Default optical tolerances on drawings

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ABSTRACT

Well written standards include default tolerances. ISO 10110, the optics drawing standard, includes defaults primarily to cover cases where drawings do not fully specify fabrication requirements. Understanding the content of the default tolerance standards, the rationale used to form the definitions, and the use of the definitions is imperative to both engineering and fabrication personnel. We will address all of these topics with the goal of explaining how to use and interpret default tolerances on optical drawings.

Keywords: optical tolerances, optical design, optical standards, optical fabrication, ISO 10110, ANSI

1. STANDARDS: THE KEY TO EFFICIENT COMMUNICATION

Communication is a quintessential element of successful optical engineering. The transition from design to production is optimal when an efficient and error-free method of sharing information, especially in the global marketplace, is understood by all parties. This rationale is the basis for development of a strong set of standards understood by designers, engineers, managers, and fabricators. Well-written standards facilitate commerce by aiding communication, simplifying drawings, enabling the same set of specifications to be used with multiple suppliers, and provide a framework for drawing generation.

The international standard for optics drawings is ISO 10110 Parts 1 through 17.[1] This standard has been developed by an international team of experts determining, through their constituent countries' industry feedback, the most effective protocols for drawings. In the global marketplace, regions and countries have different philosophies about the use of standards. Particularly, in some countries standards have the rule of law, and must always be used; in other countries standards are voluntary. Regardless, when a drawing invokes a standard it must be compliant and documented appropriately. With this in mind, the ISO optics drawing standard includes a particular section, ISO 10110-11, on "Non-Toleranced Data". This section is essential to the standard because it covers cases where drawings do not have a complete set of specified information, either by deliberate omission or error. In other words, when a value is not included on a drawing the understood value is taken from this section. While there are some default values in other sections of ISO 10110, the tolerances themselves are mostly contained within Part 11.

The purpose of this paper is to discuss the salient details of this section of the standard so that all vested parties will understand it and use it effectively.

2. DEVELOPMENT OF NON-TOLERANCED DATA STANDARD

Each part of the ISO standard is reviewed and reaffirmed regularly (every five years) and should be updated as needed. Consequently, there is a concerted effort to keep standards consistent with typical practice in the industry. In terms of the non-toleranced data standard, ISO 10110-11, the last revision was in 1996 and it is in need of a significant update. The 1996 revision of the non-toleranced data table is given in Table 1. In the process of releasing an American National Standard (ANSI)[2] version of ISO 10110-11, a concerted revision effort has been made. The rest of this section discusses

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the development of the three key facets of the non-toleranced data standard which must be considered: size classifications, tolerance categories, and magnitudes.

Table 1: Non-tolerance data (Table 1) from ISO 10110-11:1996.[3]

Property	Range of maximum (diagonal) dimension of the part mm			
	up to 10	over 10 up to 30	over 30 up to 100	over 100 up to 300
Edge length, diameter (mm)	± 0,2	± 0,5	± 1	± 1,5
Thickness (mm)	± 0,1	± 0,2	± 0,4	± 0,8
Angle deviation of prisms and plate	± 0° 30'	± 0° 30'	± 0° 30'	± 0° 30'
Width of protective chamfer (mm)	0,1 to 0,3	0,2 to 0,5	0,3 to 0,8	0,5 to 1,6
Stress birefringence in accordance with ISO 10110-2 (nm/cm)	0/20	0/20	——	——
Bubbles and inclusions in accordance with ISO 10110-3	1/3 × 0,16	1/5 × 0,25	1/5 × 0,4	1/5 × 0,63
Inhomogeneity and striae in accordance with ISO 10110-4	2/1;1	2/1;1	——	——
Surface form tolerances in accordance with ISO 10110-5	3/5(1)	3/10(2)	3/10(2) (all ϕ 30)	3/10(2) (all ϕ 30)
Centring tolerances in accordance with ISO 10110-6	4/30'	4/20'	4/10'	4/10'
Surface imperfection tolerances in accordance with ISO 10110-7	5/3 × 0,16	5/5 × 0,25	5/5 × 0,4	5/5 × 0,63
Key —— : No specification				
NOTES 1 The surface texture specifications for an optical element (see ISO 10110-8) shall always be given in the drawing; no implicit indication for surface texture is therefore given in this part of ISO 10110. 2 This part of ISO 10110 does not provide implicit specifications for laser irradiation damage threshold (see ISO 10110-13).				

The motivation for the different size classifications is based on the fact that fabrication and metrology processes depend on the size of the finished component. Clearly the defaults cannot reasonably be defined without taking different sizes into account. ISO 10110-11 differentiates default tolerances between small optics less than 10 mm diameter, optics between 10 and 30 mm diameter, optics between 30 and 100mm diameter, and large optics between 100 and 300mm in diameter. Optics not covered by these sizes are unusual enough that no clear default can be safely defined; hence all numbers should be specified. Because the manufacturing toolset is completely different for micro-optics less than one or two mm in diameter, future revisions of the standard may also include a lower limit.

The second key facet for the defaults in ISO 10110-11 is the categories of tolerances that are given defaults. The simplest rationale is to include all quantities specified in the standard in this section, with only a few exceptions. The current standard includes lens diameter (edge length), thickness, angle deviations for prisms and plates, chamfer width, stress birefringence, bubbles and inclusions, inhomogeneity and striae, surface form tolerances, centering, and surface imperfections. Categories not included but are currently being considered by the Optics and Electro-Optics Standards Council (OEOSC)[4] for the ANSI version of this document are mean index of refraction, V-number, clear aperture to part edge distance, and a chip standard. Categories to be considered in future revisions of Part 11 are index change with temperature, slope and sampling criteria for aspheres, and laser irradiation damage threshold.

The third key element of the standard is the magnitude of the errors for given sizes. Magnitudes are the most difficult part of the standard to develop. Given all of the different manufacturing processes, metrology, and materials used to produce optics, finding a one-size fits all value for defaults is intractable. Rather than split the standard into different tables dependent on these diverse factors, the need for simplicity and clarity mandates picking values based on traditional fabrication processes and standard shop practice. The goal is to define a level of tolerance which we can assume will be achieved, even if it is not explicitly required in the drawing. This will lead to the numbers being on the loose side of fabrication capability, which is justified since omission on drawings should naturally imply insensitivity to fabrication error. Of course, this means trying to determine standard shop practice (a moving target) and a consensus on what values make sense. In general, these quantities will vary from shop to shop and region to region, so the best effort possible is to gauge the industry when the standard is being updated. Note that Table 1 includes numbers that may be considered tight for bubbles (1/) and surface imperfections (5/). In particular, a common surface imperfection metric still in wide use is scratch-dig, where an 80-50 number is looser than the ISO 10110-11:1996 value.

The effort to develop the American National Standard version of ISO 10110-11 has included polling of different groups (members of OEOSC and APOMA[5]) as well as discussion with industry experts. The effort by OEOSC to plan the ANSI revision of the standard occurred throughout the 2010 calendar year and the development of the new standard is in progress. Going through all categories and details is beyond the scope of this informative paper, but some examples are described in the next section. These quantities can be compared to published sources,[6] keeping in mind that the number for the standard is intended to be an average of loose standard practice fabrication techniques. Individual shops may have looser quantities possible than the standard and others may consider no cost benefit in having numbers as loose as stated in the defaults.

3. USE OF NON-TOLERANCED DATA

As stated in the previous section, the magnitudes of the default tolerances are chosen to be on the loose side for standard shop practice. This reasonable philosophy has different implications for vested parties. The primary purpose of this part of the standard is to disambiguate cases where numbers are not on drawings, with the implicit understanding that the default applies in such cases. Of course it is necessary for all parties to comprehend the standard and the fact that it applies in these cases.

On the manufacturing end, understanding how these defaults relate to floor processing is important. Moreover, discerning when these defaults are not a good match with shop floor practice is critical. In such cases, either the shop floor should alter their processes to match the standard, or extra communication should be conveyed via exceptions during the quotation and purchase order process to the designers. This communication can apply for looser or tighter desired numbers. In the end, it all comes down to determining how best to comply with the standard and when to communicate.

For a designer, the numbers have both formal and informal implications. Formally, these are the numbers to expect the shop to hold when you omit numbers on a drawing. Omission is a direct use of the standard and totally appropriate if it is being applied to your drawings. Some shops may state a different preference for absent numbers, and it is simple enough to do optical analysis in any of the design codes. Informally, the non-toleranced data standard gives designers an idea of the loose end of the fabrication spectrum. Moreover, the standard can be used to help parameterize the trade-space during optical tolerancing and to provide guidance to the designer in generating optical drawings. The danger, however, with blindly using the defaults has been made very clearly in a recent paper.[6] Typically, applications will have a mix of sensitive parameters requiring special care and others that are less sensitive.

Of course there may be cases where no specification is desired at all. Since parameters which are not toleranced are assumed to be subject to the default values of Part 11, one cannot simply leave the requirement off to indicate "no specification". To override Part 11 for a specific specification, a hyphen is used in place of the tolerance to indicate that there is no requirement. For example, the proper indication of surface form tolerance is 3/A (B), where A is the power tolerance and B is the irregularity tolerance, in fringes at 546.07 nm. To indicate that there is no surface form requirement, one would write 3/- . If there were an irregularity specification of 1 fringe, say, but no power requirement, one would indicate 3/- (1), for example. If the default values for both power and irregularity were acceptable, no 3/ indication would be used at all.

In Figure 1, a singlet drawing is given in two different forms with identical meaning. Numbers are explicitly included in the left drawing for diameter and thickness tolerances, material specification (0/ through 2/), and values for both surfaces (3/ through 6/). In the right drawing in Figure 1, these callouts are not included, meaning that the default is to be assumed. Note that in the case of laser irradiation threshold (6/), no callout indicates a default only if one exists in the standard in a different place than ISO 10110-11 (which does not include a default value for that parameter).

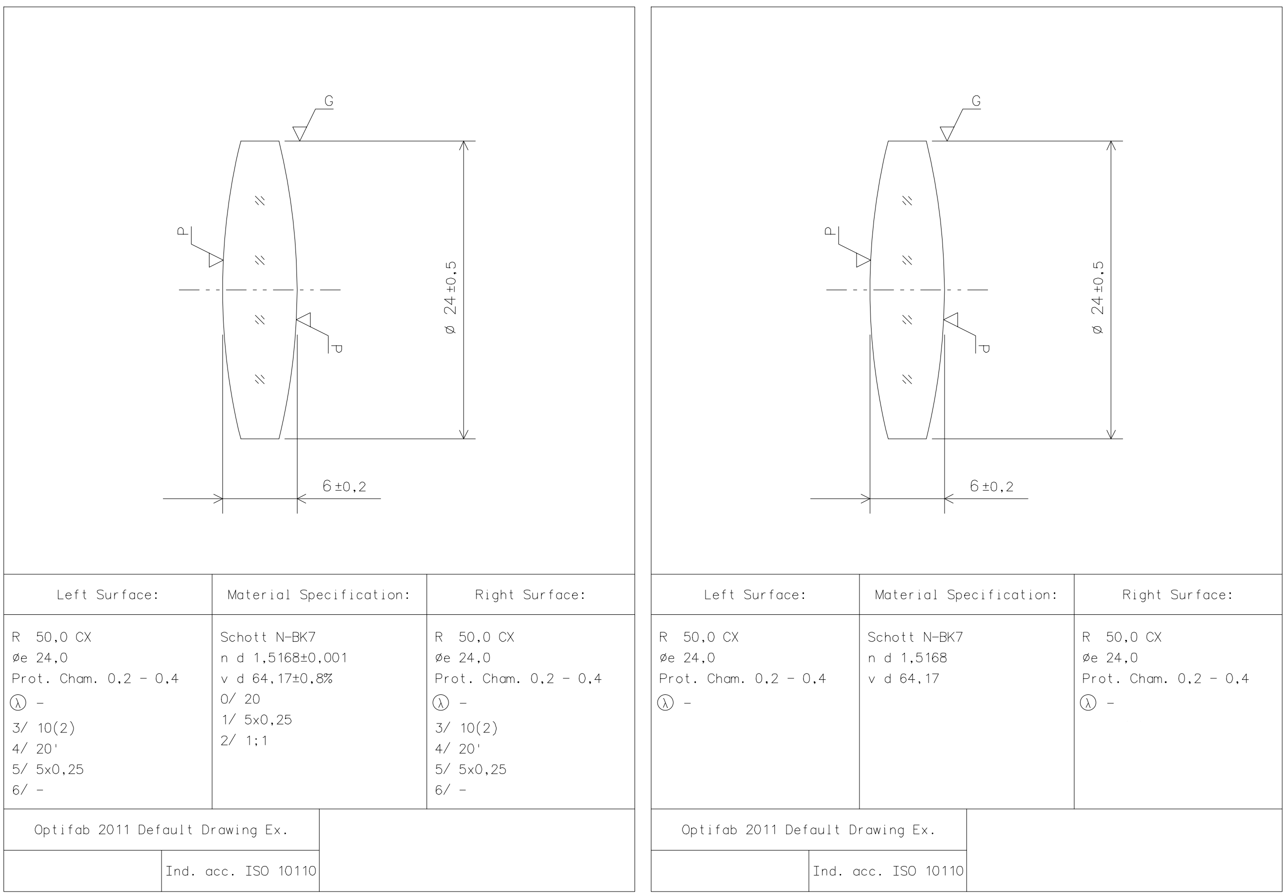

Figure 1: Identical drawings with default numbers specified (left) and numbers omitted (right). The right figure implies the defaults are applicable.

4. OTHER DEFAULTS

While many of the default values in an ISO 10110 drawing are for non-toleranced data and collected within Part 11, there are a few other default parameters which are referenced in other sections. For example, ISO 10110-1 specifies that in the case that the wavelength is not indicated, it is assumed to be 546.07 nm. Since common practice is to use 632.8 nm for the default wavelength in many optics shops, this is one default which is not recommended. In addition, parameters such as the bandwidth limits of a surface texture or waviness specification, the datums to be used in interpreting a wedge specification, and the default testing temperature are in various other sections of the standard. In each of these cases, the default parameter can be overridden with explicit notation as required.

5. CONCLUDING REMARKS

Standards are key communication tools that improve the efficiency of the global optics industry. The non-toleranced data section and other defaults are an essential part of the standard. Understanding what is assumed for unspecified values is clearly important. Since standard shop practice is continually changing as new technologies and processes emerge, the task of keeping this key part of the standard up-to-date is vital in making the standard optimally effective.

REFERENCES

1 ISO is the International Organization for Standardization (www.iso.org, verified February 23, 2011).
2 ANSI is the American National Standards Institute (www.ansi.org, verified February 23, 2011).
3 Table 1 is © ISO. This material is reproduced from ISO 10110-11:1996 with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization (ISO). No part of this material may be copied or reproduced in any form, electronic retrieval system or otherwise or made available on the Internet, a public network, by satellite or otherwise without the prior written consent of the ANSI. Copies of ISO 10110-11:1996 may be purchased from the ANSI, 25 West 43rd Street, New York, NY 10036, (212) 642-4900, http://webstore.ansi.org". (website verified February 23, 2011)
4 OEOSC is the Optics and Electro-Optics Standards Council (www.optstd.org, verified February 23, 2011).
5 APOMA is the American Precision Optics Manufacturers Association (www.apoma.org February 23, 2011).
6 J.E. DeGroote Nelson, R. N. Youngworth, and D. M. Aikens, "The cost of tolerancing", Proc. SPIE 7433, 74330E (2009).