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| Synopsis on “Specifying the Visual Optical System” |
| OPTI 521 |
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| **Abstract**  Often times engineers receive poorly written specifications to which they have to design systems for. Sometimes specifications are too vague and do not adequately describe the system that needs to be designed. Other times the specifications are too specific and constrain the design to a preconceived solution. This paper is a synopsis on the article “Specifying the Visual Optical System” by B.H Walker. The paper discusses how to properly specify optical systems used in conjunction with the human eye. The specifications describe the performance and functional requirements of the system. These parameters describe what the systems need to accomplish without the design in how it satisfies the requirements. |

**Introduction**

Engineers use their knowledge to design products that satisfy needs in society. The needs are translated to specifications which tell other engineers what their product need to accomplish in order to satisfy the need. Ideally the specification should be specific enough so that any products that satisfy the specification will also satisfy the need. If they are not specific enough then a lot of engineering effort will be wasted producing systems that do not satisfy the underlying need. However, if the specification is too specific it needlessly constrains the number of possible designs that can satisfy the need. In this case the optimal solution to the need might be bypassed because it does not meet the specification even though it could fully satisfy the need. This causes the ultimate product to be sub-optimal in schedule, cost, and/or performance.

The paper “Specifying the Visual Optical System” describes how specifications should be written for systems that deal with the human vision system. It outlines the critical components of the specification as well as talk about how that performance specification relates to the performance of the human eye.

**The Human Eye**

For visual optics the detector of the system is ultimately the retina. That means that the optical system must couple to the human eye. While the nominal human eye is well characterized, the performance of the eye is different from person to person. In addition the eye’s performance for each individual also changes as they age. Therefore visual optics must be designed so that they can accommodate a reasonable range of eyes with different visual performance.

The eye is a “dynamic detector… it is constantly scanning the scene presented to it and adjusting its characteristic to suit (Walker).” The eye’s iris can open to 8mm to collect more light when it is dark, or stop down to 2mm when there is bright illumination. The eye can also change its own optical power to accommodate for objects at different distances. The performance of the eye is also affected by race, gender, age, and sex.

**Basic Specifications**

Walker’s paper used a binocular system as an example to make the specifications more tangible. While the binocular is a specific example of a solution that meets the stated specifications, the specification does not restrict the solution to the binoculars. This set of specifications comprehensively describes the performance and function of the binocular without alluding to any specific solution.

Magnification- The magnification of the system defines the apparent size of the image with the apparent size of the object. This can be viewed as a magnification in angular space. For the example system 6X magnification is specified. This means that objects look like they are six times larger through the binoculars.

Field of View(FOV) Direct view systems like binoculars are an afocal system, so the object space FOV and the image space FOV are different. Because of the angular magnification the image space field of view is the object space field of view multiplied by the magnification. Therefore a fixed image space FOV, the object space FOV will decrease as magnification is increased. The specified FOV for the binocular is 48 degrees.

Entrance Pupil Diameter- The entrance pupil diameter determines how much light is collected by the optics. A larger entrance pupil gives a brighter image but also increases the cost of the optics.

Exit Pupil Diameter-Exit pupil diameter is the entrance pupil diameter divided by the magnification power of the system. Ideally it should be larger than the pupil diameter for proper coupling. In daylight condition the eye’s pupil is about 2mm so about 4mm exit pupil is optimal. Since exit pupil diameter is a directly related to the entrance pupil diameter and the magnification power a larger would result in either lower magnification power or a larger and more costly optics. The only justification for a larger pupil size is for dark conditions, in which case the eye’s pupil will be dilated so a larger exit pupil is needed to properly couple to the eyes.

Transmission- The transmission of the system is the percentage of light that makes it through the system. Usually more transmission is better because the images will appear to be brighter. For a refracting system it’s simply the transmission of each surface multiplied together. Transmission can be improved by decreasing the number of refracting surfaces or improve the coatings on the surfaces.

These are the basic specifications that define the basic functional properties of the system.

**On Axis Performance**

The image produced on the retina of the eye while looking through the optical system should ideally have the same resolution as the unaided eye. It is generally accepted that the limit of the eye’s resolution is one to two arc minuets per cycle. However this specification is relatively ambiguous as resolvable details are somewhat subjective. So as a rule of thumb two arc seconds is considered “good” performance and one arc second is considered “excellent” performance.

**Off-Axis Performance**

Off axis performance is even more subjective. Usually the performance specifications are written so that it allows for the maximum amount of aberrations before it is noticeable. Table 1 lists the aberration and the allowable amount before it becomes noticeable.

Table . Typical aberration specifications

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| Aberration | Typical Specification |
| Lateral color and coma | Size smaller than 4-5 arc min |
| Distortion | 8% |
| Field curvature | Less than 1 diopter difference across the field |

Because off axis performance is difficult to specify, Walker states that it is best to “specify it in general terms... and then, through a series of ‘give and take’ design reviews, settle on final values as the program and design develop.”

**Cooperation**

Systems are becoming increasingly more complex, usually one company does not make a product from start to finish. Instead they often subcontract out a sub component out to another company to produce. Especially complex systems may have many tiers where there might be sub-contractors that subcontract parts of their subsystem.

When writing specifications for subsystems engineers should prepare “a general specification covering in exact detail those items that are obviously critical to the success of the program while leaving the other performance characteristics” up to trade studies by the subcontractors.

**Summary**

Specifications should sufficiently describe the critical performance parameter of the system. The specifications will sufficiently constrain the design so that it meets the need of the end user. However, at the same time specifications should not overly constrain designs, so that it excludes possible solutions that can satisfy the need. Subjective specifications should be left to trade studies to determine what is possible and what is acceptable.

**Works Cited**

Walker, B.H. “Specifying the visual optical system,” Proc. Of SPIE Vol. 0181. 1979.