INTERNATIONAL JOURNAL OF
OCCUPATIONAL SAFETY AND ERGONOMICS 2001, VOL. 7, NO. 3, 277–284

The Relationship Between the Difference in Prismatic Refractive Power of an Eye-and-Face Protector and Its Thickness, Radius of Curvature, and Material

Grzegorz Owczarek
Adam Pościk
Zygmunt Kubacki

Department of Personal Protective Equipment,
Central Institute for Labour Protection, Łódź, Poland

Maciej Karolewski

Division of Dentistry, Medical University of Łódź, Poland

With the help of the research results presented here and on the basis of a graphic analysis we aim to prove the existence of a relationship between the difference in prismatic refractive power and the thickness, curvature radius, and type of material used for panoramic oculars in protective spectacles, goggles, and face shields. The difference in the prismatic refractive power is a fundamental optical characteristic of a protective ocular without corrective effect. According to Standard No. EN 165:1995 (European Committee for Standardization, 1995) the difference in the prismatic refractive power is a difference in the prismatic effect at 2 observation points of an eye-protector.

eye-protection   difference in prismatic refractive power   optical class

1. INTRODUCTION

Eyesight is one of the most important senses of man. Most of the messages the brain receives from the outside world come through eyes. At the same time eyes are one of the most sensitive organs of the human body and they

Correspondence and requests for reprints should be sent to Grzegorz Owczarek, Central Institute for Labour Protection, ul. Wierzbowa 48, 90-143 Łódź, Poland. E-mail: <growc@ciop.lodz.pl>.

are very susceptible to injury (Matthews & Garcia, 1995). The factors that present risk to the eye may be of various nature: mechanical, chemical, or biological. In practice the greatest risk eyes are exposed to are materials such as stone, wood, or metal while they are subjected to manual or mechanical treatment. Hazards presented by chips occur in medical dental surgery, orthopaedics, and ophthalmology. The eyes and face are protected with face shields, protective spectacles, goggles, and so forth. Recently some firms have imposed an obligation on their employees to permanently wear protective spectacles, often irrespectively of the type of work. This is a consequence of the fact that values of the highest permissible intensity of hazardous agents for chips from solid materials have not been established yet. Because mechanical strengths, especially the impact of eye protecting oculars, are important, preferred are protectors with oculars of considerable thickness, often in excess of 1.5 mm. The thickness and robustness of the protector gives the user a feeling of safety. This impression, however, is often illusory particularly in the case of mineral glass or Plexiglas. The use of oculars whose thickness is greater than 1.5 mm may lead to deterioration of the optical properties of the protector and consequently to its demotion to the second or even third optical class. The mechanical strength of the material for eye protectors is of less importance than such factors as the comfort of their use; the total weight and whether they offer good visibility (through protection glass) are indispensable and vital to the user. The necessity to provide good visibility is fundamental for performing precise work in surgery rooms, operating rooms, dentistry, and pharmacies. The hazards to which surgeons and dentists are exposed are mainly connected with the use of cutting tools such as saws, drills, and dental boring turbines. Medical staff who use mechanical tools are exposed to flying chips and dust from operated tissues, and to splashing of body fluids such as blood or saliva. In the case of dentists additional hazard is presented by dust or fillings, which may be produced when cavity filling materials (amalgam, composite) or a denture materials (acril resin, steel) are being processed. Moreover, sharp particles of the materials may penetrate the skin of the face and thus open the way to being infected by microorganisms. The mucous membrane of the conjunctive may become the locus of invasion of bacteria or viruses, if there is direct contact with infective material. On the basis of the research results presented here and graphics we aim to prove the existence of interdependence between the difference in prismatic refractive power and thickness, curvature radius, and type of material used for panoramic oculars in protective spectacles, goggles, and face shields.

Research, whose results are presented in this article, has been carried out in the Central Institute for Labour Protection (Łódź, Poland).

2. PRINCIPLE OF MEASUREMENT AND APPARATUS

The difference in the prismatic refractive power is a fundamental optical characteristic of a protective ocular without corrective effect. According to Standard No. EN 165:1995 (European Committee for Standardization [CEN], 1995d) the difference in the prismatic refractive power is the difference in the prismatic effect at the two observation points of an eye-protector. With increased thickness of the ocular and decreased radius of its curvature there is an increasing value of difference in its prismatic refractive power. The refraction of light, which occurs at the points of vision of a protective ocular, is responsible for the difference in its prismatic refractive power. (It is assumed that the spacing of the points of vision is equal to the nominal pupillary distance, i.e., 64 mm). The angle at which any light (whose direction is at variance with the radius of curvature of the ocular), passing to the inside of the protected zone, is dependent on the radius of curvature, refractive index, and thickness of the ocular. The results of graphic analysis show that the difference in the prismatic refractive power grows with increased thickness and reduced radius of curvature of the ocular.

Figure 1 shows the differences in the angle at which light is refracted for oculars with the same thickness but different values of the radius of curvature (Figure 1A), for oculars with the same radius of curvature but different values of thickness (Figure 1B), and for oculars with the same radius of curvature and thickness but different values of the light refraction index (Figure 1C).

Figure 2 is a schematic diagram of the test assembly used for measuring the difference in the prismatic refractive power according to the European standard procedure EN 167:1995 (CEN, 1995b). The principle of operation of the test assembly is as follows.

The diaphragm LB_1, illuminated by the light source, is adjusted in such a way that it produces an image on the plane B when the eye protector P is not in position. The eye-protector is placed in front of the lens L_2 so that the axis of the eye-protector is parallel to the optical axis of the test assembly. Adjustable tilt eye-protectors are positioned with their oculars normal to the optical axis of the test equipment. Measured are the vertical and horizontal distances between the two displaced images arising from the two ocular regions of the eye-protector. These distances, in centimetres, are

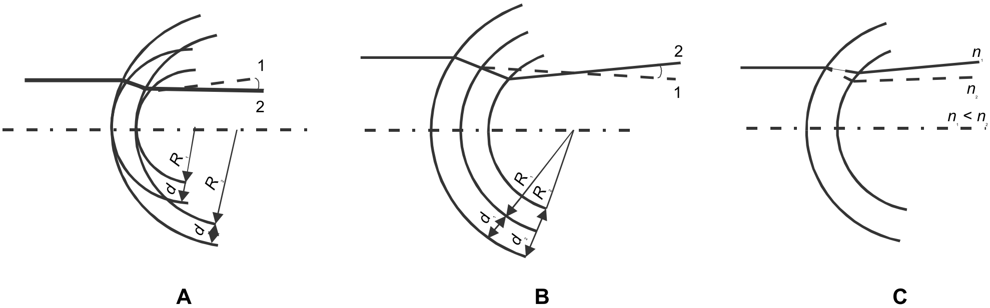

Figure 1. Differences in the angle at which light is refracted for oculars with the same thickness but different values of radius of curvature (A), for oculars with the same radius of curvature but different values of thickness (B), and for oculars with the same radius of curvature and thickness but different values of the light refraction index (C). *Notes.* d, d_1—thickness of oculars; R_1, R_2—radius of curvature; n_1, n_2—refractive index; 1, 2—light beams.

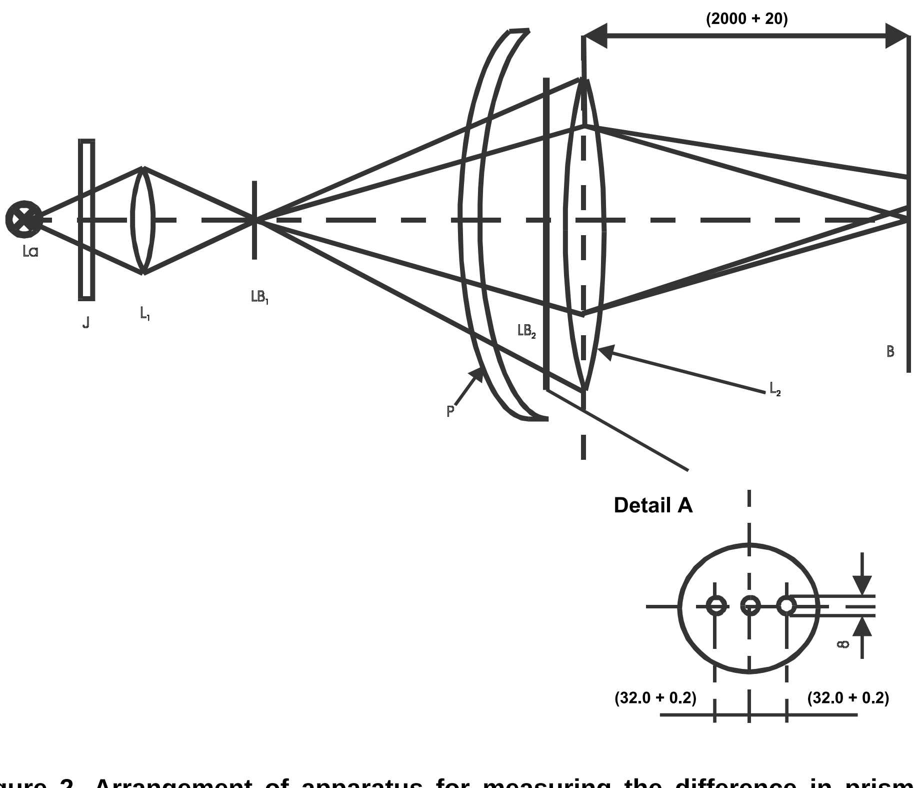

Figure 2. Arrangement of apparatus for measuring the difference in prismatic refractive power. *Notes.* La—source of light; L_1, L_2—lenses; J, LB_1, LB_2—diaphragms; P—eye protector, B—plane.

divided by 2 to give the horizontal and vertical differences in centimetres per metre. If the light paths—which correspond to the two eye regions—cross, the prismatic refractive power is “base in” and if the light paths do not cross, it is “base out.”

A special holder was used to change the length of the radius of curvature. The value of the radius was measured with a spheremeter, adjusting the distance between the stationary pegs to 64 mm (pupillary distance). Deflection of the movable centre peg of the spheremeter was measured with a dial sensor. The readings of the sensor were converted, using a simple geometrical relation, into values of the ocular curvature radius. As it was necessary to compare the results, the oculars were removed from their housings and were then given the required radii of curvature. All tested samples showed a horizontal difference in base-out prismatic refractive power. The vertical prismatic difference was 0 cm/m.

3. RESULTS AND DISCUSSION

The materials most frequently used at present for eye-protecting oculars are polycarbonate and polymethyl methacrylate (Plexiglas). Consequently oculars made of either of the two materials were selected as test samples for testing the differences in prismatic refractive power and resistance to high speed particles. The oculars subjected to the tests were made of polycarbonate about 1, 1.2, 2.0, and 4.0 mm thick and polymethyl methacrylate—1.5, 2.0, and 3.0 mm thick. The tests were performed for five samples of each thickness of oculars, and the results are mean values.

The permissible tolerances for, among others, differences in the prismatic refractive power of eye-protector oculars, without a corrective effect, and their corresponding optical classes are presented in Table 1 (CEN, 1995c). Oculars of the third optical class cannot be used continuously, particularly if work is performed under near-point conditions of vision. The results of the study of the relationship between the difference in prismatic refractive power and the radius of curvature, for samples representing polycarbonate and polymethyl methacrylate, are presented in Figures 3 and 4.

In the case of test oculars made of polymethyl methacrylate the obtained values of difference in prismatic refractive power for the tested radii of their curvature were not good enough for the first optical class, which is a serious limitation as regards their suitability for practical use. (The boundary value of the difference in the base-out prismatic refractive power for the first

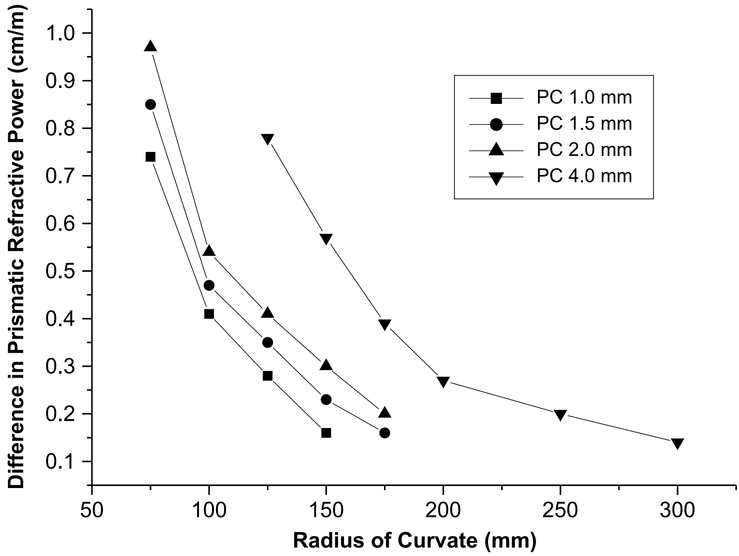

Figure 3. The relationship between the difference in prismatic refractive power and the radius of curvature for samples made of polycarbonate (PC).

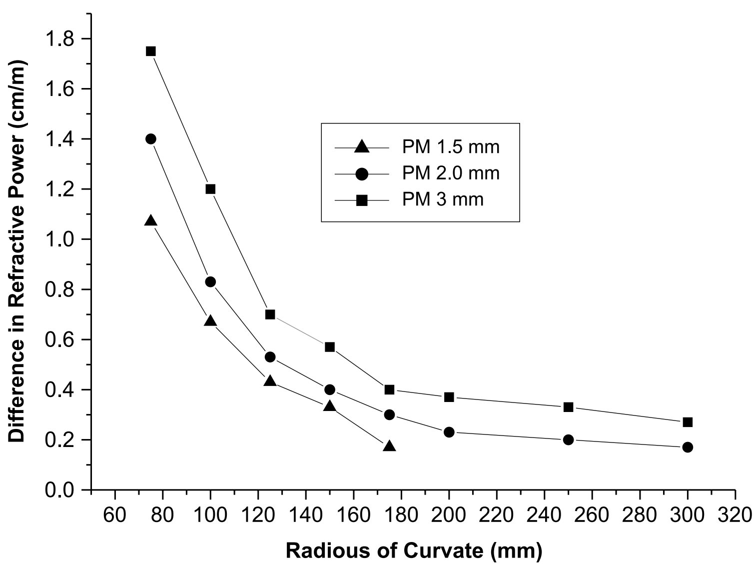

Figure 4. The relationship between the difference in prismatic refractive power and the radius of curvature for samples made of polymethyl methacrylate (PM).

optical class should be 0.75 cm/m, the value for the second and third optical classes being 1.0 cm/m, see Table 2). In the case of test oculars made of polycarbonate the requirements for the first optical class were met only by oculars that were 1.0, 1.5, and 2.0 mm thick. Most tested eye-and-face protectors had the values of the radius of curvature in the range from 75 to 150 mm so that protection could be provided to the entire eye-and-face area, both in front and at the sides. Panoramic oculars whose radius of curvature is in excess of 150 mm can be used only in protective goggles or protective spectacles.

Compared to oculars made of polymethyl methacrylate those made of polycarbonate and with the same values of thickness and of the radius of curvature showed noticeably higher values of the difference in their prismatic refractive power particularly for low values of the radius of curvature.

The presented results show how complex a problem has to be solved to reconcile the protective properties of an eye-and-face protector with what is needed and expected by the user.

4. SUMMING UP

The investigation and graphic analyses have shown that the difference in prismatic refractive power of the protective oculars used in eye-and-face protectors is dependent on the radius of their curvature and thickness and type of material they are made of. Using a material of high mechanical strength (CEN, 1995a), such as polycarbonate, an eye-and-face protector can be made without impairing the optical properties of the oculars. Prolonged continuous use of an eye-and-face protector with a high prismatic refractive power difference may lead to fatigue of the eyes, especially if work is being done under near-point vision conditions, which requires convergent motion of the eyeballs. Change from divergent to convergent eyeball motion occurs when the eyes shift from a far to a near point of vision. As soon as the axes of vision cross, at the point of fixation, the pupils are instinctively contracted and subjected to accommodating tension by the convergence accommodation reflex. This process of accommodation may be disturbed by a changed degree of convergence produced by the prismatic refractive capacity of the eye-and-face protector (Silbernagl & Dispopoulos, 1994). The resulting discrepancy between the degree of accommodation and the convergence in high precision work at near-point vision causes rapid fatigue of the eyes and a feeling of discomfort (Bartkowska, 1996). The measured prismatic refractive capacity of the eye-and-face protectors results in convergence deficiency proportional to the curvature of the protector (smaller radius of curvature) and pupillary distance of the worker, aggravated if the worker is short-sighted (weak or absent accommodation reflex to near-point vision). It is often manifested by a headache and hurting of the eyeballs.

For those reasons, in the making of eye-and-face protectors preference should be given to polycarbonate, which has superior mechanical strength and optical properties. In selecting means of protection of the eyes and face consideration should be given to the mechanical strength and optical class of the protector. This is particularly important if the protector is to be used in near-point work requiring high precision of performance.

REFERENCES

Bartkowska, J. (1996). *Optyka i korekcja wad wzroku* [Optics and correction of ametropia]. Warsaw, Poland: Wydawnictwo Lekarskie PZWL.

European Committee for Standardization (CEN). (1995a). *Personal eye-protection—Non-optical test methods* (Standard No. EN 168:1995). Brussels, Belgium: Author.

European Committee for Standardization (CEN). (1995b). *Personal eye-protection—Optical test methods* (Standard No. EN 167:1995). Brussels, Belgium: Author.

European Committee for Standardization (CEN). (1995c). *Personal eye-protection—Specifications* (Standard No. EN 166:1995). Brussels, Belgium: Author.

European Committee for Standardization (CEN). (1995d). *Personal eye-protection—Vocabulary* (Standard No. EN 165:1995). Brussels, Belgium: Author.

Matthews, L., & Garcia, G. (1995). *Laser and eye safety in the laboratory*. Bellingham, WA, USA: SPIE—The International Society for Optical Engineering.

Silbernagl, S., & Dispopoulos, A. (1994). *Kieszonkowy atlas fizjologii* [Handbook of physiology]. Warsaw, Poland: Wydawnictwo Lekarskie PZWL.