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Some factors to consider in prescribing tints for pilots

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Contents

I. Introduction

Airplane pilots present two occupational vision problems for eye care practioners to solve. The first, that of multifocal design, is dealt with adequately in several articles.[1-3] The second is the selection of appropriate ophthalmic tints for visual efficiency and comfort. The variety of seeing conditions and the visual demands encountered in aviation guide the use of tint in pilots' glasses.

One analysis[2] of a pilot's visual tasks produced the following: "The pilot must take in a tremendous amount of pertinent information at a glance. He must, first of all, be concerned with dozens of dials relating to flight and engine performance; there are a multitude of switches to be checked, levers to be adjusted, wheels to turn, warning lights to watch, while handling the control column and rudder pedals. In addition to the visual demands in the cockpit, the outside airspace requires a constant and alert watch for other aircraft in the vicinity, for weather emergencies and visual identification of landmarks in navigation."

"Where visual flying requirements (VFR) are present, the pilot is concerned with the outside environment while he keeps constant watch on the instruments. In instrument flying requirements (IFR), the pilot is concerned only with flight instruments, not looking outside until almost upon the runway."

A fundamental see-and-be-seen situation exists even in present day aviation. Middleton states that in aviation there is a "need for public acceptance of actual seeing" and that we are dealing with a public oversold on such non-visual aids as radar and ground control."[4]

He also lends some insight into the night vision problems of pilots: "reading instruments will raise the threshold and the speed of the aircraft will render it more difficult to detect faint sources. . . windows in the way also. . .he must have brighter lights than the mariner on all counts." Maximum visual efficiency and comfort for pilots is again underscored by the fact that a majority of near misses can and do occur enroute, in full daylight, with a visibility of fifteen miles.[5]

Vision in the aircraft cockpit is more demanding than the analogous tasks in driving. As Tredici and Kislin[3] point out: "Graphs and tables showing aircraft performance factors are usually furnished to each pilot in the form of a spiral-bound book. These are scaled-down reproductions from flight manuals, and even under ideal viewing conditions some are exceedingly difficult to resolve. Unfortunately, vision experts are not consulted before final makeup of these items, to insure usability under adverse in-flight conditions. Full scale graphs and tables are usually used in preflight planning, but when a diversion to an alternate airfield must be made or an in-flight emergency requires the use of the spiral references, the pilot with inadequate vision has his troubles accentuated because of the small size of the chart. Some of the letdown charts, which show the flight pattern approach to the runways of the destination airbase, also present vision difficulties. ." As a statement to finalize the value placed on pilots' vision, the preceding two authors present the following evidence: "The importance of good vision for pilots can be assessed from a perusal of the [Air Force medical examination form and medical standards manual.] Twentyeight percent of the required medical data recorded for pilot candidates is devoted to eye findings."

In addition, it should not be assumed that vision demands are less stringent for the casual pilot of a small airplane compared to his professional and military counterparts. In fact Backman[2] believes vision to be more demanding in small aircraft due to "unfamiliar territory and lack of instrumentation."

Any highly occupational prescription lens is vulnerable to compromise through mishandling on the part of the prescriber. Pilots' glasses are no exception, particularly in the matter of tint and when taken with current trends in the use of tints. Tint has invaded the eyewear industry. As Brooks[6] puts it: "previously only certain frames were popular during certain time periods. . . now all different designs are used simultaneously and the same effect has been seen in lens tints recently." Drew concurs: "Today is the Day of the Tinted Lens. . . something like fifty percent of all lenses worn by the public have a tint of one kind or another. . . not because the color has any prescriptive or corrective value, but because tinted lenses are fashionable." Manufacturers' eagerness to sell tint produces designer frames supplied with tinted lenses already glazed as part of sales promotion. Numerous articles to make professionals aware of how to make more patients interested in a wardrobe of sunglasses succesfully adds to the impetus of the trend. Articles in professional publications range from approval to condemnation. One writer describes the "misuse [of tint] among certain groups of the population. . ." and adds: "commercial advertising exploits color, appearance, and other unessential qualities of sunglasses."[8] Another apparently feels it is "up to us to give our patients their choice."[6] And how have professionals reacted to all this?

At least one survey[9] claims that patient choice ranks with photophobia as reason for prescribing tint. It continues by pointing out the "irregular and unofficial status of the matter of prescribing light tints in the work of so many refractionists" but also that the comfort of the patient was an approximate guide for most practitioners. That tint is used for everything from reducing the edge glitter of lenses[10] to helping the neurasthenic patient where the relief may be nothing more than psychological recognition of treatment,[11] gives further account of the all-pervasive use of tint. Clark[12] continues: "The appearance a person either consciously or subconsciously wishes to achieve by wearing sunglasses may thus determine the choice of dark or light shades of lenses, regardless of whether the shade chosen is suitable in other respects." The use of tint is therefore widespread and its prescription can follow various philosphies, either well-defined or ill-defined.

The prescription of tint for pilots however should be treated by professionals as a variable in an occupational lens. There is an additional responsibility to insure an appropriate tint is prescribed and suitable patient education takes place. Basic guidance is given by Dowaliby[13]: "those needing full protection glass lenses can be identified through a detailed case history," while Richards[14] emphasizes that in all cases: "The same professional consideration and advice should be used for sunglasses as for spectacle lenses."

What should be prescribed? Depending on the source,[1,12,15-17] aviators should use yellow ("Kalichrome is particularly useful for shooters, skiers, boaters, and fliers"), brown photochromic (Ambermatic), 15% transmission mirror coating over clear lenses with clear windows, rose lenses, high altitude green or gray lenses, and 10-25% neutral sunglasses. There is the American National Standard for Non-Prescription Sunglasses and Fashion Eyewear or the Australian Standard AS 1067-1971 that can be consulted for general guidance. Finally, the desires of the pilot, whether based on subjective preference or habit, will have to be dealt with in prescribing the tint.

What are the factors involved in providing optimum visual function for pilots? What is an acceptable level of transmission? What are the purported problems of altered color vision with tinted lenses; the value of polaroid and photochromics? Is there special need for ultraviolet and infrared absorption? There's no unequivocal basis for selecting one tint over another, but past and current research can provide some guidance.

II. The Need for a Tint

Experiments based both on theory and on subjective preference show benefit from tinted lenses at elevated levels of illumination. Clark[12] writes: "Although the human eye evolved in illumination conditions probably like those of the present, and can adapt within a range of 10^{10} in field luminance, it is nevertheless common experience that high natural illumination may result in visual discomfort and that relief may be obtained by a suitable reduction in the amount of light entering the eye." Williams[18] states: "bright sunlight frequently produces glare and under intense illumination visual acuity is decreased." Some feel that squinting from intense light drains physical energy, adds to nervousness, and increases bodily fatigue,[19] while with more precision Richards[14] states: "The optimum lighting for vision is about 400 footlamberts (fL). More or less light reduces acuity." Miller[20] feels sufficiently dark sunglasses will improve visual discrimination for certain types of targets but not for others. Brooks[21] follows in this opinion by stating that a sunlens may improve daytime visual acuity "but only under certain conditions depending on background illumination and target type." Also, in Berggren's[8] words: ". . . much of our visual information is based on our capacity to discriminate between differences in brightness, the differential sensitivity is constant only in luminosities in the middle range and considerable deviations occur in high and low intensities, in sum the power of discrimination is diminished and visual acuity decreases. . . . absorbing glasses used in bright sun extends the range of constant differential sensitivity."

Specific to aviation, Allen[22] found improved visual performance in simulated flight under adverse glare conditions when using tints. The measure of visual performance was the response time to adapt to a near target after adjusting a threshold spot at distance. He concludes that a properly designed sunglass could be beneficial under the high intensity, adverse visual conditions often encountered in flying. In a study made in Iraq in 1932, Livingstone[23] (as cited by Clark[25]) found that constant exposure to glare resulted in "definite clinical changes" that were "significantly detrimental" to aviation, along with some other occupations.

Further experimental proof comes from Peckham and Harley[28] who used the critical flicker frequency (CFF) as an indicator of cone vision sensitivity. At one extreme, dark sunglasses resulted in an improvement of sensitivity of ten times over the unprotected condition. Peckham and Arner[29] demonstrated the relation between visual acuity and CFF and, again, the adverse effect of excessive sunlight on visual acuity. That filters are essential when glare is present and are suitable for visual detection tasks that present contrasts above threshold and that these conditions are found in aviation are mentioned by additional writers.[2,12,24]

From a pure comfort standpoint Brooks[21] states ". . . for high illumination a person's ability to see clearly <u>may</u> be helped but his visual comfort <u>will</u> improve." Another writer points out that acuity is not synonymous with visual performance or with comfort and that comfort thresholds are equally important.[11]

Sunglasses protect retinal sensitivity and preserve normal dark adaptation. Experiments by Clark, et al.[25] showed that subjects exposed to sunlight for three to four hours a day over a period of two weeks have an elevated night visual threshold immediately following exposure. A 50-percent loss in night visual efficiency was reported. In addition, an increased adaptation time to maximum night visual efficiency by those exposed to intense sunlight for lesser periods was described. Eye patches used over one eye and,later, 12-percent transmission sunglasses during exposure periods were found to preserve night-visual thresholds. They recommend: "personnel engaging in night duties requiring a high degree of night visual efficiency. . . should be provided with sunglasses to be worn during any daytime activities which expose them to excessive sunlight." Hecht, et al.[26] in an earlier study showed how after a single exposure of two to three hours the onset of rod adaptation was delayed and a normal final dark adapted threshold was not reached for several hours. They also relate how this exposure, causing a rise in threshold of about 0.2 log unit can cut night acuity in half, decrease range to half normal, and increase the contrast which can just be recognized by 50 percent over normal. "This deterioration in visual function is of about the same order of magnitude as that suffered by an aviator flying at night between 12,000 and 15,000 feet without oxygen."[27] Effects were both temporary and cumulative. Peckham and Harley[28] support these findings as do others. Clark[12] summarizes: "There is no doubt that persons engaged in tasks where night vision is critical should wear suitable sunglasses when in bright sunlight. Sea and air pilots. . . could benefit in this way."

III. The Need to Avoid a Tint

Visual acuity data was reviewed by Farnsworth.[30] While both he and Neumueller[31] state that even with heavily tinted lenses visual acuity losses are insignificant for average illumination, the wearing of sunglasses during twilight or night can cause a 20 to 40 percent loss in visual acuity and . . .this could be hazardous in driving motor vehicles and in piloting aircraft. . . "[12] Allen[22] found that vision tended to be as good or better unaided than with any filter for a distant threshold target at 490fL. The times when maximum light transmission is desirable are definite. This has been addressed extensively in the subject of night driving by Luckiesh and Moss,[32] Brooks,[21] Miles,[33] Lauer,[34,35] Fletcher and Nisted,[36] Clark,[12,37] Richards,[14,38,39,40] Stone & Lauer,[41] and Blackwell,[48] among others. Everson and Levene[24] show the effect of tint on the contrast sensitivity function of the visual system. They state: "For low-contrast grating targets of high spatial frequency, the best contrast sensitivity is obtained without the use of any of the three filters tested. This was a consistent result at the 36fL photopic level and tended to apply as well to the 2750fL level which corresponds to sky luminances. Examples of low-contrast, high spatial frequency tasks for aviators would be the detection of aluminum colored aircraft at great distances in the sky or of the parallel markings of an airport landing strip when seen from a distance."[11] The best summarizing statements include: ". .in dim illumination as the tint increases the visual acuity decreases";[21] "any absorbing glass. . . will reduce glare in proportion to the amount of light absorbed. At the same time the same proportionate amount of seeing is removed and the seeing loss is more important than the glare reduction. . . tinted glasses. . .have been found to reduce vision at night driving levels by about the same amount as the overall light absorption."[39] This fact should be considered in the use of light tints, photochromic lenses, and tinted contact lenses by pilots when flying in times of decreased illumination. Not only the effect on distant visual acuity should be realized but also the degradation of near acuity in cockpit tasks.

Age is a complicating factor in the use of any tint in reduced illumination. Vision in the aging eye has been characterized by loss of contrast sensitivity,[42] changes in dark adaptation,[43] and the need for increased light for equal seeing with advancing years.[44] The absolute threshold is raised and the time to reach a given level of adaptation is longer. Lenticular yellowing and greater intraocular scattering of light can reduce retinal illuminance at age 60 to 1/3 that of age 20.[42] Cole[42] found a systematic reduction in contrast sensitivity from ages 30 to 40 and advises "any measure which reduces the amount of light reaching the eye should be avoided." Richards[44] has chronicled the change in visual function. He finds, for indoor seeing, no need for increased illumination for high-and-medium-contrast targets at age 40 but need for increased light in specific ratios for those older. In addressing night driving situations it was found, for example, that at typical luminance levels, fifty-year-olds required 87% contrast to detect 20/40 letters. Clark[12] describes how even lightly tinted lenses, say with a luminous transmission factor of 50 percent, can cause appreciable loss of contrast discrimination ability in all but brightly lit interiors of buildings. The detrimental effect of any tint in situations where maximum seeing is needed at low luminance levels is accentuated by aging.

Given optimum conditions of eyewear and pilot age, other factors can reduce vision at night. Visibility distance for objects seen at night can be decreased by windscreen dirt, fog, or rain. These agents lower target contrast by absorption and scattering of light. Luczak[45] found dusty or dirty windshields absorbing 40 to 65 percent of the incident light. Such losses would be in addition to the visual losses in those whose eyes are unprotected from overexposure during the day or from the tint of contact lenses or fashion spectacle lenses; ". . .it appears that the combination of these factors has not previously been considered.. . ."[12]

Miles[33] shows how complementary combinations of colors in glasses (or contact lenses) and windshields under night seeing conditions can produce practical losses in visual acuity, stereopsis, angular velocity discrimination and simultaneous contrast. For example he demonstrates that the 20/30 possible through a clear windshield at night (with specified lighting) is rendered 20/40 with the wear of pink #2.

Some aircraft utilize red cockpit lighting to preserve dark adaptation. The lights are most effective in this with a cut off at 640 nanometers (nm).[5] While the loss of acuity under red light compared to white is negligible*[46] it can be made much worse if viewed through a complementary tinted lens of any transmission level.

Any of these factors taken singly or in any combination can compound the already demanding job of night piloting. Garner[47] addresses this theme in writing of driving: "under conditions of poor lighting, a dirty windscreen, and an elderly driver, the reduced transmission of a tinted lens may be the contributing factor that causes an accident."

*The chromatic hyperopia induced by the longer wavelengths is troublesome for some presbyopic pilots.[3]

IV. Concerning the Level of Transmission

Comparison of characteristics between lenses and the need for a certain degree of any characteristic requires proper descriptive terminology. This applies to the transmission properties of tinted ophthalmic lenses. McGinty[49] writes: "physical data can tell us how much light is transmitted, absorbed and reflected at various wavelengths. It will also indicate the modification of these effects brought about by the thickness of the lens material. But physical data cannot describe the subjective appearance of the lens, nor can it alone provide an adequate classification. This is because it takes no account of metamerism. . . " "Following the introduction of Crookes glasses and other types of tinted ophthalmic lenses, it became obvious that some system for organizing tinted lenses was required." The luminous transmission factor (LTF) or integrated visible transmission is currently the most widely used description. Pure optical transmittance refers to one wavelength in one medium. The LTF deals with the effects of every wavelength in the visible spectrum via integration. It again deals with one medium, that of the tinted ophthalmic lens. It therefore considers the effect of the lens on white light, light from the whole visible spectrum. The LTF also attempts to consider how the eye would respond to the light transmitted by a lens. The sensitivity of the eye as defined by the CIE standard observer is used. Further details of the procedure for obtaining the LTF can be found in McGinty.[49]

The advantage of the LTF is that it "allows one to make a quantatative assessment of a tinted lens. . .it therefore becomes possible to. . . compare the visual effect of one type of tinted lens to another."[49] Certain aspects of the LTF however, (for example not accounting for psychological factors and adaptation) cast doubt on its validity in expressing the subjective evaluation of tinted lenses. The luminous efficiency function has its inherent drawbacks and new methods are not proven.[49] While the LTF purports to be a psycho-physical (subjective) assessment, it does not allow for patient participation. It remains, however, the only quantitative assessment.

While many writers use the LTF, others do not or its use is left unclear. This is the case when reviewing certain promotional material from manufacturers. It is also the case encountered in the collection of opinions referred to in evaluating an appropriate tint density for pilots.

The amount of light that true sunglasses should transmit varies in the opinions of professionals but generally falls within the range of 10 to 30 percent: ". . .such designs should theoretically transmit 20 to 30 percent of incoming light";[13] "glasses with a LTF of 12 percent will keep the apparent field luminance below the fatigue threshold of about 3400 cd/m";[30] "sunglass lenses should in general have a light transmission within the range 10 to 25 percent."[12]

Occasionally the separation of true sunglasses from fashion tints is blurred: "many individuals who exhibit neither a physical or a physiological basis for light sensitivity do suffer from discomfort when exposed to ordinary quantities of illumination and they seem to see better or with more ease when illumination is reduced slightly. . . such cases may be psychological but since it is our duty to provide comfortable as well as efficient vision, the patient's complaint of light intolerance must be given major consideration."[50] Many more accounts are clear: "the impact of tinted fashion lenses intended for sunwear, designed with little regard to their optical value brings a startle to eye care professionals. . .the term sunlens is not very appropriate for most of the outdoor tints worn today;"[13] "it would certainly seem a futile gesture to 'protect' eyes from the excessive energy transmission of light to the extent of 4 to 12 percent (average of #1 and #2 tints usually prescribed for constant wear) when eyes have a mechanism for this already";[51] "to be effective. . .should not transmit over 30 percent . . .some feel even lower. . .without this much absorption the main reason for prescribing absorptive lenses cannot be met";[18] "sunglasses absorbing 50 percent of the light usually are useless for eye protection";[14] ". . .the disadvantage of wearing sunglasses, such as the restricted field of view, and (for people who do not normally wear spectacles) the possible discomfort of ill-fitting frames and the loss in visual performance that may be caused by dust on the lenses appear to counter any advantages gained by wearing lenses with LTFs greater than about 25 percent."[12] Similar views are expressed by additional writers.[19,21,52,53] Further, Clark theorizes that light tints (LTFs greater than 25%) when worn as sun protection are more likely to be worn habitually and that several of his sources either stated or implied that this lessens a wearer's tolerance to glare.[12] In dispensing tint of any density the wearer should be made aware of its intended purpose and limitations.

Some writers feel that the transmission level specifically for aviation sunglasses requires closer tolerances than the 10 to 30 percent transmission range of usual sunglasses: "10 percent transmission or less in the air. . .more than 10 percent for driving in town";[54] "if the refractionist is dealing with the glare of excessive illumination - above 6000 feet elevation - such as the aviator. . . is subjected to, the degree of energy reduction necessary to comfort would be greater than that which can be habitually worn with comfort and a much darker tint is indicated than can be used constantly";[18]

"field luminances in aviation conditions are often comparable with those found in brightly - lit snowfields. . .the allowable LTF should preferably be between 10 and 16 percent".[12] On the other hand, at least one writer states that sunglasses for military aviation should have a LTF of 15 to 30 percent.[55] The work of Hecht, et al.,[26,27] Peckham and Harley,[28] and Clark, et al.[25] on excessive sunlight and dark adaptation impairment support this. Hecht recommends 10 percent or less transmission to protect night vision and Clark mentions the value of 12 percent transmission sunglasses in his experiments. Peckham and Harley feel that 35 to 50 percent density will provide some protection to retinal sensitivity for short periods and that 10 to 12 percent density is required to insure protection for longer periods of exposure. They state: "the problem of obtaining a sufficiently dark pair of sunglasses is acute: and, "the conclusion would seem to be 'the darker the better.'"

References have been made to 10 percent or less in transmission levels. For general purposes one writer states: it is ". . .important that the percentage of absorption prescribed be not so large as to reduce the total illumination below the optimum point determined by acuity, visibility, and other components of visual performance."[11] Also, Clark relates how observer reaction time for red signal lights is independent of the LTF of the observer's lenses at certain background field luminances, but for faint signals near threshold the recognition probability is reduced by the use of absorptive lenses. He recommends 10 percent be considered the lowest LTF for aviation purposes to avoid the possible hazards of missed signals.[12]

Prescribing of protective sunglasses has had little scientific guidance. Writers acknowledge the individual treatment each patient deserves: "the difficulty that arises with prescribing of sunglasses at the correct absorption level is that the upper light threshold varies considerably from one individual to the next";[18] "some have filters which are 10 to 20 times the density others are born with. . . the differences among individuals are greater than the density of the darkest glass on the market."[30] Heddon,[53] among others, uses a method similar to that described for milder tints. In deciding whether to prescribe a tint and the shade needed, trial lenses are used by the patient in various environments. Richards[14] offers a method, succinctly stated with examples, that is more challenging. Clark[12] shows how a range of luminances found in various circumstances can be brought into an optimum brightness discrimination range with 10 percent LTF sunglasses. In general, the density necessary is acknowledged to depend on the individual's sensitivity, the illumination and its distribution, and whether the subjective or objective effects of the excess light are to be reduced. Comfort thresholds are less easy to determine and are "evidently even more subject to individual variations."[22]

Can the sunglass needs of pilots be met through commercial sources? According to Brooks,[21] most commercial sunglasses transmit more than 30 percent, this from their being tried on indoors and evaluated under indoor lighting. Manufacturers make what is sold most often. One evaluation of commercially available lenses in Australia against the current national standards showed 20 out of 57 tested conformed to the general use sunglass standard and 5 conformed to the specific use standard.[56] The proportion of quality sunglasses is small. Can the pilot (or non-pilot for that matter) select appropriate sunglasses with these odds?

V. Specific Lenses

A. Colored lenses.

The wide use of tint in lenses is equated to the equally wide use of the spectrum of colors in those lenses. A representative company currently offers 96 colors.[7] Colored lenses are those that distort the visible spectrum to some degree. Color by itself is a poor basis for classification since similar colored lenses may absorb differently depending on the chemical colorant used. Absorption curves should be used for comparisons,[18] but as mentioned above, the LTF should be used as a better indicator of the light loss to the eye.

Is color by itself good or bad? Various writers provide the span from pure opinion to pure theory on this subject. Clark[37] states that with the exception of therapy in some illnesses, there is no advantage to vision gained by observing through colored as opposed to neutrally tinted lenses. Richards[38] agrees: "Unless the advantage of color contrast can be used, I believe that only neutral glasses should be worn." Peckham's experiments[57] using five colors of lenses and evaluating the perception of small chroma differences found that selection of peculiar tints of low chroma with close color tolerance may not be essential or even advantageous. Everson and Levene,[24] using gray, yellow and rose filters measured changes in the contrast sensitivity function. They conclude: "Although contrast sensitivity was found to vary with luminance level, it has not been possible to demonstrate the clear-cut superiority of one colored sunglass filter over another in this experiment. The differences that are seen are related to the luminous transmittances of the filter and not to their intrinsic colorations." Another experiment[58] using magenta, green, and yellow filters as evaluated with Snellen acuity and contrast thresholds for sinusoidal gratings found that "none of the filter combinations was associated with any marked improvement in acuity." The authors continue: "It could be argued that for certain atmospheric and/or target to background color contrast conditions that the spectral characteristics of certain colored glasses could enhance target acquisition. However, light reduction by transmission loss through the glasses appears to offset any gain from the filter characteristics."[58] Clark,[59] referencing Middleton,[4] states that it is seldom that the atmosphere becomes spectrally selective enough to justify the use of colored lenses. Neuberger[60] shows that in using a red filter and viewing a cloud against a blue background that the apparent improvement is in visibility rather than in visual range. In no instance could a dark object with the horizon light as background be made visible by any combination of filters if the object was not visible to the unaided eye on account of haze, fog, or dust. This conclusion is supported by Middleton's finding[61] that the visual range of colored objects differs little from that of achromatic objects of the same luminance factor. Neuberger[60] also stated that if color contrast is important, for example, in spotting certain objects on the ground from airplanes, then the use of suitable filters may be helpful.

Fletcher and Nisted[36] studied the effects of red, brown, and blue contact lenses and found visual acuity insignificantly affected but dark adaptation thresholds raised. But the raised thresholds are, again, independent of color.[37]

The effect of color alone on stereoscopic acuity was left unresolved by an investigation by Rosen and Band.[62] However amber is claimed to improve depth perception and red is claimed to help contour resolution on snow. The results of Miles[33] in studying the effects of pink lenses and green windshields on stereoacuity has been previously mentioned.

The recognition of signal lights through colored lenses has been studied. The influence on reaction time is addressed by Clark,[37] Phillips and Kondig,[63] Garner,[47] and Berggren.[8] A signal visibility factor equation, devised to indicate effects of individual tinted lenses on red signals, is reviewed by Clark.[37] It is used, in part, by this author as evidence in recommending a standard excitation purity of 20 percent or less be adopted for colored lenses.

Closely related to the effect on signal light detection is the controversy of altered color vision through colored lenses. Writers' conclusions follow their method of experimentation. Those studying changes in anomaloscope settings and color vision test scores with colored lenses conclude the use of colored lenses is counterproductive and dangerous.[13,19,24,38,54,65,66,67,68] Verriest states: "It is easy to demonstrate selective absorption of short wavelengths causes a defect resembling the tritan type congenital color vision defect."[64] That color changes introduced by a filter can produce an effect similar to anomalous color vision is additionally held by Phillips and Kondig,[63] Berggren,[8] Williams,[18] and McGinty.[49] Attempts have been made to order the severity of this effect by specific color. Farnsworth found rose, smoke, blue, and yellow lenses to reduce color vision scores more than green lenses. The degree of impairment appeared to be related to excitation purity more than to chroma.[65] Another group using different color tests, ordered their test lenses from most deviation to least as green, brown, pink, gray, and yellow.[68] Rose and Schmidt[86] also found green and brown lenses to give the worst deterioration in color vision. Other tests produce results different from these and they can only be evaluated by considering the combinations of testing devices used in each study, whether anomaloscope, HRR plates, Munsell 100 hue or others. The particular type of anomaly produced by different colored lenses also varies with the tests used and has been recorded.[8,68,86] Spectrophotometer curves of colored lenses allow approximation of the resulting hue discrimination problems observed when the lenses are worn. The article by Kors and Peters[69] presents spectrophotometric charts for representative commercially available tints. Finally, von Schelling[87] devised a method for predicting the chromaticity shift when colored filters are used.

The foregoing arguments against the use of colored lenses because of color vision alteration is diluted when observer responses in practical environments are studied. Watkins[70] states: "spectral transmission curves are necessary but seem to stand apart from a sheer subjective view of our surroundings." Phillips and Kondig:[63] "when an observer wears colored lenses the background as well as the signal color changes, color adaptation takes place, and compensation for some of the color shift occurs." They also state that the color changes introduced by a filter can produce an effect similar to anomalous color vision and that the accident rates between the two groups is inconclusive. Chromatic adaptation is also mentioned by Clark,[37] Matthews et al.,[73] and McGinty.[49] Even though blue or green lenses should make red dimmer, Goldie[72] found subjects with normal color vision could perceive signal colors equally well when wearing green and neutral glasses.

This is not the case for those with defective color vision. Clark[37] writes: "for color normals chromatic adaptation can counteract most of the color changes caused by colored lenses so that colors in scenes tend to look natural. . .color defectives, on the other hand, apparently do not experience chromatic adaptation effects so that colored lenses could cause color defectives to see objects with unusual or unnatural colors, adding to their already large handicap. The use of only neutral lenses on color defectives is recommended. Stair,[74] Judd,[75] and Brooks[6] present similar conclusions.

In summary, what are the know effects of color alone in sunglasses on vision? The most severe effects of colored lenses will be found in color defectives who comprise only 8 percent of the male population and 0.4 percent of the female population. A case can be made for not applying colors to color defectives since the outcome is not easily quantified.[77] Also, caution should be used when prescribing colored lenses because many patients are unaware of their color vision defects.[18] Subjective claims by users about the beneficial effects of colored lenses are usually not confirmed by objective tests.[59] Current reports give unsatisfactory answers because of the lack of practical application or because of methods that are inequitable in comparing the results of one study to another.

B. Neutral lenses.

Neutral lenses are those that are spectrally non selective. Neutral gray tints are well accepted by most professionals: Dowaliby:[78] "the most sophisticated sunlenses optically speaking are the neutral grays in glass;" Garner[47] "in daylight [gray] produces no change in the ability to notice or react to signals;" "neutral gray gives best color perception and least color distortion. . .other colors are of lesser or no value in a sunglass lens;"[19] Cline:[50] "G-15 when true color discrimination is important;" "neutral absorbing lenses are best used against large amounts of uneven extrafoveal light. . .it has a calming and stabilizing effect on vision;"[11] Clark:[37] "Since there are no colored lenses that could improve the color - discrimination of natural objects by color normals or by color - defectives, it seems desirable from the aesthetic point of view that all sunglass wearers, particularly color defectives, should use spectrally neutral lenses;" Richards:[14] "Unless there is gain from color contrast, colored glasses reduce seeing more than neutral glasses." Wyszecki[79] reviews some studies that conclude neutral lenses are best. Williams[18] reports the most frequently prescribed sunglass lenses are the neutral ones. He also reviews the use of neutral lenses for those demonstrating dichromatism "so as not to disturb the acquired hue matching arrangement used by the patient." On the other hand, Peckham,[57] Ginsburg and Nelson,[58] and Everson and Levene[24] feel that various colors other than gray do not have enough undesirable features to make them completely unacceptable.

In considering the wear of colored or neutral lenses by pilots as an isolated group the major point of discussion is color vision efficiency and signal light detection. Voke[80] reviews how color is used in the military and in navigation to code information. Aeronautical charts are color coded and signal light systems are used in aviation. Clark[59] points out that aircraft are flown in the U.S. and elsewhere by pilots with defective color vision. The medical standards for certification of pilots requires only "the ability to distinguish aviation signal red, green and white" for second- and third-class medical certificates. The first-class certificate standards are more stringent however.[81] Protanomals (either congenital or produced in any degree by a lens) are urged to be excluded when red signal lights of low intensity are involved.[82] Heath and Schmidt[83] describe signal light conditions encountered in aviation as flashing or steady and both spatially isolated and also in the neighborhood of other non-signal background lights. They state that in aviation recognition becomes critical at distances of one to one and one-half miles. For color deficient persons the ability to differentiate red and green point sources varies with the intensity of the stimulus and with the degree of defective color vision. Gray won't help a color deficient perceive colors better but neither will it cause further misjudgement of colors as often happens to a color defective person when wearing lenses having specific spectral transmissions.[6] Clark[12,37,59,84] continually urges the use of neutral lenses in aviation. Matthews[85] writes that some subjects classified as "safe" could be rendered "unsafe" by the use of colored lenses, and therefore only neutral-tint lenses should be used by aircrews. Rose and Schmidt[86] concluded that for general use in ground traffic and by pilots, colored filters should not be used.

Not all writers have a strict adherence to gray for pilots. "It is interesting to note that pilots still subjectively report better visual performance using colored glasses even when there has been no scientific confirmation. Since there does not seem to be any degradation or enhancement of visual performance with colored glasses, it is recommended that those pilots who do want to wear such glasses do so if for no other reason than psychological comfort."[58] "All three filters [yellow, rose, and gray] have been worn successfully by aviators. Unquestionably different aviators prefer one filter over another. Their expression of preference may have a psychological basis if not a physiological basis."[24] They also add, however, that each of these filters changes the hue of colored objects, and gray the least. A final source states: "The above four colors [light and dark gray and green] are the only ones I would recommend for high altitude. Anything lighter in green or gray would not give adequate protection. Blues, pinks, yellows, browns, or any of the fashion tints should be avoided. . ."[17]

The research on traffic signal visibility with colored lenses is not applicable with respect to at least one aviation signal system. While traffic signals require the observer to locate and decide which light is on and what color it is, the VASI system for landing approach requires an evaluation of the saturation of a red light, the apparent saturation changing with the approach altitude flown. Again, if colored lenses change color discrimination, the interpretation of this signal system may change with different colors of lenses.

According to Clark,[12] color defective pilots have an additional problem to consider. Deuteranopes appear to be only 65 percent as efficient at perceiving light as normals and protanopes, 50 percent.

The apparent overall decrease in sensitivity to light is said to be good reason for encouraging color-defectives to avoid the use of darker shades of sunglasses.

In summary, an unequivocal basis for selecting one color over another is hard to find. A few writers do not object to the use of colored sunglasses by pilots, whereas many more feel, on the basis of minimum color distortion, that neutral lenses are the ones of choice for all pilots. Conservative practice would follow the recommendations of the latter group. There are however many pilots successfully wearing strongly colored tints. Those pilots inquiring about enhancement or "correction" and the resulting complications will require individualized counseling.

C. Yellow lenses.

The use of yellow lenses for a variety of activities and the attention it has generated in lay and professional writings warrants its separate treatment. Yellow lenses have been used for shooting, night driving, viewing sports, and flying, among other things. Sheard[88] stated that acuity was increased with the use of amber lenses. Birren[89] wrote: "yellow eyeglasses, which are commonly worn by pilots, gunners, and sportsmen to lessen the glare of full sunlight and overcome chromatic abberation in the eye, actually make for clearer vision despite the amount of light absorbed by the yellow filter."

Transmission levels of current yellow lenses range from 77 to 83 percent and one manufacturer even warns that they are not intended for sunny days.[19,53] Yellow lenses are reported to afford clearer vision on dull days, hazy days, and in fog. Under these conditions and on clear days they are reported to enhance the brightness of the outdoor scene, sometimes to the extent of making it too bright for comfortable vision.[24] Verplanck[90] found yellow did not help extend the visual range at which targets could be discriminated through haze. Reduction of haze seems theoretically possible because of the Rayleigh principle but Robertson[91] writes that yellow does not work well practically because the eye is less sensitive to the wavelengths filtered out. Luckiesh and Moss[32] point out that "fog is not selective like gases in the wavelengths scattered so yellow is no better than anything else."

In 1972 Luria[92] wrote: "most of the scientific work both experimental and theoretical has concluded yellow glasses are of no value, if not actually detrimental." Yellow is believed to improve visual acuity. The effectiveness of yellow decreases with target size and the fovea's inherent decreased sensitivity to blue is likely to negate any similar contribution by a yellow lens in increasing the contrast of a small target.[93] Everson and Levene[24] found enhanced contrast sensitivities with yellow lenses for target sizes of 20/500 to 20/100. They speculate that selective absorption of the short wavelengths would reduce chromatic aberration in the eye and the fluorescence of the crystalline lens and retina. These effects should improve contrast sensitivity not only at the low spatial frequencies but at high frequencies also. They report other influences might be accommodative accuracy in yellow light, heightened simultaneous contrast with large grating targets, and the relationship between saturation and contrast. "Also, we should not overlook the possibility of psychological influences."

The use of yellow glasses for night driving has been condemned.[14,34,39,94] Blackwell[95] found night driving detection distance worsened by 33 percent. Luckiesh and Moss[93] state that any advantage of yellow decreases with decreasing luminance because of the Purkinje effect. Glare recovery time has been reported to be increased by 12 percent and the time to identify a target in the presence of glare was found to be increased 29 percent.[96] As discussed, any tinted lens can reduce night seeing depending on age, lighting, and other factors.

Bierman[97] found yellow lenses generally did not help shooting scores. An experiment by Ross,[98] also evaluating shooting accuracy, supports Bierman's conclusions. Color vision is "noticeably affected" by yellow lenses according to several writers. Stair[74] in particular was concerned about color defectives confusing red and green signals.

The foregoing review of the effect of colored lenses in general on color vision should apply.

Finally, writers have recorded the subjective rejection of yellow lenses by some. Neumueller[31] found that amber was the "most unpleasant" of the colors he tested. Allen,[22] in one study, reported that all observers disliked the yellow test lenses and that increased apprehension and tension was evident during the trial with yellow.

While Bierman[97] was forced to conclude that the benefit of yellow lenses depended entirely on the individual, further evaluation is valuable. Luria[92] describes the essential conditions for the effective utilization of yellow filters as "a fortuitous combination of virtually optimal pairs of contrasting colors." He points out that yellow filters will improve lower resolution threshold vision when the target is of long wavelength and the background is of short wavelength. Kislin[99] has apparently documented this effect in finding a significant advantage in using yellow lenses in simulated aerial spotting over jungle terrain. His experiment was prompted by the subjective reports of aircrews using yellow lenses in early morning and late afternoon on defoliation operations in Southeast Asia. In reviewing the results he cautions: "The subjects in this study were able to find brown targets in a green background slightly faster when wearing yellow glasses. . .however their ability to find gray targets was markedly decreased. This must be considered when interpreting the subjective opinions of those who think they can see better in the jungle when wearing yellow lenses. A forward air controller, for instance, has a wide variety of targets. He may find that, while wearing yellow lenses, some targets stand out and can be perceived very easily; yet he may be unaware of any targets he missed that were made more difficult to see by the yellow lenses. . .his opinion may be based entirely on targets that could be seen more readily with yellow lenses." Kislin feels for these reasons yellow lenses should be carefully controlled and that it would be necessary to know the target color and brightness before every use to be able to recommend yellow lenses.

Kislin's report also reviews calculations for predicting the improvement or decrease in brightness contrast by yellow filters on targets of various color, brightness, and surround. He predicts the yellow filter will enhance brightness contrast if the brighter of two colored objects has a greater relative spectral reflectance for the longer wavelengths of the visible spectrum. As others have, he warns of the eye's decreased sensitivity to short wavelengths compared to photographic films. Strict parallels between the effects of Wratten haze filters on photography and on seeing should be avoided.

In a final section of his work, Kislin dispensed yellow glasses to F-4 pilots and collected data on sighting distance for low level flights and the pilots' subjective impressions. No advantage or disadvantage for visual detection with or without the yellow filters was found. Pilots' comments ranged from "excellent in haze and overcast" to "amplifies glare in all quadrants."

Very recent work is beginning to delineate the exact value of the usage of yellow lenses. Compared to transmittance matched neutral lenses, yellow lenses improved both perception of depth of low contrast contours and the time required to respond to low contrast patterns in the laboratory. This work by Kinney, et al.[100] uses the physiology of color vision as a theoretical explanation for the paradox of why yellow is popular but acuity is no better than with matched neutral lenses. For some visual functions the output of three different types of cones is combined additively, while for others the output of one type is subtracted from that of another. In the first condition (achromatic system) the color of the light is not a factor and more light produces a larger response. In the second (chromatic system), the presence of more than one color may cause an inhibitory effect and the response may be smaller even though more light is present. Yellow lenses, by reducing the subtractive blue input, could result in a physiologically stronger signal and hence enhanced subjective vision. Any visual function mediated at least in part by the opponent system could be improved by yellow lenses.

It is also stated that an optimum range of light levels for the best use of yellow lenses in improving low contrast vision and depth perception will be sought. They conclude: "While these results have demonstrated the effectiveness of yellow goggles under certain conditions, we are not satisfied that the paradox has been completely resolved. First, the differences between yellow and luminance-matched neutrals were small; practical experience suggests they should be larger. Second,we have not shown yellow to be better than no goggles at all, but only the same. . .we believe. . .yellow goggles can be effective, and that we can start to explain why, but we do not believe we have elicited the maximum benefit possible."

A recent field experiment conducted by the same investigators showed yellow lenses improving depth perception 11 percent in flat lighting conditions and 20 percent in snowy conditions.[101] The need for determining the range of light levels over which yellow lenses are effective was again recognized. Practical experience has always suggested an optimum range of illumination for yellow glasses.[70]

While investigation continues and is promising, yellow lenses have limited use and should be prescribed by professionals with extreme caution.

D. Polarizing lenses.

Typical ophthalmic polarizing filters transmit 30 to 35 percent and are often combined with absorbing glass or are coated when more absorption is needed.[14] Their effectiveness against plane polarized light leaves them a specialized type of glass. Williams[18] (in citing Farnsworth) mentions more color distortion through polarizing lenses than through pale green lenses. At least one writer believes polarizing glasses transmit too much infrared in relation to visible light and gives situations where this might be consequential.[102] Another source suggests that the disadvantages of polarizing lenses may exceed the benefits except in specialized cases.[54]

Except for extended flying over open water on bright days, the need for polarizing filters in aviation is limited. A cloud undercast is an ineffective polarizer of light and cloud under- and overcasts destroy any existing polarization through multiple scattering. Polarizing lenses are much less of an advantage to the pilot than to the automobile driver.

E. Photochromic lenses.

Photochromic lenses are presented by distributors as the all-purpose lens that protects eyes from glare and insures comfortable seeing under any lighting conditions. Manufacturers may present another side: "[photochromic lenses] darken to a comforting medium tint in full sunlight. . .were never intended to function as sun-glasses and certainly not to act as a general purpose substitute for two units."[103] Borish[104] judges them not suitable as an only pair of glasses due to inadequate light transmission in the faded condition. He believes they should not be used for night driving. Brooks[107] finds the residual tint of photochromics especially bothersome to the elderly needing more light indoors. Garner[47] advises against photochromics for those over fifty years old in considering the residual tint, the need for extra light, and the possible driving hazard. He points out that most photochromic glasses won't ever achieve the maximum quoted transmittance due to some normal exposure to ultraviolet in each 24 hour period. He theorized that fluorescent lighting may inhibit the complete bleaching of the lenses indoors. The old Photosun material (68/25) would serve much as a conventional fashion tint in its lightest state. All photochromic lenses have this residual tint disadvantage. The original Photogray 83/44 is an example. Second generation materials are somewhat better in this respect however: Chance-Pilkington Reactolite Rapide 90/16; Corning Photogray Extra 87/23; Hoya 85/25; Rodenstock Colormatic S 85/25; Zeiss Umbramatic 90/40.[106]

A final factor is the lowered infrared absorption of photochromic lenses compared to traditional sunglass lenses. The importance of this is weighted differently among writers but is addressed as an important factor when full protective lenses are required.[13,107]

For use by pilots specifically, photochromic lenses have good and bad characteristics. Photochromics can be brought to a transmission level in the lightened state that approximates white crown glass through the use of antireflection coatings and chemical tempering instead of heat tempering.[76] This makes them without criticism for use in night flying. However they would still not meet the transmission requirements laid down for full protection of retinal sensitivity in the darkest state, if this is decided to be important. Coatings can be applied to the posterior surface to adjust the minimum transmission, but at the expense of the maximum transmission state.

Photochromic lenses must be prescribed taking color into account also. Ambermatic lenses pass from dark silver gray through brown to amber and will give some degree of yellow lens effects. Reactolite and Umbramatic lenses are also brown. Rodenstock's Colormatic S is gray when bleached but the Colormatic 2 is brown in the same condition. Hoya's Sungold varies from rose to auburn while Sundrive progresses from light blue to blue-gray in increasing light.

There are additional factors. Flying produces fewer abrupt changes in lighting than does driving (for example driving through a tunnel). Therefore the reaction time of the material is less of a factor than in other instances. The positioning of the wearer can be a factor. Clark[12] writes: "a driver positioned so that direct sunlight falls on only one lens will be subject to the visual disturbances that result from anisopia."

Backman[1] reports that photochromic lenses darken substantially toward their minimum transmission in aircraft, presumably because of the use of plastic rather than glass windscreens. He has no objection to their use by pilots. The U.S. Military Optical Service on the other hand has not authorized or recommended the use of photochromic lenses.[108] They state: "all flying personnel are not permitted to use photochromic lenses while engaged in aerial activities. . .flying personnel seeking best visual efficiency are better served continuing to use two different lenses." They apparently choose not to add a changeable lens to other variable factors such as atmospheric haze, geography, and physical and physiological conditions such as age. This position was based on the original photochromic materials.

In summary, certain aspects of transmittance or color may be factors in the use of photochromic lenses by pilots. Some qualities of the lenses are inconsequential or even better in the aircraft cockpit than in an automobile.

E. Mirrored, gradient, and special design lenses.

The mirrored lens has been advertised for use by pilots. A popular transmission level is 15% with the reflecting medium frequently combined with an absorbing tint. The mirrored coating over clear glass would be classified as a neutral lens whereas, in combination with a tint, the lens should be evaluated according to the specific color and saturation of that color as discussed previously.

Mirrored lenses and conventional neutral and colored lenses are made in gradient form. A top gradient lens with 10 percent transmission in the center and 0.1 transmission at the top gave good results in simulated conditions in experiments by Allen.[22] Richards[14] states: "It is not usually possible for a sunglass to give optimum seeing against both ground and sky. When the sky is far too bright and one needs to see objects against the sky a gradient density glass can be a useful solution." The factors to consider in prescribing gradient lenses would be obtaining the transmission desired at the proper height on the lenses and insuring equal densities at corresponding heights in the pair. Farnsworth[30] suggested matching transmission levels in a pair to 20%, while Clark[12] adheres to 0.1 of the higher LTF value. Frame alignment would be a factor in this respect for mounted gradient lenses. Only single (top) gradient lenses should be allowed for pilots, who need a clear view of instruments and glide path.

Closely related to gradient lenses for use by pilots is the specially designed pilot's goggle with clear windows in the lower portion. These are either coated or mirrored to 15 percent transmission or less in the upper portions.[19] The window line should be set to follow the upper instrument panel edge or slightly below it to avoid unnatural head positions while looking inside or outside the aircraft. The specification of this line requires care parallel to determining a bifocal height for pilots and Backman[1] provides the guidelines for doing this.

VI. Concerning ultraviolet and infrared transmission.

Writers differ in their concern about the amounts and effects of extravisible energy transmitted by ophthalmic lenses. The idea of a tinted lens not filtering non visible radiation to the same extent as visible radiation and this resulting in a circumvention of the eyes' inherent safeguards has been addressed.[47,109] The dangers of disproportionate amounts of nonvisible radiation reach- the eye has been discussed but not documented.

The ultraviolet threat to the eye in this respect is little. No pathogenic ultraviolet reaches the retina under normal conditions. Conjunctivitis and keratitis may result from sufficient intensity and duration of exposure (snow blindness). While the ultraviolet radiation effect is cumulative and potentially harmful in the uncovered eye, transmission studies on a random sample of sunglasses indicated that ultraviolet irritation of the sunglassed eye is very unlikely.[109] There may be a greater need to consider ultraviolet radiation for pilots because of altitude effects. Kors and Peters,[69] Graham,[14] and Garner[47] point out the higher levels of ultraviolet with increasing altitude. In particular, ultraviolet below 200nm is present at high altitude only, because of atmospheric absorption at lower levels.[69] Increasing amounts of ultraviolet radiation may mean increased fluorescence of the crystalline lens and of ophthalmic lenses. Bailey and Hofstetter[111] studied the fluorescence of ophthalmic lenses and found that any fluorescence in these lenses could negate any reduction in crystalline lens fluorescence they effected. Their subjects reported a veiling haze except when a lens which absorbed ultraviolet and did not itself fluoresce was used. They suggest the possible use of clear ultraviolet absorbing lenses by pilots subjected to excess amounts at altitudes.

In Peckham and Harley's[28] study on sunglasses for protecting retinal sensitivity, they concluded that the causative factor in dark adaptation changes was the visible portion of solar radiation. Kors and Peters[69] have additionally stated that the 300-365nm portion of the ultraviolet causes dark adaptation interference.

Pilots probably don't generally need extra ultraviolet protection if they already wear a quality sunlens or prescription glasses. For very high altitude flying the effects of increased ultraviolet on each pilot will be the guiding factor as to the need for special attention in this area.

In contrast to the low ultraviolet transmission of most lenses, the low visible - high infrared transmission of the majority of sunglasses in one test indicated that thermal energy received by the retina was not reduced in proportion to the visible.[109] Polarizing lenses are particularly poor in reducing infrared in proportion to visible radiation.[102,109] While some writers find little conclusive evidence that levels of infrared encountered under normal conditions are responsible for any detrimental effects on the eye.[14,47] McCullough and Fullerton [109] describe calorophthalgia as one outcome of low visible - high infrared exposure. Whereas good sunglass lenses offer some protection, many plastics and photochromics offer comparatively less.[78] These lenses may afford comfortable vision for only a short period in situations of constant direct or reflected sunlight.[13] As more work is done on the levels and effects of infrared on sunglass protected eyes, better recommendations can be made for sunglasses for pilots and nonpilots.

VII. Contact lenses.

The main areas to be considered in the wear of contact lenses by pilots is the matter of color and the effects of any tint at night. Clark[12] points out that contact lenses have been tinted in a deliberate attempt at changing the color of the wearers' irises with no regard to the effects on vision. All that applies to color selection in spectacle tints can be applied to contact lens tints. Berglund[112] stressed that since tint is provided as a convenience to patients to help guard against loss, only the color that will transmit the most light should be used. He recommends light blue based on his finding that it transmits more light in the area of greatest retinal sensitivity in the scotopic situation. Richards[40] writes specifically of the danger of deeply tinted contact lenses at night and recommends only the palest of tints be used. Both Berglund and Richards offer data on transmission of various contact lenses. In addition, tint matching, both for color and shade, should be carefully carried out in replacement of single lenses.

VIII. Summary

Brooks[76] writes: "one of the most misunderstood areas in ophthalmic dispensing centers around the subject of tinted lenses." The professional must evaluate which characteristics must be used in designing a prescription ophthalmic lens, including the tint. To make intelligent selections, absorption characteristics should be available. Since inappropriate tints "can be a source of discomfort, fatigue, or inadequate vision"[40] tints should be individualized for a patient's specific requirements. This individualization should be applied to all cases, but because of the occupational need, an extra measure of care may be required in selecting a tint for the pilot. The following should be considered:

1. The age of the pilot, type of aircraft, type of flying and times of flying are basic to the individualization process.

2. Fashion tints cannot substitute for sunglasses.

3. Any tint at night whether from contact lenses or the residual in a photochromic may adversely affect vision.

4. Nighttime visual acuity is best maintained by protection from intense daytime sunlight.

5. Ten to fifteen percent transmission lenses have been shown to be effective in preserving normal dark adaptation.

6. Colored lenses may affect color discrimination depending on the individual with most severe effects on color defective persons.

7. Patients already wearing special lenses may require counseling concerning their use while piloting aircraft.

8. Neutral lenses are indicated to insure no color distortion and for all color defectives.

9. Yellow lenses give advantages under very limited conditions and are not of value to most pilots most of the time.

10. Polaroid lenses have limited application in most aviation situations.

11. Photochromic lenses have pros and cons; the main disadvantage is a possibly inadequate minimum transmission level, since the maximum can be effectively increased by coatings and chemical tempering.

12. Despite increased ultraviolet at high altitudes, conventional sunglass lenses provide adequate protection in most instances.

13. Quality glass absorptive lenses provide some protection from the discomfort of infrared; plastic and photochromic lenses provide less.

14. Ten percent transmission is the practical and safe minimum transmission limit. Darker lenses should be fit with caution.

15. In actual prescriptions the transmission properties vary with thickness and field of view.

16. The degree of energy reduction frequently necessary in flying requires a tint darker than can be worn constantly.

17. The density required will depend on the pilot's sensitivity, the illumination and its distribution inside and outside the cockpit, and how much the subjective and objective effects of the excess light are to be reduced.

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