). They tested the Ken-Labs device, the Mark 1610, the Trans-Lens D3 and the Stedi-Eye 3ma. Upon completion of their data collection period, a decision was made to discontinue testing the Trans-Lens D3 as its performance was markedly inferior to the remaining three devices.

The three subjects on the second day were all scientific investigators experienced in making visual observations. The design was repeated except that the Stedi-Eye 3p was substituted for the Trans-Lens D3. The Stedi-Eye 3p was not included on the first day because the optics are the same as those in the Stedi-Eye 3ma. The only differences between these two units are the slightly larger size of the 3ma and their power requirement. The 3p is a passive device while the 3ma requires power (self-contained batteries).

Each of the six subjects made two runs with each device for a total of eight runs per subject.

The visibility was seven nautical miles or greater on both days.

PART I - RESULTS

Figure 7 is a comparison of the five devices using the mean angle subtended by the target at the distance at which the target was first identified and later confirmed. Since two of the devices were ten power and the other three were eight power, angular subtense was needed to eliminate this magnification difference. By using the proximal angular stimulus after magnification in this way, the differences shown in Figure 6 may be attributed to the stabilization capability and the optics of each device.

Figure 8 illustrates the mean distances at which correct and confirmed responses were made. In this figure compensation for magnification difference (8X vs 10X) is not made, allowing direct performance comparison of each device as it is commercially available.

The data were subjected to the Friedman Two-Way Analysis of Variance Test. The results from the three devices tested by all six subjects were analyzed. Separate test were made from the aircrewmen and scientists' data. The results are shown in Table 1.

TABLE 1 - CHI SQUARE SCORES USING THE FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST ON BOTH THE CORRECT AND POSITIVELY CONFIRMED SCORES FROM (A) ALL SUBJECTS, (B) AIRCREWMEN AND (C) SCIENTISTS

	CORRECT	CONFIRMED
All	6.33*	7.00**
Aircrewmen	7.0*	7.0*
Scientists	7.0*	5.4***

Reject Ho at: *.054, **.029, ***.175 (not sig.) where Ho is the hypothesis that the samples are from the same population.

PART I - DISCUSSION

In order to fully appreciate the differences in devices tested and to make final recommendations, it is necessary to compare additional information such as cost, weight, and reliability. This information is available from the manufacturers or from Frankford Arsenal[2,3].

It can be seen in Figures 7 and 8 that the performance results of the Mark 1610 (10X) and the Stedi-Eye 3p (8X) are similar, and that both of these devices were superior to the other devices tested. However, in addition to a considerably reduced cost, the Stedi-Eye 3p has several additional features which favor it. It does not require any electrical power (i.e., a passive device), and it is sufficiently small to be easily hand-held without requiring bracketry in the helicopter. Its size would allow easy storage; for example, in the UH-1, it could be stored in the map compartment available to both pilot and co-pilot. Also, the slightly lower magnification of the Stedi-Eye 3p allows a larger field of view.

A question might arise concerning the cause of the differences in the results between the two Stedi-Eye models. As mentioned previously, these two viewing devices have similar optics with the Model 3ma having the additional option of electrically-assisted stabilization. Yet, the passive Model 3p yielded better results. The differences can be attributed primarily to two reasons. The Model 3ma had an additional unit magnification sighting lens to be used for scanning. This sighting lens system caused some slight disabling glare because of an eye cup which was not sufficiently light-tight and a highly reflective posterior lens surface. Also, during the transition from a passive mode to an active mode on the Model 3ma, low frequency oscillations caused by the stabilization system interfered with the observations.

A comparison was made between the present results and data from Part II in which a different Dynascience's stabilization device (XM-76) was tested with the same target and helicopter as were used in this study. The results from the previous study indicated a resolution for the XM-76 was 2.8 minutes of arc, i.e., poorer than all of the present devices but the Trans-Lens.

The target was resolved by the unaided eye, in flight, at an average distance of 1710 meters. Figure 8 may now be used to also appreciate the increase in stand off range when the various devices are used.

PART I - RECOMMENDATION

The Fraser-Volpe prototype Stedi-Eye 3p should definitely be considered for use as a hand-held stabilizer for aerial observation. It has the advantages of performing as well or better than devices which are more costly and weigh more (and therefore would need to be mounted in the helicopter). The lower magnification (8X vs 10X) will also provide a larger field of view, seemingly without compromise in stand off distance for observation.

PART II - METHOD

The XM-76 (redesignated Dynalens model MS-023) manufactured by Dynascience Corporation is a monocular viewing device with a zoom capability. The optical image is stabilized by a gyroscopically controlled, variable wedge, fluid prism. It is powered by either an attached battery cassette or by 15-33V D.C. power. In this study, 28V D.C. power from the aircraft was used because the mission length exceeded the charge of the battery cassette. The device weighs 40 oz.[2,3].

All airborne observations were made from the observer's seat (left front) of a JUH-1H helicopter between 1000 hrs and 1430 hrs and only on days in which the visibility was greater than ten kilometers.

Twenty-nine subjects were used. All were commissioned officers in the Army. Two had graduated from the rotary wing flight training program, one had completed 94 hours in the roatry wing program, and the remainder were entering students. All subjects had previous flight experience either as civilian private pilots or as passengers in Army tactical operations.

The test course was nine kilometers in length over slightly rolling farm and woodlands.

Each subject flew one flight on each of three separate days. A flight consisted of five passes at the targets. Passes one and five were flown straight to the targets. Passes two and four were "pop-up" maneuvers in which the aircraft would fly below the line of sight to the targets then increase altitude until the target area was just visible and repeat this cycle as he approached the targets. Pass three consisted of continuous "S" turns with heading changes 30 to 40 degrees either side of the center line. All passes were flown at 55 knots to remain out of the dead man's portion of the engine failure envelope.

The first day's flight was made using only the unaided eye. On the second day, in order to prevent biased results from learning effects, half of the subjects used the XM-76 in a caged mode (as a control) and half used it as a stabilized viewing device. Their roles were then reversed on the third day. The subjects were not told which mode was being used. In both modes, the XM-76 was a seven power monocular viewing device. Although the XM-76 has a zoom capability from 1.5X to 12X, it was used in the 7X mode throughout to prevent confounding zoom effects with the stabilization effects which we were studying.

The subject's first task on each pass was to locate the target area with the unaided eye before viewing through the XM-76 (except on the first day when all sighting was with naked eye only). He then reported when he could detect the target panels followed by when he could distinguish that there were two separate panels. The targets on the panels were Landolt C's as shown in Figure 6. Target #1 was twice as large as #2 which, in turn, was twice the size of target #3. The gap in the C, which could be in any one of eight possible positions, was controlled by ground personnel at the target sites. The subject's final task was to report the gap position. A forced choice procedure was used. The subject was repeatedly requested to "guess" the position of the gap as soon as he reported that he could detect the two panels. The criterion for correct response was two responses of the correct orientation of the C in succession. The subject then diverted his attention to the next smaller target, and the procedure was repeated. This continued until the aircraft was within 1000 meters of the target at which time observations were terminated. The orientation of the C's were randomly selected and changed after each pass.

Before each flight and after each pass at the target, an on-board observer evaluated and checklist scored each subject relative to selected airsickness symptoms including pallor, sweating, facial expression, and in-flight anxiety. A second observer performed a similar evaluation immediately following the flight. These observer ratings were totaled and the resultant sum used as an over-all rating of airsickness susceptibility on an individual subject basis. At the end of the second and third flights, the subjects were required to complete a questionnaire which dealt with their subjective evaluation of the performance of the device and any observed airsickness reactions.

Observation distances were computed using the Aeromedical Research Laboratory's radio-radio range system on board the aircraft[1]. The system consists of four ground transmitters located on the corners of a 10 mile square giving 100 square miles of ranging area. Distances for this study were accurate to 50 meters through the 9000 meter course.

PART II - RESULTS

TABLE II

SUMMARY OF IN-FLIGHT AIRSICKNESS SYMPTOMS RECORDED BY THE ON-BOARD EXPERIMENTERS FOR THE THREE VIEWING CONDITIONS OF THE STUDY
Statistical summary for the entire subject group (n=29)

	Unaided eye (no viewing device)	XM-76 (Caged)	XM-76 (Stabilized)
Group mean	40.6	61.1	55.2
Standard deviation	5.9	20.0	15.5
Standard error	1.1	3.7	2.9

The group mean, standard deviation, and standard error of the mean of the airsickness evaluation made by the two observers are listed in Table II for the three different flight conditions. Figures 9, 10, and 11 show distances for panel detection, distinguishing two separate panels, and correct identification of the Landolt C positions, as a function of the type of flight maneuver, for each of the three modes (unaided eye, XM-76 caged, and XM-76 stabilized). It is interesting that in all of

these figures, the subjects' performance with the more demanding task of detecting the orientation of the Landolt C was equivalent or slightly better on the pop-up maneuvers as on the straight and level passes. This could possibly be attributed to the subjects' awareness of the limited viewing time possible with the pop-up maneuvers. With the relatively unlimited viewing time in the straight and level passes, the subjects could have been more reticent to "guess" until they were more positive of their answers.

PART II - DISCUSSION

Referring to Table II, the group mean of 40.6 for the airsickness symptoms manifested during the first flight when the targets were viewed with the unaided eye represents the reference baseline for this subject group. This score indicated that the subject group was relatively undisturbed by the viewing task during the five-pass flight. As indicated by the group mean of 61.1 for the caged XM-76 flight and 55.2 for the stabilized XM-76 task, airsickness symptoms rose considerable when the visual task involved using an optical viewing device. A t-test comparison of the individual means for the three test conditions indicates a statistical difference (pL-.01) for both the caged XM-76 flight relative to the unaided eye flight (t = 5.29) and the stabilized XM-76 flights was not significant (t = 1.25). In this respect, these data indicate that the stabilization feature proper of the XM-76 did not in itself account for the observed rise in airsickness symptoms in that a comparable rise occurred when the device optics were not stabilized. There was a low but statistically significant correlation between airsickness rating data (r_s = 0.40, Spearman Rank-Order Correlation) and the subjects' target identification performance while using the XM-76 in the stabilized mode. The correlation was not significant (r_s = 0.30, pL .10) between target identification and results of the subjects' self-rating questionnaires. Details pertaining to these flights and questionnaire ratings of airsickness will be outlined in a separate following report[4]. A third report[5] will summarize the laboratory testing phase of the study which was directed toward gaining an over-all evaluation of vestibular function, visual function and motion sickness susceptibility rating of the subject group. Preliminary analysis of the results of these laboratory tests indicates that the subject group could be considered average or slightly above average in motion sickness susceptibility, although this is subject to some interpretation because of the special conditions under which the tests were carried out[5].

In 87 flights, including 435 target passes, there were no cases of nausea to the point of vomiting. One subject began sweating profusely on his second pass while using the XM-76 in the control (caged) mode, but was able to complete his five passes. (He had 60 previous flight hours including a private license.) Terminating each pass at approximately 1000 meters probably helped avoid nausea because the relative motion of the aircraft and target was slight at distances greater than this.

The static Snellen visual acuity threshold on normal observers is 20/15 to 20/20. All of the subjects were within this range. An acuity of 20/15 is represented by a gap size on a Landolt C of 0.75 minute of arc. The mean angular subtense for the unaided eye in flight was quite near the static threshold (identification of target #1).

Visual resolution or acuity is a rather complex measure. Many parameters (e.g., angular size, contrast, color, observation time, figure-ground visual complexity, luminance conditions, etc.) can have a profound effect on the performance results. The targets used in this study consisted of black Landolt C's of standard dimensional ratios on a white background yielding a contrast measured at the targets of 0.86. Obviously, when viewing through optical instruments, the contrast and image fidelity will be altered. Such a change is apparent in Figure 12. As shown in Figure 12, the observation distance to detect the gap in the larger target with unaided vision was 1697 m while with the stabilized XM-76 the distance was 2960 m. The corresponding target angular subtenses for these distances were 0.70 minute with the unaided eye and 0.40 with the stabilized XM-76. Therefore, the gain in performance was less than a factor of two (instead of seven) with the 7X magnification used in the XM-76. Such a non-linear gain can be attributed in part to a loss in contrast and the degraded quality of the image presented to the eye. These results can be used as an example of any discussion of performance and magnification. There is no simple relationship between optical magnification and visual observation distances. Some compromise in image quality is always necessary with optical viewing devices. The magnitude of the trade-off will depend upon the quality of the optics in each individual instrument.

Figure 12 shows the increased observation distances possible with the XM-76 when used in the stabilized mode compared to those found with the caged mode. While the differences were slight, they were statistically significant (p = 0.01, Wilcoxin Matched Pairs, Signed Ranks Test).

The Combat Developments Experimentation Command (CDEC) experiment 43.6 contained a resolution section in which the XM-76 was compared with an XM-26 and an XM-27 (other target acquisition sights)[6]. The resolution of the XM-76 was 2 1/2 times poorer than the other two. The CDEC mean resolution for the XM-76 was 2.8 minutes of arc, the same as our finding.

PART II - CONCLUSIONS

The use of the denoted optical device under the flight regimen selected for this study did not result in a significant airsickness problem. It was observed, however, that the incidence of airsickness symptoms rose when the subjects performed their assigned visual task with the device rather than the unaided eye. Since there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged, the stabilization feature proper could not be identified as a problem source. The data also indicate that target acquisition performance was significantly correlated with the airsickness ratings of the on-board experimenter. Correlation with the postflight self-rating questionnaire, though in the same direction, was not significant. The direction of the correlation, assuming it would be sustained in repeat testing, suggests that individuals who maintain good visual performance tend to show fewer signs of sickness or conversely, those who show signs of sickness tended to perform below average. In this experiment, because very little airsickness was encountered, there was little opportunity for potential relations between airsickness and visual performance to become manifest.

DISCLAIMER

The findings in this report are not to be construed as an Official Department of the Army position unless so designated by other authorized documents.

REFERENCES

1. Huffman, H.; Hofmann, M. A. and Sleeter, M. R., Helicopter in-flight monitoring system, March 1972, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, USAARL Report 72-11.

2. Britten, A. J.; Cook, R. T. and Sorin, S. M., Comparative evaluation of militarized commercial hand-held stabilized optical viewing devices, January 1974, Frankford Arsenal, PA, Memorandum Report No. M74-3-1.

3. Britten, A. J.; Cook, R. T. and Sorin, S. M., Comparative evaluation of commercial hand-held stabilized optical viewing devices, November 1972, Frankford Arsenal, PA, Memorandum Report M72-26-1.

4. Hixson, C.; Guedry, F. E., Jr.; Norman, J. W.; Glick, D. D.; and Wiley, R. W., Development of a prototype experimental plan to evaluate stabilized optical viewing devices: II. In-flight measures of airsickness potential, (In preparation).

5. Guedry, F. E. Jr.; Hixson, C.; Norman, J. W.; Glick, D. D.; and Wiley, R. W., Development of a prototype experimental plan to evaluate stabilized optical viewing devices: III. Laboratory evaluation of individual susceptibility, (In preparation).

6. ____Attack helicopter daylight defense, USA CDEC Experiment 43.6, Final Report Phases I, II, and III, Volume I, Annex J, Fort Ord, CA, #ACN-1871.

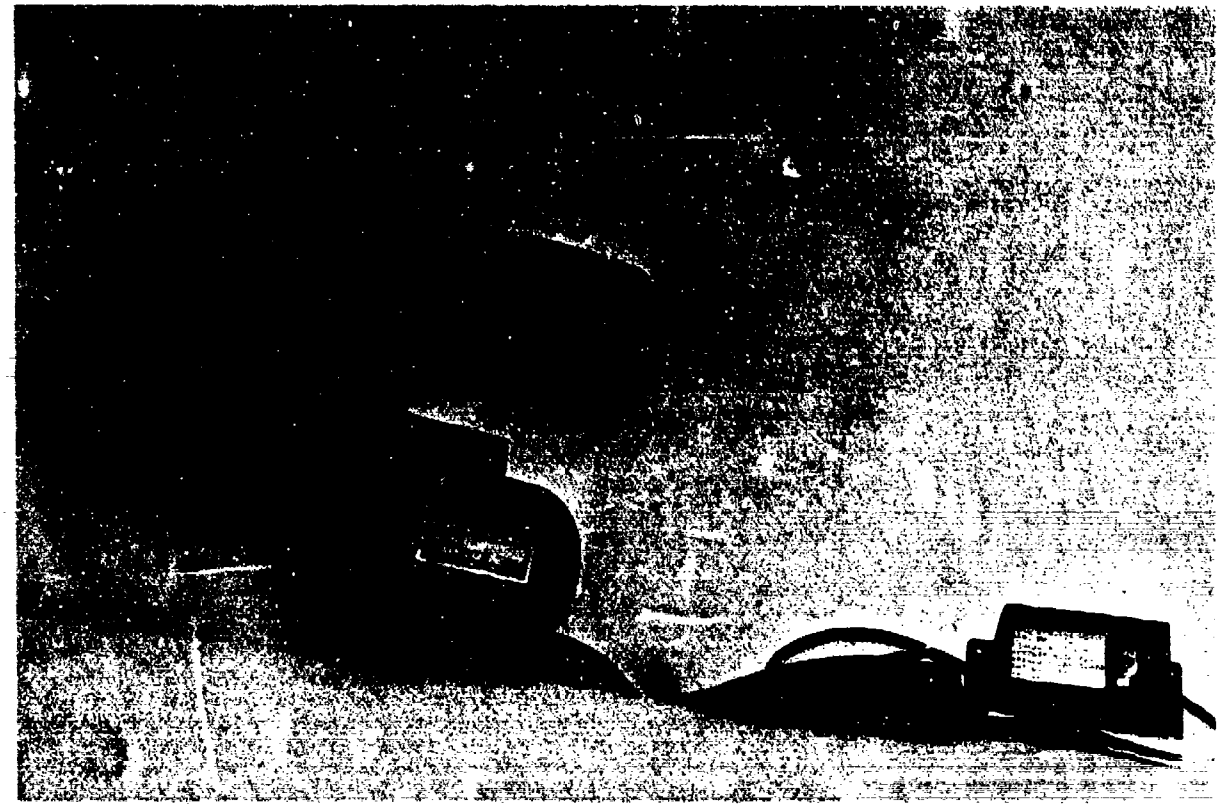


Fig.1 Ken-Labs, Inc. Stabilizer EXFA 28 volt direct current (with 10 x 50 Bushnell binocular)

Fig.2 Mark 1610 (10X)

Fig.3 Stedi-Eye 3ma (8X)

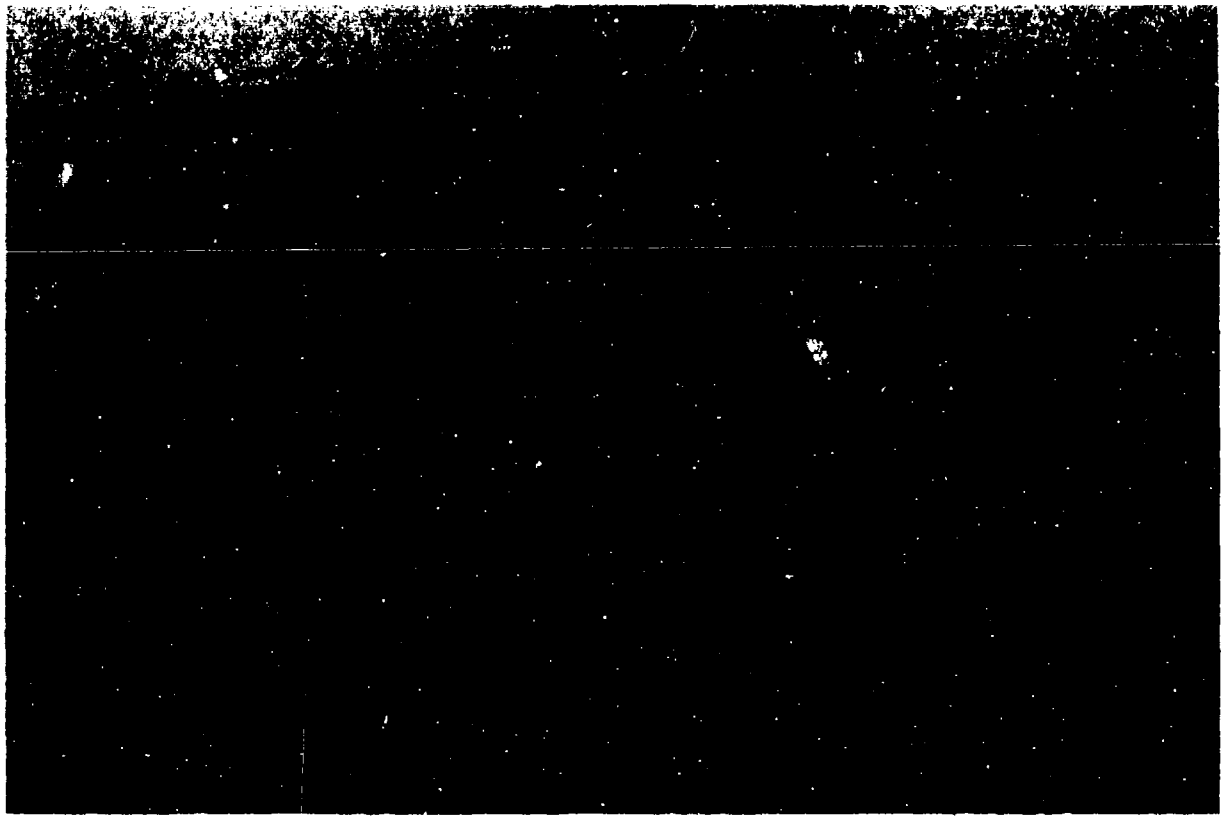
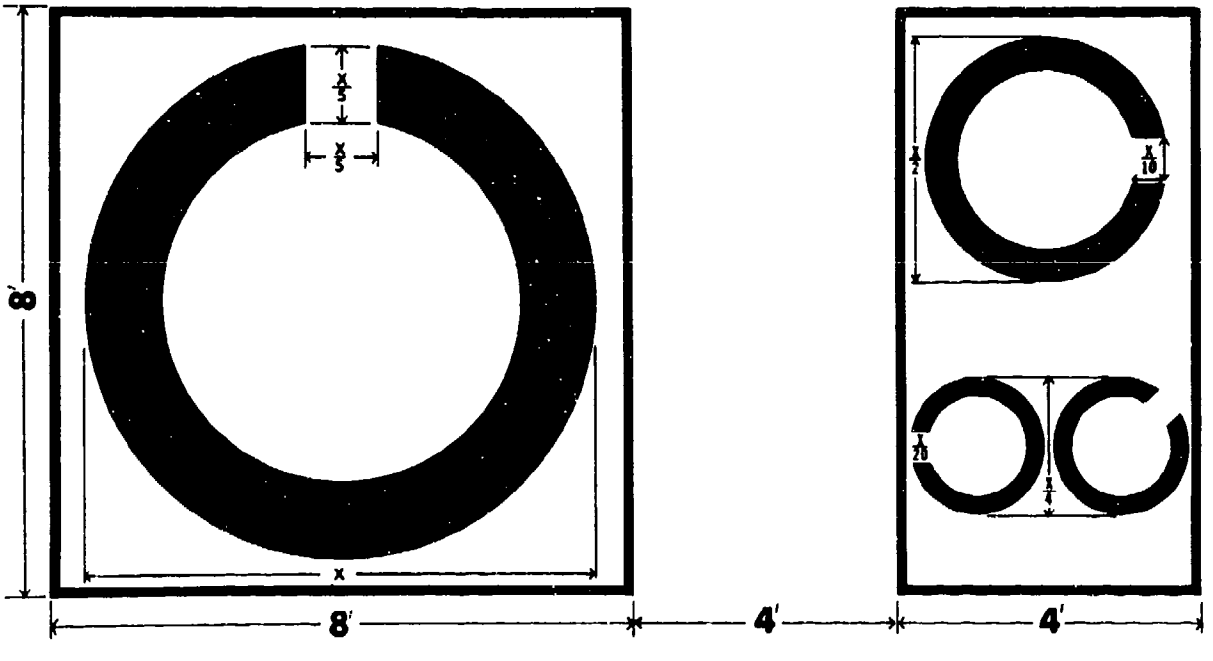


Fig.4 Stedi-Eye 3p (8X)

Fig.5 Trans-Lens, D3 (8X)



TARGETS ROTATABLE AND WERE POSITIONED
IN ONE OF 8 POSITIONS X=1.754M (5.73FT)

Fig.6 Target design and dimensions

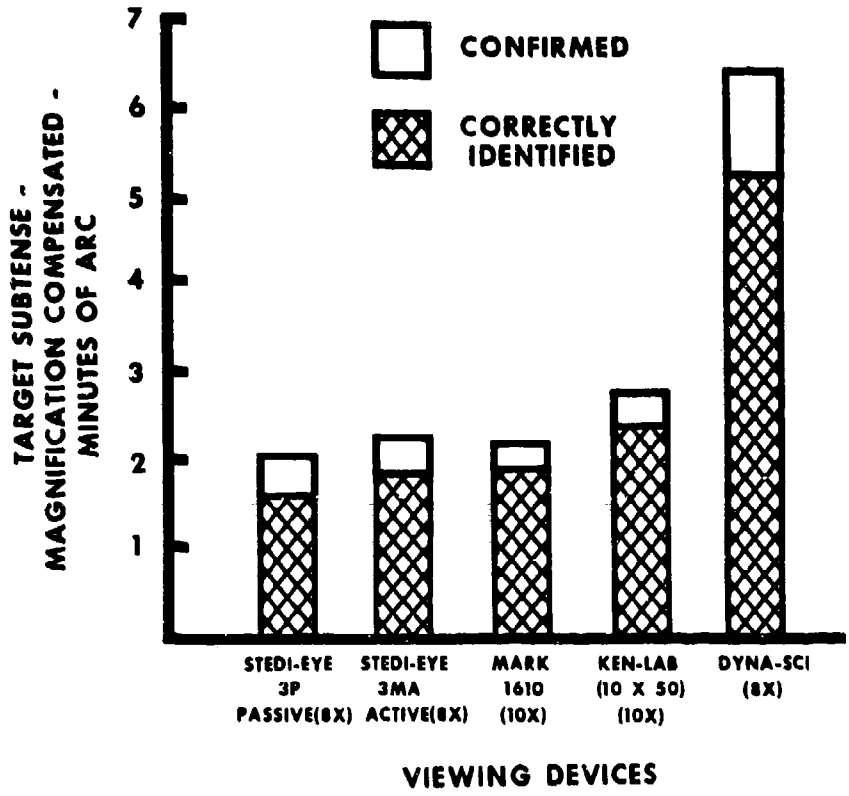


Fig.7 Target size at the identification distance as a function of viewing device. Magnification differences have been compensated (8X vs 10X)

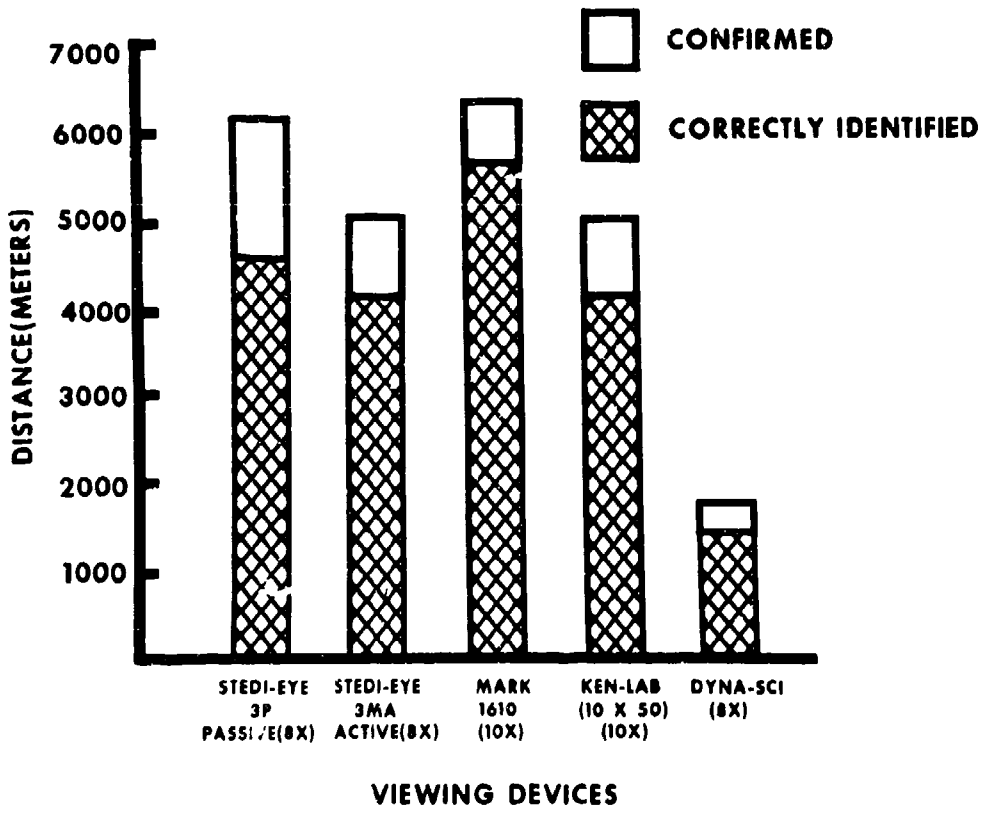


Fig.8 Target identification distance as a function of viewing device

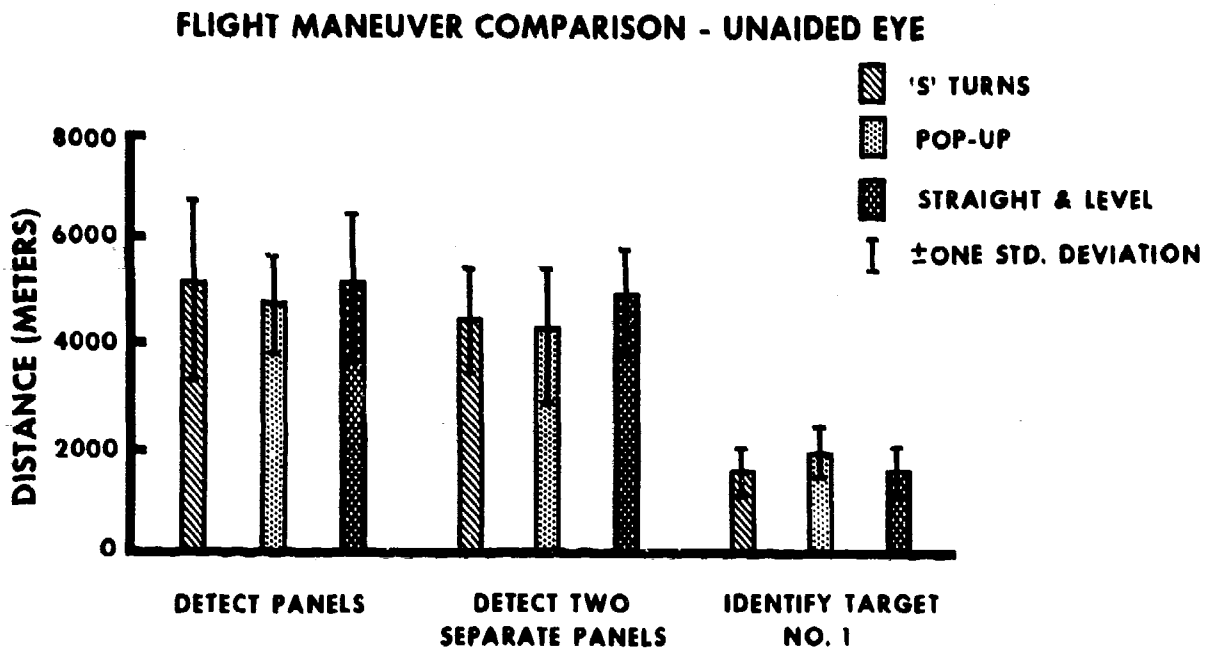


Figure 9

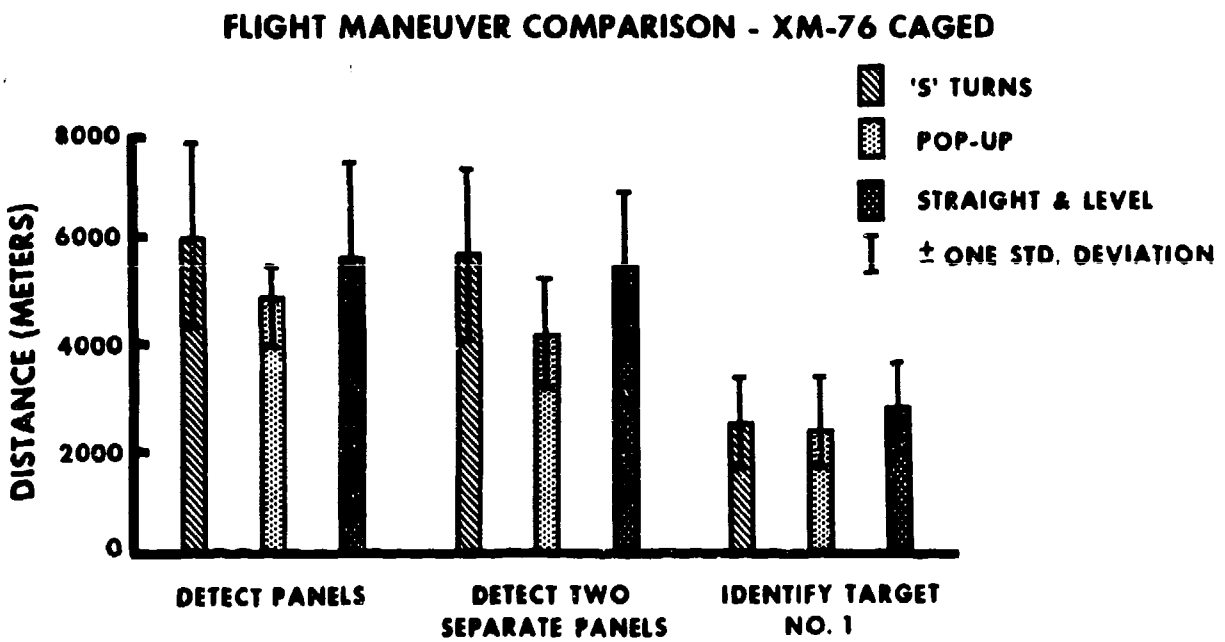


Figure 10

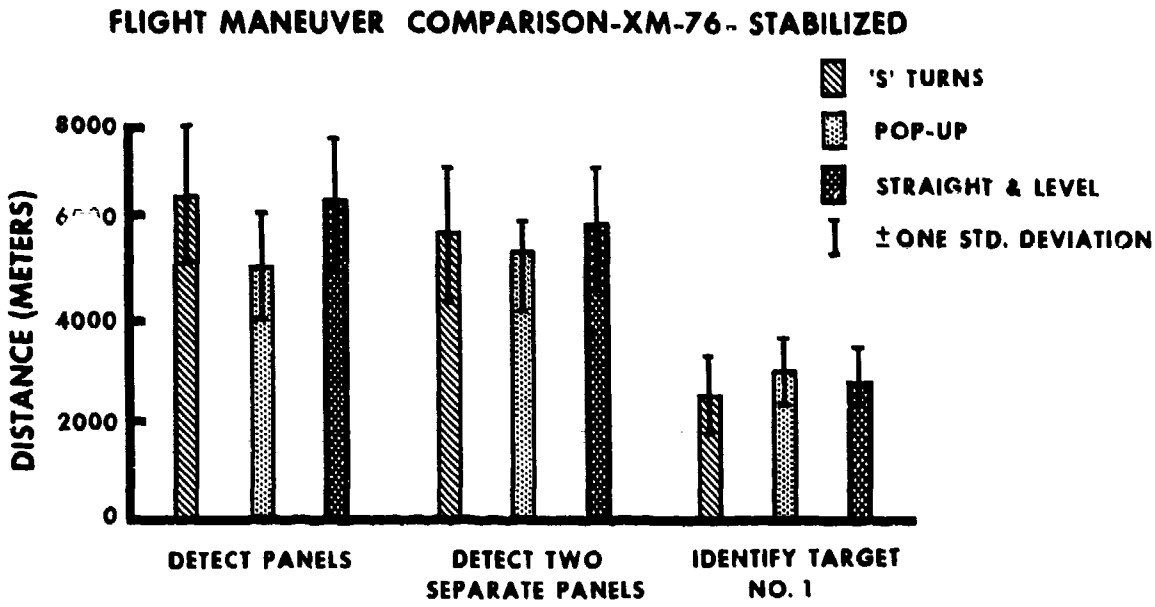


Figure 11

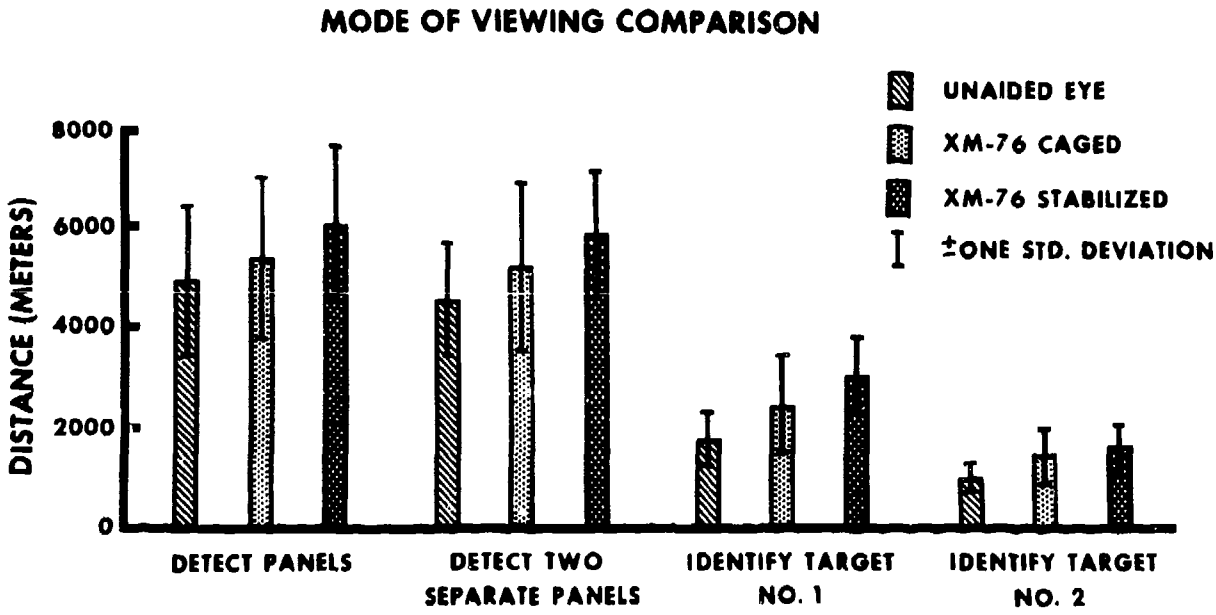


Figure 12

DISCUSSION

TREDICI: This stabilized target acquisition device is a gyroscopic instrument which is spinning at high speed?

GLICK: Yes.

TREDICI: Are they held?

GLICK: Hand-held.

TREDICI: I do not quite understand how a prism is incorporated.

GLICK: The prism again is mounted loosely so that it moves with the vibration of the helicopter. In effect, when the device moves, the prism remains stable.

TREDICI: I see. It is more or less fluid?

GLICK: It is a fluid dampening motion.

FUCHS: You just said that you saw a need to stabilize the device. Didn't you see any equal need for stabilizing the pilot?

GLICK: Yes, however, stabilizing the device, the eye is able to track the picture quite well. As I mentioned, if you move your head your eye will track and it can stabilize. I have seen designs of helicopters in which by leveling mounting the rotor blade will dampen some of the vibrations themselves.

TREDICI: I made this note when I read this paper--I may be incorrect, but you talked about the Stedi Eye 3P which was selected for the test and yet this model is not mentioned again. Why did you skip over to the XM-76 model in the test?

GLICK: I am sorry, I meant to show this is a two-part paper, a second study.

TREDICI: But we do not know any of the baselines on the XM-76, as I recall, it appeared out of nowhere.

GLICK: It was not in the first part of the test. That was a second study in which we used the same parameters and I wanted to include that as a sixth device. It was an earlier study, an earlier model, but it is still around, so it needed to be mentioned.

GENERAL DISCUSSION
Thomas J. Tredici, Colonel, USAF, MC

TREDICI: In the first part of this session we will once again simply open it up to questions from the floor, questions of any type, on any particular paper on Visual Aids or Eye Protection or how one might relate to the other. We will try to answer our questions by the combination of this "expertise" that we have here. Dr Forgie, you had a question concerning the CR-39 plastic lenses that warped.

FORGIE: Amongst the other nationalities, are they utilizing plastic lenses in their aircrew? We have here the United Kingdom and France.

BRENNAN: Not at the moment, No.

TREDICI: So whatever spectacles are used are glass. Are they impact resistant as they are in the United States?

BRENNAN: I must admit this is not my subject. I believe they are hardened glass, but I really cannot answer for the others.

ATKINSON: You and I have spoken, Mr Chairman, at the tea break. I think it may be interesting for people to know the Royal Air Force's attitude towards contact lenses. And as we heard from Dr Chevaleraud, work done some years ago rather suggested that the hard contact lenses were not really suitable for aircrew. And this has been our policy in the Royal Air Force: that hard contact lenses should not be worn by aviators. However, with the introduction of soft lenses it is likely that some aircrew members have taken private advice and are actually flying using the soft lenses. The RAF feels it should inform those people, after a suitable reappraisal of the situation, that either their use is discouraged or that a relaxation of our attitude may be possible. Therefore, about 20 suitable aviators currently in staff posts in London will be selected and fitted with soft lenses. The project will be jointly monitored by the RAF and Moorfield's Hospital in London. After an adequate trial with the maintenance of an acceptable correction of visual acuity these personnel will become involved in the second phase of the trial. This will involve subjecting the individuals to changes of environment in the climatic chamber, decompression chamber and centrifuge at the Institute of Aviation Medicine. Only if there are no problems will personnel be subjected to Phase 3, which is actual flight trials using soft lenses. It is hoped some results may be made available by the end of 1976.

TREDICI: Well, I think that will make a fine project. We will be watching your experiment, which appears to be a little more formalized and a little more directed than what we have done. For instance, concerning the soft lenses, we have done very little besides just observing. We did not feel they were that great an advantage over the hard lenses. Hard lenses have a limited use in the US Air Force. We are only using the hard lenses on medically indicated individuals to allow them to continue to fly, and the soft lenses would not be appropos for these cases. Anyway, because most of these had to do with the refractive status, irregular astigmatism, some mild cases of keratoconus, etc., the soft lenses do not work very well in these situations. Now, we, too, know that there are some individuals flying, maybe a fairly large number, with contact lenses that we never know about. But, we have all contact lens wearers theoretically listed at the USAF School of Aerospace Medicine because we have a USAF regulation that says they should all come there if they are going to be fitted, since we never anticipated a large number of cases and so we could keep better control. Presently, it is about 25 to 30 patients, and this system has worked very well. We have kept two of these who had the most severe keratoconus on flight status, one for a decade and one for 11 years. We recently had the first flyer to have to be subjected to a corneal transplant for his keratoconus. He is now in the recovery stage and he is not flying any longer. But, we had good success with the contacts in his case up to this point.

FUCHS: Just one comment. Since we have heard something on the attitude of the Royal Air Force at this point and your explanation as the practice stands within the US Air Force, I think it would be of utmost interest for all participants here to hear something on the attitudes as practiced in the other Air Forces.

BRENNAN: Returning to your original subject about corrective flying spectacles, I think one of the reasons we do not use columbian resin or any of these other plastics, polycarbonates, is that the prime protection against damage is by our visor system--the spectacles, of course, are worn behind the visor.

WARD: A comment and a request concerning contact lenses. Air Commadore Price's study being done in the UK might help us. When you get these individuals to the Institute of Aviation Medicine, could you please throw some dirt and some dust in their faces--that would be analogus to our operational conditions in the Army with helicopters and also some chemical substance--tear gas--which sometimes we come in contact with or something similar and a follow-on in close-to-the-ground environment and lengthening the ability to wear these devices, again, in relatively primitive operating conditions. I think they are very pertinent to military operations but many of you in the Air Forces have lived in a quite luxurious environment--we, in the Army and those of you in your armies also might not

soft contact lenses by aviators. It did not quite go into the tear gas routine and all these other tortures, but it was not very favorable to the soft lenses although that was the most complete study that I know of at this time.

BRENNAN: I think it is most important that we do look at toxic fumes because it has been reported that soft contact lenses can absorb and release them slowly thereafter, so it is a very valid point--not perhaps with tear gas.

WARD: Just another comment along the same line from the US Army and helicopter environment. The points you mentioned earlier about having to boil or asceptise these things--now, when we can, and I think we will shortly, go beyond that stage, the Army will try another study but that is a real stumbling block in the field now.

TREDICI: That's another reason I agree with you. The first reason was that if we were to eliminate anyone with astigmatism, almost all of our contact lens patients were because of irregular astigmatism or keratoconus. Another thing that we just cannot live with is all the paraphenalia that one needs to care for soft lenses. Now, I do know that in some foreign countries these soft contact lenses are being sterilized with chemical methods. But we cannot do that. The Food and Drug Administration has not allowed that as yet. We have to do it by boiling, which means you have to have your 110 volt electricity--you take the baby bottle sterilizer that comes with the kit and sterilize the lenses. The people we have given hard contacts to like to place them in their thin case and put it in their pocket and that is it--they can clean them with a lot less bother than the soft lenses.

PERDRIEL: What Dr Tredici just said is quite correct. At present, in France we have the possibility of using chemical sterilization methods which are furnished with the lenses and which improve the hygiene of these lenses. On the other hand, one should also realize that in France they are not worn unless they are prescribed by the ophthalmologist, and adaptation is done under the control of an ophthalmologist. Consequently, less and less individuals (subjects) go to a fitter who is not a physician because in the latter case the tolerance is always less than when one sees a physician. This is not only true for aviation, but also for violent sports, such as rubby or skiing as indicated by the interest for the lenses. Moreover, I believe that the reservations advanced relating their use in the Air Force are correct. Whatever the advantages of these soft lenses, they do avoid the wearing of spectacles; they increase the field of vision; they ensure a better depth perception because the size of the retinal image is much closer to reality than with the glasses, and this is important. And, despite everything, one needs to be careful, and in our regulations we do not recommend the contact lenses unless the visual acuity of one eye is 10/10. Therefore, if the pilot loses accidentally the lens he is authorized to wear, he still has one good eye without any aid. We usually allow the wearing of these lenses to seasoned pilots who were able to continue their flying activity, thanks to a unilateral contact lens. And, presently, we believe that better than the scleral glass (lens) the soft lenses, as demonstrated by results obtained by clinicians, are by all means best indicated. Thus, militarily speaking, we can salvage excellent pilots whose career would be otherwise finished.

TREDICI: This is exactly our USAF policy on the use of contact lenses by aircrew. They are for medical indications only and presently we have found the hard contact lens much more satisfactory than the soft lens. We, too, have fitted only one eye in most cases. Our indications have been to continue a flyer's career after he has suffered trauma to the cornea, loss of a lens, irregular astigmatism or keratoconus.

CLARKE: If we go back to the earlier sessions on acceleration and consider some of the concerns that were spoken about during the pathology session having to do with the effect of helmet weight with regards to escape and consider the many missions that require some kind of visual protection to be placed on the helmet, such as the protection against flash blindness, the new capabilities that are associated with visually-coupled systmes, laser protection, night vision devices, blast protection and ballistic protection, it seems to me that it might be worth considering the kind of approaches that are going to be required in the future to perform the integration of all of these performance capabilities into a system that the pilot will still be able to safely wear and use.

TREDICI: Well, Dr Clarke does have a very valid point. One approach would be better selection of individuals at the onset. At least spectacles and contact lenses would be eliminated from Dr Clarke's list of appliances and protective devices. Without these extra factors to integrate into the system, this would at least simplify things a bit. Does anyone else on the panel wish to comment.

CHISUM: I think that once you have selected pilots with good visual function, you still have the problem of the other visual aids and protective devices, and it seems that mission-specific equipment is one direction that might be considered. One point that I had meant to make, which I missed this morning when I spoke was regarding the very great importance of crew equipment people communicating with the engineering community early in the development phase so that inadequate fixes can be avoided. The integration can be considered very early in the development stage--what happened with VTAS for example was that the engineers were able to do all of these wonderful things and the physicists could design an optical system but they really did not consider the man and the platforms on which this had to be mounted so that they wound up with a lot of things that had to be, in retrospect, adapted

interface with the equipment, We are considering those problems very early but the mission-specific equipment seems to be a good resolution too with this kind of an approach, this kind of a problem rather, but in the attack community where we may require flash blindness protection or we may require some laser protection and we may also want to use some of the head-coupled visual aids, then we have a very severe integration problem, and we will undoubtedly have to make some kind of trade offs of things that we add or leave off the helmet because we cannot really sacrifice the protective function of the equipment in order to add some visual capability which may or may not really be necessary.

YELLAND: I would like the Panel's opinion on the science of orthokeratology which involves molding the cornea with a graduated series of contact lenses and it is my understanding that you can bring a person with visual acuity of, say, 20/200, 20/300 range going to 20/20, 20/30. Now, there is an increasing number of airline people who are doing this, having this done, and I suspect that the military people may also be involved.

TREDICI: Well, I am sorry that you brought up that topic. I think I have written the only article on that topic, which appeared in the medical literature. Now, I am supposed to be an expert, but I am really not because I have not practiced orthokeratology. Some of you may have not heard of orthokeratology. This is a term that was conceived by optometrists in the US, meaning straightening of the cornea. Now, any of us who have fitted contact lenses know what a misfit lens or a large, thick lens will sometimes alter the corneal curvature. If it is altered in the right manner, it may help the patient because altering the corneal curvature makes a large change in the refraction since the cornea does two thirds the refracting of the light rays. This might create another problem in that if you begin to fit such lenses you are going to have to monitor them very carefully because in a short time you may not know what their refractive error really is. On an annual examination they may be myopic; on the next they could be emmetropic or develop a little bit of astigmatism, etc. This is a real problem for our flight surgeons who are not ophthalmologists. Now, concerning orthokeratology, in the first place I am not sure that you will be able to tell who is being treated if he does not volunteer the information. One would need to know the patient's original keratometer readings, refraction and visual acuity and compare these findings with the present ones to evaluate the entire procedure. We do not recommend orthokeratology at all; we do not practice it in the US Air Force. We know that it is being performed, especially on people in the ROTC and cadets at the AF Academy, but these individuals are civilians and we really have no jurisdiction over what they do on their own time. What we have done was to observe what has been going on so we could get data and then perhaps either attempt to outlaw the procedure, condone it or change the visual standards. My own experience is that to alter one's cornea so as to alter the refraction from 20/300 or 20/400 acuity down to 20/20 is highly unlikely. I have seen only one case in which treatment of such a gross error was attempted. She was a female dietician and that young lady never came down to anywhere near 20/20 but she was 6 diopters myopic and her cornea was flattened down to about 2 diopters. Mostly, orthokeratology works on people who have about 1.00 to 1.50 diopters of myopia, just enough to fall outside of the pilot population or cut-off (-1.00D). They rush out and are orthokeratologized but you cannot predict whether they are going to end up with a nice sphere or they are going to develop some astigmatism or, like we have seen, keratoconus. We have seen only two such cases. One case has developed keratoconus only on the side wearing the contact lens, the other eye still looks like it is in pretty good shape. Now, what you are asking for is some guidance as to what you ought to do. I suppose if you have an adequate supply of aviation candidates you can simply say that you are not willing to accept anyone who wears contact lenses or needs contact lenses to bring his visual acuity status up to a certain level. Your problem then will be how you are going to find those undergoing treatment. The ones we have been following volunteered the information. They said: "We are having this treatment and we will let you observe what is happening." You can flatten the cornea to where you get a fairly decent acuity even when the contact lens is removed, but in about 95% of the cases the corneal collagen will all bounce back and the corneal curvature will revert back to what it was before the treatment, but not in every single case. That is where this procedure stands right now. You cannot predict whose cornea is going to change how much.

YELLAND: I suspect it is going to be a continuing problem but there is an optometrist in Toronto who is doing a flourishing practice in this. I know there are some airline pilots who are attending him, at least before their annual medical so that when they have this their visual acuity is going to acceptable levels, which is not were it not for orthokeratology.

FUCHS: May I add one question to follow Dr Yelland's. We have to consider that this is some kind of self medication, and my question is a practical one. Can you as an ophthalmologist doing an annual physical examination be aware that the aircrew did not use before such self-medicated orthokeratology just to get through the examination?

TREDICI: Yes and No. If you are willing to go through a lengthy examination and you have a baseline, then you can find it. A baseline means you have the pre-contact lens refraction, findings, and keratometric readings. Then compare these to your present findings and then you will know, but if he knew that he was coming in for an examination within a two-week period and he could titrate his contact lens wear against a very easy target--his acuity, he can tell when his acuity is at a certain level, then he could remove the lens and come to see you a day later, then the answer is No, because there usually is no abrasion or stippling of the cornea. So if you did not have the pre-contact lens data you would not be aware

people who want to get into aviation. What we have done at the AF Academy is to liberalize our visual standards. A small percentage of each graduating class are allowed to begin flight training wearing spectacles to correct their refractive errors. Orthokeratology results appear to be only temporary.

GRABAREK: I have one question concerning paper No. 6, a question of Prof Chevaleraud. Did you check the reaction of those soft lenses also during rapid decompression in your chamber flights or do you believe that there would be expected bad reactions. That is the first question, and the second question concerning paper No. 4, the paper of the Session Chairman is: Have you any experience of this same kind of sandwich-construction eye protection glasses? I could imagine that there could be good effect from combining different materials, to combine the good things of all those?

CHEVALERAUD: No, we have not made any rapid decompression runs because I had chosen to make one climb and one descent at 10 m/sec. It is, thus, relatively of little importance. As to what could happen during a rapid decompression, I believe there is less chance of bubbles or of a lens injury than with a hard contact lens. And this is an additional advantage of the soft lenses over the hard lenses.

TREDICI: I would like to add one word here. I believe the last slide that I had indicated that there would be changes in the materials, in new techniques and in fitting procedures which are a decade or two into the future. I know Zeiss of West Germany is working on a combination soft-hard lens, soft on the inside, hard on the outside, so that it will fit with comfort and still correct astigmatism. Now, this kind of an approach when you add perhaps increased oxygen permeability means that then the lens could be placed on the cornea and perhaps not be removed for months. As for the sandwich construction (laminates), Yes, combination of glass and plastic lenses have been made (like automobile windshields). They are very resistent to breakage but have never found wide favor because they are much too heavy.

PERDRIEL: I am going back to what has been said regarding the articles in daily publications (news) that both pilots and navigators may read concerning processes to improve their visual acuity. I believe that the role of the flight surgeon is to warn them against this procedure. In France, for a few years many pilots have tried to use Bates' method. It was a so-called method of relaxing and which apparently showed, as possibly the method just proposed in Canada, a certain success in the civilian but not in the aviation population. In time it was found that this method brought no results, but deteriorated already existing conditions. I believe that one must be extremely cautious, and stress this point to the pilots regarding the danger of increasing a 1/2 diopter to one full diopter as it has happened with some of Bates' methods. Therefore, I believe one must emphatically discourage these procedures. On the other hand, we know that eye surgery and corneal surgery may be performed on flying personnel and that keratoplasty on pilots following certain traumatic lesions yields excellent results. The Japanese have also used a surgical method called Sato's method to treat astigmatism. It consists in a posterior corneal incision to redice the curvature radius. This intervention has not proven to be effective. Unfortunately, at present, with the exception of optic procedures and certain surgical procedures one cannot improve vision following a corneal lesion.

TREDICI: I am going to take the liberty of changing the subject here rather abruptly to get on to one of the other areas. I will ask Dr Chevaleraud the question since presbyopia obviously does reduce the effectiveness and efficiency of a flyer: Was there any consideration given of just grounding the flyer rather than going through all of these manipulations?

CHEVALERAUD: No. I think that in our text we have a measurement (value) for near and far visual acuity. When an individual (subject) does not meet the conditions as defined, we are just as concerned with correcting both near and far visual acuity. And, so far as I know, we have never had to ground someone because he refused to wear near vision corrective aids. These, as you know, are necessary in certain phases of aviation where one needs to read using near vision.

TREDICI: All right. That is why I brought the subject up--if we had an oversupply of pilots, that would be the easiest way out of this whole thing. It would be a rather difficult thing to do, but we have brought in so many difficulties and to integrate even a bifocal or a trifocal with all the other apparatus that we are talking about, it is just not too efficient. I realize that my solution is like an ax, but I only brought it up to generate a discussion but since apparently nobody is willing to take that position we will go along and continue them in the cockpit with bifocal and trifocal lenses.

WARD: Addressing your question about the problem of bifocals, trifocals, glasses, contact lenses, and all these other vision aid devices, I am afraid that the individuals making the decisions and having the final decision-making authority fall within the category of those needing visual assistance. Also, they have sons and very good friends in the young age group that also need visual assistance to meet the flight standard training requirements. As long as we have this bias, I am afraid that we as physicians, physiologists, and optometrists are going to have to learn how to make these individuals who do not fit the ideal physical standards compatible with the mission profile and the machines they must fly.

GLIGE: A comment to the gentleman in reference to flashblindness. First, I would like to commend them all on what I think is an ingenious device and pass our regards to Dr Kutchins;

weapons, I think, has to be considered and would encourage you to continue in your work to see if we could get increased transmission. I agree that the KC 135 and B-52 missions could do well with 20% transmission whereas if you get into trees in the dusk and at dark it is just not a tenable situation so I would encourage you to continue with the efforts.

PFOFF: I could comment on that. We have on our continuing work with the Polaroid Corporation from whom we are obtaining our polarizers and from whom we plan on obtaining them in production. Commercial polarizers are designated as HN-22, HN-32, HN-38, the number being the percent transmission from unpolarized light. Within the past 6 months Polaroid has been successful in developing for us an HN-36 polarizer that has an improved off state when compared to their previously available HN-32 polarizers. Granted, we are talking about small percents but every little bit helps. The other two avenues they are working on for us is improving the off axis protection level for the polarizers and in bonding techniques. Realistically, we will probably do well to increase this figure to 25% unless we find out that we can alleviate the protection levels that the US military is asking us for--you can move up the transmission level in the open state if you are willing to sacrifice from a closed state. In other words, if you are willing to work with an OD of 2 to 3 rather than 3 to 4.5, then we could possibly raise this transmission level up to around 30% but you would have to give on one end. We will not get 50%, I assure you because if we have to use KG3 glass, they only transmit 87% of the light. Then, of course, you have the windscreen which is going to reduce the transmission even further.

TREDICI: I want to add something here, simply because these two gentlemen may not be aware that the Ophthalmology Branch at the USAF School of Aerospace Medicine was involved for nearly a decade--I inherited the project from Jim Culver on this flashblindness protection. We really were not successful in solving the riddle even though we spent a lot of funds,but we were laying down the foundation for the solution to this problem and so I do not think it was all done for naught, that when we finally did achieve a photochromic device it was like the EG&G goggle. In the goggle form, all the apparatus that were needed to set it off were so cumbersome--it had about 50 pounds of electronics, battery packs, etc., so this PLZT system is really one of the big breakthroughs--it is the fact that your weight is on the order of magnitude of 10X less and that is really what I think is the main advantage.

PFOFF: With our approach we are saving quite a bit of funds because now the magnitude of funds required for retrofitting the aircraft is reduced by quite a bit.

KNAPP: If I sound pessimistic, I do not mean to be so. I would like to just amplify a comment you made earlier, and I hope it is a comment that would bring a little realism to this. Everything we have heard has been about enhancement of one of man's sensors; the flash protection devices is nothing more than an enhancement of his blink reflex; the night vision goggles are enhancement of his normal physiologic ability to see at night or not to see at night; the hand-held stabilization devices and the VTAS, etc., all are extension of a normal sense. What this is going to amount to, if we keep going, is either we are going to have to go back to Mustangs and Hurricanes and leather helmets or we are going to have to get the orthopedists involved. We are going to have to fuse the man's neck so that he can support all of this weight and he can actually use it in the environment. And I will only plead, as I am involved in the biomechanics end of this and see these pilots come back from the test range, realize they cannot button their collars of their dress shirts at night because of acute muscle swelling. We have problems--if we add ounces to the man's head for whatever purpose. Now, I realize that we need enhancement to do our tactical missions, but there has to be a compromise, there has to be an end someplace to all of this.

I am both an engineer and a physician. And I know that, from the physical scientist standpoint, when we find a way of enhancing man's normal senses we sell it immediately to the operational community. This immediately brings to the line officer new tactics, new doctrines, new strategies. Then the medical department is asked to make the man work better as a human being in this environment and you just can't do anything to improve the physiology of man--all we can do it support him, and I think that, like Dr Chisum said, we need to get the medical people and the engineering people involved--and that just never happens. We have to be realistic about it. We hope it will work but we are reaching a limit here from a realistic pragmatic standpoint of what we can do with a man's head.

TREDICI: I agree with what you say, based on the observations you have made. We are out to prioritize things, advise what trade-offs would be necessary to what part of a mission. We are not dealing with an omni solution for all things, for all men and all situations--that might be the only way to go.

WARD: I thoroughly concur with that. I think that within the research community there are too many of us that promise too much to the engineer, to the operational side and are not honest and say we cannot extend reasonably the physiological limits of the individual and tell them: "You can give us all the money in the world and we cannot within a reasonable time, at a reasonable cost, and with a reasonable weight penalty solve your problems"; whereas there are a lot of people that will say: "Give us a lot of money and we will look at that problem." Okay, it keeps the jobs going; it keeps the institute open, but we are not being honest to the people we are supposed to be supporting.

TREDICI: But those are the people who may solve the problem. Where we are missing the point is that they are not involved in the overview of the whole thing--how important is that

PFOFF: I think our project shows an example of this. What we are looking for is not the goggle that we see here today--that is an interim goggle. Our goal was to keep it at one pound or less and we are there now, but we are not going to stop at one point or less. We will keep on going down; however, we are going to keep the endeavor open even after we get these in production to develop a pair of what you might call sunglasses. It is even our hope that these might even become the sunglasses and the flashblindness thermal protection for the eyes. For the B-1 bomber, we have already decided we are not going to man at all; it will be in the thermal shields, therefore, we have taken all the weight off the man in that particular circumstance. Now, I will give you a personal opinion. I would rather see us go back to a leather helmet and take everything off of it, and if we do have a necessity for a mission specific, for a device which puts some kind of beam or picture in a visor in front of the man's head, then we get a man that can operate in a high G environment to do that specific mission, and I would trade off the possibility of hitting his head after ejection on the ground to accomplish the mission because being very cruel, I would rather accomplish the mission and fracture the skull later than to protect the skull now and not be able to accomplish the mission. That is my personal opinion, please.

BLACKBURN: How much can we add in terms of devices of various types? We can, I believe, to some degree--we do have to make a valid judgment as to the value of these devices as compared with the physiological capability of the man to perform that mission. I can give one example, however, where when engineers who develop weapon systems and the crew systems people get together that accomplishments can be made. In the first days of the VTAS when the engineers who developed that electronic system were working independently they took a standard issue 5.5 pount Navy helmet and added 14 ounces to it, way forward to the center of gravity and much more bulk and when it was sent out to be evaluated, they said it did not work. It did not work not because of the electronics but it did not work because of the poor pilot who could not hold up their heads because of the weight on them in pulling G's. When they finally came to us in the development of the helmet, during the course of several evolutions, he now has a 2.5 to 3 pound helmet with the VTAS integrated into the shell of the helmet and we have lessened the weight and the penalty of man by at least 50% by doing so.

TREDICI: In a way what you are saying is that we should go back and evaluate the mission and see of what importance all of these things are. How necessary are they rather than just the continual addition of more and more gadgetry so that in certain cases what we really need to be doing is substituting one for another rather than adding on and on. And, if the substitution is not an improvement, then we should not fool with it.

KNAPP: I will make just one more comment and then pull out of this dialogue. I think it is not so important to worry about the safety aspect as it is the human performance of the mission, the efficiency during the mission, and that is what I am talking about. I am not talking about crash effects or anything like that; I am talking about man's efficiency during the mission. We supply him with black boxes to do his job better but in fact we may compromise his ability to do the overall mission. Night vision goggles--he can only see 20/70. Does he need to see better than 20/70? It would be terrible to get out there and to find out that he cannot deliver the weapon or that he cannot fly the mission at 20/70 at night. And realize that all you have done is for naught. Because if all he needs is 20/70, it improves our selection criteria for aviators to only 20/70 instead of 20/20.

TREDICI: I am in agreement with your philosophy of efficiency, but I disagree with your last comment. If he starts out with 20/70 and then he further degrades, you are now down to nothing.

PERDRIEL: I believe that all the comments made are very important because the role of the Sensory Committee, of our Panel, is actually to discuss the limits of the visual aids of the general personal type, and of the visual aids adapted to air navigation; namely, those that are placed in the aircraft. And, I may add, that each time that one of us communicates with an engineer or a technician proposing a new visual aid, we always must ask whether it may be placed in the cockpit. I shall use atomic protection as an example. Present technology prevents the use of proper protection against flash on the transparent walls of the cockpit. And I believe that it is time we try to concern ourselves with this, let us say, general protection to the aircraft rather than place this protection on or before the eyes of the aviator. This would permit us to consider a protection from both the lasers and the atomic flash rather than give the pilot only hard glass to protect him against external trauma. We need to place some substances on the walls of the cockpit which would avoid shock. We could, thus, place a visual protection on the plane. I realize that this, in aviation terms, would increase the "payload" or weight of the aircraft and may modify its performance. Conversely, one may also wonder whether this protection would not be better than to transform the pilots into true visual robots. Because, if we try to imagine the pilot with all the apparatus, all the visual aid equipment we have heard about today, well, I wonder what it does represent from the human point of view.

TREDICI: The General has made a very good point. This panel has today heard about the ultimate in sophistication in instrumentation and yet sometimes we cannot afford the penalty it extracts in other areas, such as a too great increase in payload or a decrease in maneuverability. This brings us back again to the point made previously: There will be a need for trade-offs or specialization in mission capabilities.

FUCHS: May I take the privilege of the Chair of the panel and bring this discussion of philosophers to a close. When you look into the entire history of the past ten thousand years, nobody

the aeromedical scientist and practitioner to assist Man to his best. I would not like to go so far as to say--this is making a joke--that you can put a blind man in primary control of a high performance jet aircraft if you can provide him with a specially trained German shephard. But, nobody would believe when the Wright Brothers started flying that within a very short while we could reach more than 3 Mach.

TREDICI: On that vein then, General Fuchs, we will close this session.

FUCHS: In summarization, then, I would remind you that Vision plays the most prominent role in data gathering for man, so much so that anything affecting it will be significant for the aviator. Those of us caring for the aviator or attempting to increase his effectiveness could not look at a more fruitful area.

Clear vision assures us of processing uncluttered and accurate data in our mental computer. What occurs with this information after its reception is concerned with the training and developed skills of the aviator. However, if inaccurate or incomplete visual information is received, we are almost assured of failure of that task. The shortened time element available in decision making in modern aviation makes it imperative to look carefully at the visual task.

It is because of this that we have in this session, this morning, looked at visual aids for the aviator. In an attempt to extend his visual range, reduce his decision and reaction times, we have examined aviator spectacles to improve and maintain his basic vision, by correcting his refractive error and presbyopia. We have also looked at newer modalities such as contact lenses; we have explored ways to further extend his visual capabilities when his visual apparatus is deficient--especially in his limited ability to see at night; and to extend his useful life in the cockpit, we have discussed the available solution to the inevitable problem of presbyopia.

Once selected for exceptional visual capabilities and expensively trained for aviator duties, of necessity, the vital visual sense must be protected and preserved. This, too, has been addressed in this Session. Protection of vision from excessive physical and electromagnetic energy is being achieved by the use of spectacles and visors produced of materials that are the latest breakthrough in the state-of-the-art.

This Session also brought forth that much more needs to be done--from making difficult decisions concerning visual standards to continued exploration, hopefully leading to the ultimate "omni" aid and visual protector. We hope this Session has set the tone for continued exploration and development to enhance and protect the flyer's most valuable resource--HIS VISION.

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14. Abstract

Discussed during this conference are both the established, proven methods of eye protection and visual enhancement and newer, just emerging modalities, products of recent space age technology. Presentations are made on USAF aviator's sunglasses, lenses for correction of presbyopia, and contact lens use by the aviator. Also discussed are the newly developed helmet-mounted sights and display systems, as well as recent innovations in ceramics (PLZT) that show great promise in solving the retinal born/flashblindness problem. Other areas of discussion encompass such physiologic extenders as the AN/PVS-5 night vision goggles and hand-held optically stabilized target acquisition devices. With these devices, man's most important sense – VISION needed for flying is being extended, amplified, and enhanced in an attempt to bring his physiologic capabilities on par with the performance capabilities of modern aircraft.

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