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OCCULAR SAFETY ASPECTS

OF

LED's IN FIBER OPTIC SYSTEMS

ELECTRONIC INDUSTRIES ASSOCIATION
Engineering Department

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or the inability of the eye to focus on the source. Since typical distances for viewing with the unaided eye are greater than 20cm (8 inches), fiber ends and sources smaller than 0.150" fall into this category. The irradiance at the cornea, E_c is related to the radiant intensity, from the fiber, by the formula:

$$E_c = I_s / D^2$$

where D is the viewing distance. For safe observation, E_c should be less than the corneal MPE rate for continuous (8 hour) viewing at the emission wavelength. Sliney and Freasier (Applied Optics 12, 1973, pp.1-24) suggest a MPE of $1.0 \mu W.cm^{-2}$ for the wavelength range of 400-550nm, but allows greater exposure at longer wavelengths. Figure 1 shows the ANSI defined MPE for wavelengths of 400 to 1100nm. The curve was obtained from Table 5, Figure 8, and Figure 9 in the ANSI standard. For convenience, photocopies of these are attached. The curve is summarized as $1 \mu W.cm^{-2}$ from 400-550cm, linearily increasing to $160 \mu W.cm^{-2}$ at 700nm, a step increase to $320 \mu W.cm^{-2}$ at 700cm and linear increase to $1600 \mu W.cm^{-2}$ at 1060nm and remaining constant out to 1400nm.

To illustrate the use of the MPE, consider a fiber of .32NA emitting $100 \mu W$. The radiant intensity may be approximated by

$$I_s \cong P_0 / \pi(NA)^2 = 0.31 \text{ mW.sr}^{-1}$$

If the MPE is taken as the low value ($1.0 \mu W.cm^{-2}$), the safe viewing distance is greater than:

$$D = \sqrt{I_s / MPE}$$

$$\sqrt{.31 \times 10^{-3} / 1 \times 10^{-6}}$$

$$\sqrt{.31 \times 10^{+3}} = 17.6\text{cm} = 6.94 \text{ inches}$$

If the ANSI MPE at 701nm is used as the limit ($320 \mu W.cm^{-2}$), the safe viewing distance must be greater than 0.99cm. At this close distance the unaided eye will not produce a sharp image and the corresponding reduction in retinal irradiance should allow an even larger value for MPE.

3. CONCLUSIONS

3.1 Based on the appropriate eye exposure limits given in ANSI Z136 and other documents, and assuming further research does not indicate modification of these limits, even with an 8-hour exposure it is reasonable to believe that non-lasing (LED) emitters are safe when used in fiber optic systems.

3.2 It is further recommended that additional study be undertaken to understand and document the MPE with multi-mode and non-coherent sources.

1. INTRODUCTION

1.1 General

This EIA Engineering Bulletin was developed by the P6.5 Working Group on Optical Transducers which is made up of technical experts from sixteen EIA member companies. This group includes both manufacturers and users of fiber optic components.

1.2 Purpose of this Bulletin

A. Provide initial collection point of information relating to eye safety when using LED source emitters. This Bulletin does not provide information on eye safety of fiber optic systems which use laser diodes.

B. Inform the fiber optic community of technical safety consideration when using LED sources.

C. Stimulate the industry to adopt appropriate safety measures when warranted and alert the industry to the need for further study in eye safety.

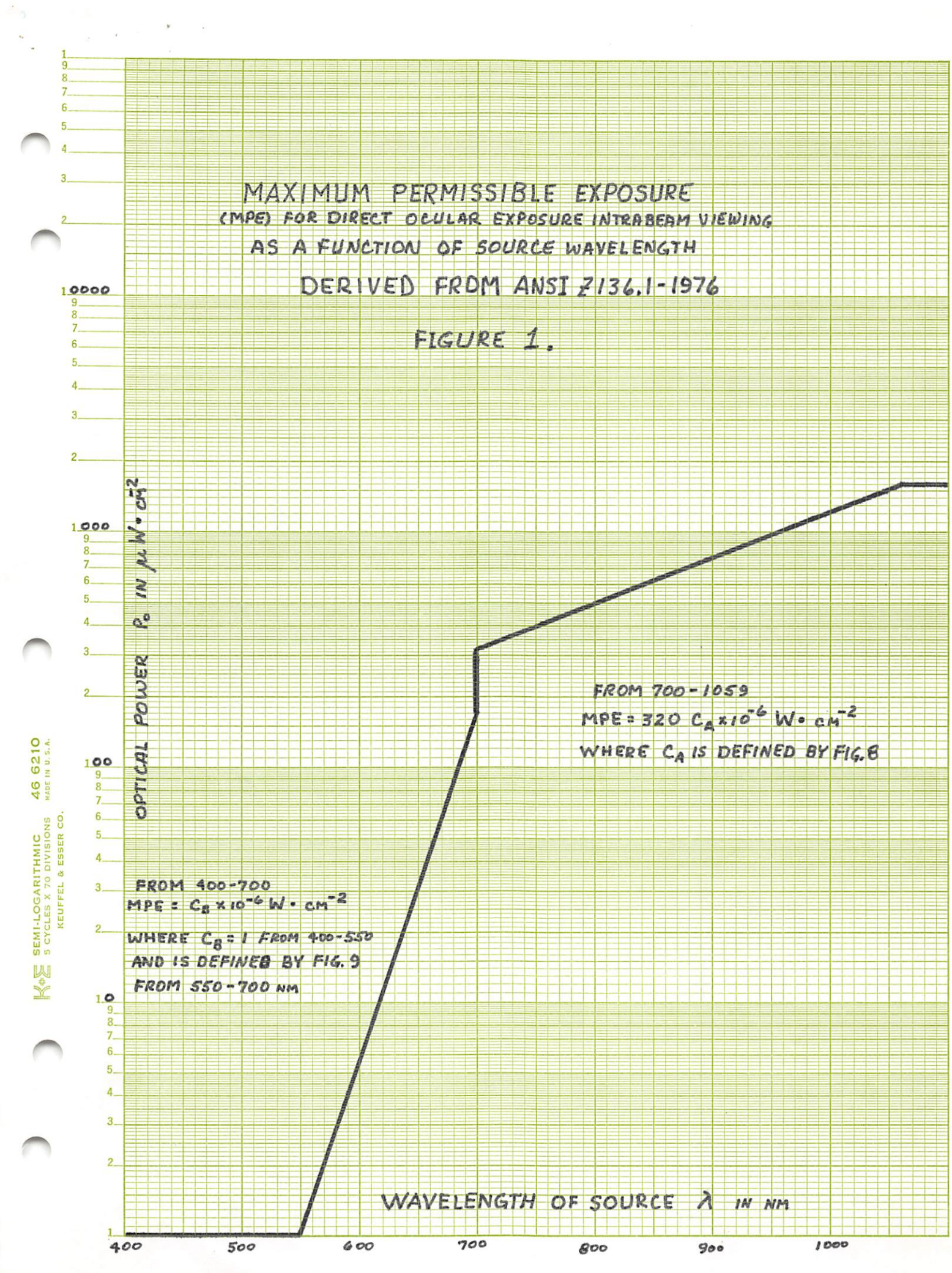
2. EVALUATION OF EYE SAFETY HAZARD

2.1 Introduction

Maximum Permissible Exposure (MPE) limits for direct ocular exposures by intrabeam viewing of lasers have been documented by the American Standards Institute (ANSI) in their document Z136.1-1976. Other agencies, e.g. Bureau of Radiological Health (BRH) have suggested somewhat different limits for laser safety. In fiber optic subsystems, in which injection lasers or high radiance LED sources are coupled to an output port either directly or through an optical fiber, similar concerns exist. Currently, there is no definitive medical evidence whether the existing ANSI limits apply directly to the non-coherent output of multimode optical fibers with LED sources. It was these thoughts and a desire to provide some initial guidance on the safety implications of using LED sources that prompted this study.

2.2 Detailed Analysis

Sources viewed at distances greater than approximately fifty times the largest dimension may be treated as point sources. Viewing distances less than this result in a retinal image which is not a spot either due to the shape of the source


MAXIMUM PERMISSIBLE EXPOSURE
(MPE) FOR DIRECT OCULAR EXPOSURE INTRABEAM VIEWING
AS A FUNCTION OF SOURCE WAVELENGTH
DERIVED FROM ANSI Z136.1-1976
FIGURE 1.
OPTICAL POWER P_o IN $\mu W \cdot cm^{-2}$
FROM 700-1059
MPE = 320 $C_A \times 10^{-6}$ W · cm^{-2}
WHERE C_A IS DEFINED BY FIG. 8
FROM 400-700
MPE = $C_B \times 10^{-6}$ W · cm^{-2}
WHERE C_B = 1 FROM 400-550
AND IS DEFINED BY FIG. 9
FROM 550-700 NM
WAVELENGTH OF SOURCE λ IN NM
400
500
600
700
800
900
1000
SEMI-LOGARITHMIC
5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
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