Tales from an Oklahoma Shooting Range

Recently, a friend of mine in Oklahoma, Bruce Palmer, participated in a shooting match on a foggy day. The conventional wisdom among target shooters is that, to sight your rifle, you must use a fluorescent orange disk against a white background. This opinion is so strongly held that Bruce was severely ridiculed when, in defiance of accepted practice, he used a black disk. Yet he was the only shooter that day who could see his sighting target. To make this triumph of science over folklore even sweeter, Bruce used a black disk much smaller than the bright orange disks of his fellow shooters, who had to resort to the ridiculous measure of sighting their rifles by shooting blindly into the fog and listening for the sound of their bullets hitting targets.

Atmospheric Visibility

What Bruce knew that his fellow shooters did not is that the distance at which an object can be seen (along a more or less horizontal path) depends on the contrast between the object and its surroundings. A persistent misconception is that attenuation is the reason we cannot see objects in the distance. The easiest way to refute this is to note that even a perfectly black object, from which there is no light to be attenuated, cannot be seen at an indefinitely large distance (even if the earth were flat).

Although light can be seen coming from the direction of a black object, the source of this *airlight* is not the object, but rather, scattering toward the observer by all intervening molecules and particles. When the relative difference between the luminance in the direction of a black object and the luminance in the direction of its surroundings falls below the contrast threshold of the human eye, the object cannot be seen. If an object reflects some of the sunlight incident on it, this reflected light—attenuated along the line of sight—adds to the airlight, hence reducing contrast to below that of a black object. Bruce chose a black disk for sighting his rifle because he knew that this disk would give the greatest contrast.

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Why Fluorescent Orange for Safety Vests?

My curiosity about fluorescent orange was piqued by Bruce's story. And this was more than scientific curiosity. We live in isolation on the side of a mountain in central Pennsylvania, surrounded by hundreds of acres of forest. During most of the year, life at our mountain retreat is peaceful. But in late fall, the woods are invaded by hunters hot on the trail of white-tailed deer. On opening day of buck season, we find ourselves in the middle of a war zone. To keep our golden retrievers (who, bounding through the woods, resemble nothing so much as deer) from becoming casualties, we outfit them in fluorescent orange vests. Are these vests really fluorescent? What is it about them that makes their appearance strange? Why are they effective?

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To help me answer these questions, Michael Churma measured the spectral radiance of a fluorescent orange hunter's safety vest and of a white card purported to have a reflectance of over 90% (see Fig. 1), both vest and card illuminated by daylight. The peak of the radiance spectrum of the vest is at 620 nm, which corresponds to an orange. This peak is over twice the peak for the white card. How can this be? It is clear from its spectrum that the vest efficiently transforms light of wavelengths shortward of 600 nm into light of longer wavelengths. Fluorescence is a process by which light at the short wavelength end of the visible spectrum is transformed into light of longer wavelengths, *e.g.*, blue light being transformed into yel-

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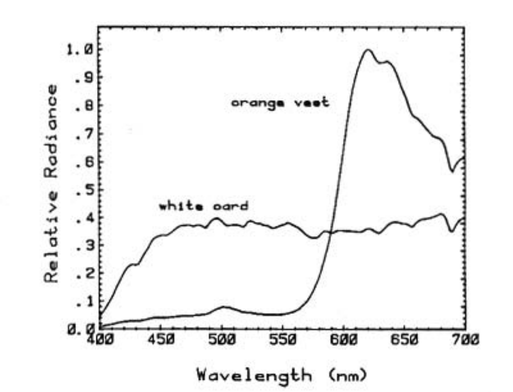

Figure 1. Radiance spectra (relative to the peak) for a white card and a fluorescent orange vest of the kind worn by hunters and highway workers.

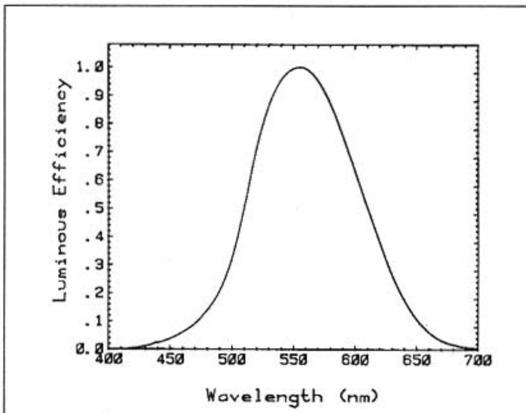

Figure 2. Luminous efficiency of the human eye.

Building Blocks for the Future

I am often asked for background material relating to standards, standards organizations, and policy about standards. Until recently, I have not been aware of a good reference addressing these questions. In March 1992, the Congressional Office of Technology Assessment published the results of a study on standards issues at the request of Congress. This report, *Global Standards: Building Blocks for the Future*, is the most comprehensive document I have seen about the history of standards writing, the effect of standards on the economy, and the changes in policy needed to keep the U.S. standards effort abreast of the changing world economic situation.

The report is a 110-page document comprised of four chapters, two appendices, over 400 references, and a list of about 120 people involved in standards writing and issues who were interviewed in the course of the study.

The first chapter provides a summary, a list of findings, and three strategies for making improvements in U.S. standards writing efforts. The report notes that standards will play an increasing role in the economic well being of all countries, and that there is too little attention and financial support given to standards development in the U.S. The report also argues that the various public and private agencies involved with standards must cooperate more, and that the U.S. has a lot to learn from Europe about standards policies.

The three strategies outlined for improving the situation include greater government leadership and financial support of standards activities; promoting a standards information infrastructure to make information about the applicability and availability of standards more readily accessible; and that reorganizing public and private standards bodies so they can function more efficiently.

The second chapter deals with standards writing in the U.S., and gives a nice history of the development of the many standards organizations here, their organizational structure, and why most are private. It also discusses the government's role in standards writing and how this has increased recently as the result of changes in technology.

The third chapter covers the same material with a focus on European standards organizations, and contrasts their operation with those in the U.S. The report points out that standards have always been strategic items of economic policy in Europe because of the need for trade between neighbors. This was not so in the U.S., since we had a one market economy for so many years.

The final chapter looks at the structural changes in the standards environment due to the global economy and the rapid pace of the introduction of new technology—particularly in the information exchange industry. It is clear that nations that ignore these changes as they apply to the standards setting will suffer economically.

For anyone interested in the economic and marketing aspects of standards policy, this information-packed report (S/N 052-003-01277-4) is available for $5.50 from New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, Pa. 15250-7954.

—*Robert Parks*

Light Touch

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low. Whatever is used to dye orange vests, it definitely is fluorescent and has a high fluorescence yield; very little radiant energy is lost.

The radiance of the white card integrated from 380-780 nm is 1.365 W/sr-m^2, whereas the radiance of the vest is about 7% higher: 1.446 W/sr-m^2. I interpret this as follows. The vest transforms some of the incident ultraviolet light *shortward* of 380 nm into visible light. Moreover, the radiance of the white card drops sharply shortward of about 490 nm.

We do not, however, perceive radiance, but rather luminance. Luminance is radiance weighted by the luminous efficiency of the human eye, which does not, in general, transform equal amounts of radiant energy of different wavelengths into equal sensations of brightness (see Fig. 2). The luminance of the white card is 2.719 cd/m^2, whereas that of the vest is 1.894 cd/m^2, the relation between the two luminances being the opposite of that between the two radiances. This turnaround is a consequence of the shape of the luminous efficiency curve. Note that the white card is brighter than the vest. We probably call the vest bright because it is brighter than familiar orange objects, the colors of which are a consequence of selective absorption, which decreases radiance.

Bruce Palmer's colleagues at the shooting range were using fluorescent orange sighting targets against a white backdrop. The intrinsic contrast between the two (in the absence of airlight) is about 30%. The intrinsic contrast of a black object on a white background is 100%. No wonder he could see his target in the fog when they couldn't see theirs. It seems that they were misled by assuming that, if fluorescent orange vests are worn by hunters (and also by highway workers) who want to be seen, disks of the same fluorescent material should make the most visible targets.

As determined strictly by luminances, white clothing can provide greater contrast in dark forests. But to avoid being shot, it is not enough to be seen, you must be seen to *not* be a deer. If the deer in my woods were orange-tailed deer, my dogs and I would wear white clothing during hunting season.