Solar Filter Safety

By: Ralph Chou | August 1, 2006

A total eclipse of the Sun is probably the most spectacular astronomical event that people can experience. Every year there are at least two solar eclipses of one kind or another (and sometimes as many as five) visible from different parts of the world.

In the days and weeks before an eclipse occurs, news stories in the media provide information on what will happen and how to watch the event safely. Unfortunately, despite the best intentions, inaccurate or confusing information on safe observing techniques is often provided. This is especially true when the recommendations concern protective filters for directly observing the Sun. (Here is a list of solar filter suppliers.)

I first published solar filter data in *Sky & Telescope*'s August 1981 issue (page 119); in the years since then new filters intended for both visual and photographic uses have come on the market. In June 1996 I participated in a NATO-sponsored meeting on solar-eclipse astronomy. This prompted me to make spectrophotometric measurements of a variety of materials and assess whether they provide adequate protection for the eyes. These included such oddball items as the internal magnetic disk of a 3½-inch floppy, multiple layers of space blanket (a very thin type of aluminized polyester film), CDs, and metal-coated polyester food packaging.

How the Eye is Damaged

Solar radiation reaching the surface of the Earth ranges from ultraviolet light at wavelengths as short as 290 nanometers (2,900 angstroms) to radio waves in the meter range. Lifetime exposure to solar ultraviolet radiation is an established contributor to accelerated aging of the outer layers of the eye and skin and the development of cataracts.* But more immediate damage takes place from directly observing the Sun with inadequate eye protection. The eye will transmit most of the radiation between 380 nanometers (violet) and 1,400 nanometers (near infrared) to the light-sensitive retina, resulting in retinal burns.

Exposing the retina to high-intensity visible light triggers a series of complex chemical reactions within the light-sensitive rod and cone cells. The products of these reactions impair the cells' ability to respond to light and in extreme cases can destroy them. Depending on the severity of the damage, an affected observer experiences either a temporary or permanent loss of visual function. This *photochemical* injury occurs mainly when the retina is exposed to blue and green light.

When longer wavelengths of visible and near-infrared radiation pass into the eye, they are absorbed by the dark pigment epithelium below the retina. The energy is converted into heat that can literally cook the exposed tissue. Photocoagulation destroys the rods and cones, leaving a permanently blind area in the retina. This *thermal* damage also occurs during extended exposure to blue and green light.

Both photochemical and thermal retinal injuries occur without the victim's knowledge, as there are no pain receptors in the retina, and the visual effects do not occur for at least several hours after the damage is done.
For wavelengths between 380 and 1,400 nanometers, we find that a filter with a transmittance of 0.0032 percent, corresponding to a shade number of 12, provides "adequate" retinal protection during solar viewing. However, this does not take into account visual comfort, in which case a darker filter having a transmittance of 0.0003 percent (shade number 14) is often preferable.

Relative Safety of Filter Materials

For this article I tested a variety of samples. Photographic film samples were purchased from a local retailer, exposed to full sunlight, and developed to maximum density according to the manufacturers' instructions. The smoked-glass filter was produced by depositing soot from a candle flame onto a glass microscope slide. The other materials were obtained by random selection from retailers' stocks. Floppy disks were tested with the outer plastic casing removed.

There are numerous solar filters on the market that weren't evaluated here because of their similarity to other items tested. The purpose of this effort was to determine the general types of materials that make safe filters, not to compare similar designs by different manufacturers.
Not surprisingly, I found a wide disparity in the attenuation of visible light by these materials, even among the "safe" filters. For example, the differences in processing methods and chemistry gave varying optical densities for the silver-bearing black-and-white film emulsions. The double-layer filters had shade numbers ranging from 11 to 16.

Welder's glass of shades 12 through 14 are popular and safe solar filters, easily obtained at welding-supply outlets. Most observers prefer shades 13 or 14; the solar image through a number-12 filter is uncomfortably bright.
Sky & Telescope photo by Chuck Baker.
I also found a wide range of optical densities between individual audio and data compact discs because of variations in manufacturing processes. Some CDs have aluminum films that are so thin they appear semitransparent at normal room illumination levels. These are obviously unsuitable for use as solar filters. Other CDs, however, are suitable if the aluminum coating is dense enough that the glowing filament of an incandescent light bulb is just barely visible through them.

Floppy disks have only a marginally safe infrared transmission and produce poor-quality images of the solar disk. The magnetic medium scatters visible light to such an extent that you see a dull red disk surrounded by a broad halo of red light. I would not recommend using this material for a solar filter.
Aluminized polyester and glass filter materials gave the most consistent performance. Most of the items specifically designed for eye protection easily met all of the transmittance criteria for safe filters. I would avoid aluminized polyester used in packaging for food products and collector cards because of the inconsistent optical quality, though the particular pop-tarts wrapper I tested performed surprisingly well. (It rated as marginally safe.)

Acceptable and Unacceptable Filters

Unsafe filters include any photographic emulsion bearing an image, chromogenic (non-silver-bearing) black-and-white film, black-processed color film, photographic neutral-density filters, and polarizing filters. Although these materials have very low visible-light transmittance levels, they pass an unacceptably high level of near-infrared radiation. The black color film is a good example, having a shade number of 15 for visible light but transmitting almost 50 percent of the infrared radiation!

Smoked glass had very good performance in terms of radiation transmission. However, it is a dangerous filter material for two reasons. First, it is very difficult to produce a uniform heavy coating of soot on glass. Second, the coating is fragile. The filter is very easy to destroy by handling — much of the soot on my sample came off because of contact with its protective wrapping. It also made quite a mess.

Acceptable solar filters for unaided visual observations include aluminized polyester specifically designed for viewing the Sun, shade 12, 13, and 14 welding filters, black polymer filters, and two layers of fully exposed and developed silver-bearing black-and-white negative film.

For photographic and aided visual use, particularly with binoculars or telescopes, acceptable filters include aluminized polyester specifically designed for the purpose and Type 2-Plus glass filters. The Thousand Oaks Type 3-Plus filter should be used with extreme care for photographic use only.

Not recommended are metal-coated polyester film that is not specifically intended for solar observation, smoked glass, floppy disks, black color transparency (slide) film, chromogenic film (not tested here), and compact discs (because of the inconsistent quality of the metal coating).

My data and further comments on safe solar fillers appear on the NASA/GODDARD eclipse page

Tech specs article:

http://quark.uwaterloo.ca/~brchou/solarfilters.html

https://www.rasc.ca/tov/safety

Safe Solar Filters (from Fred Espenak)

http://www.mreclipse.com/Special/filters.html#vfilter

"Filters" not designed for solar viewing	**Filter materials designed for solar observations**
- 2 layers of photographic film - Black colour transparency (slide) film - Ilford FP4 - Kodak Plus X - Kodak TMAX 100 - Lithographic film **Other materials:** - Compact disk (CD-ROM) - Floppy disk media - Poptart polyester wrapper - Smoked glass - Welding filter glass shade 12 - Welding filter glass shade 14	**Aluminized polyester:** - Rainbow Symphony visual grade - Rainbow Symphony optical grade - SolarSkreen visual grade - SolarSkreen optical grade - Thousand Oaks polyester **Metal-coated glass:** - Questar - Thousand Oaks T1 - Thousand Oaks T2 - Thousand Oaks T3 - Polymer filter - Rainbow Symphony black polymer - Thousand Oaks Solar Shield 2000