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Effective Training Inc., Westland MI, 734.728.0909

**Volume 01: Issue 10**



Known as the "Doctor of Dimensioning," Alex Krulikowski is a noted educator, author, and expert on Geometric Dimensioning and Tolerancing (GD&T). A design manager with one of the world's largest manufacturing corporations, he has more than 30 years of industrial experience putting GD&T to practical use on the shop floor.

ETI Mail is a regular online publication devoted to Geometric Dimensioning & Tolerancing. Each edition features a host of GD&T resources and links, as well as dimensioning tips by noted GD&T author and ETI founder, Alex Krulikowski. We also invite you to visit our website, [etinews.com](http://etinews.com). To view past issues of ETI Mail, see the [archives](#).

ETI Mail is now available in [PDF format](#). To read the PDF file, you will need [Adobe Acrobat Reader](#).

### In This Issue

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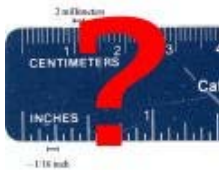


#### Simplify Your Tolerancing Methods

Viewing these six key factors as a system—while sketching geometries—provides a workable methodology for consistently good casting designs.

To read the article, [click here](#)  
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This article by Michael A. Gwyn of Pelton Casteel, Inc., Milwaukee, is from [Engineered Casting Sources](#) online magazine.



### Measurement Uncertainty

[Michael A. Murphy](#)

Is your goal to help your organization reach Tolerancing Heaven? Do you desire complete understanding of variation in your company's product development process? If so, allow me to inform you of a topic that you may not have considered that could significantly impact your ability to achieve your tolerancing goals.

The topic in question is measurement uncertainty. [See ASME B89.7.3.1-2001 Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications.] Measurement uncertainty always exists by nature, and controlling it may improve the quality of your products. Once you have achieved Tolerancing Heaven in an engineering environment [see [ETI Mail, Vol. 1, Issue 8](#)], tolerance specifications on produced pieces must be verified by inspection before they are sold to customers. Are the parts actually within the specified tolerance or are they outside of the specified tolerance range by a significant factor? Some parts that appear to exist in Tolerancing Heaven may be of low value to the customer. With some widely used methods of accounting for measurement uncertainty, parts can be measured and found to be within the specification, but in reality they exceed the specified tolerance by as much as 25-33%.

Not all sources of measurement uncertainty are easily identifiable. Measurement uncertainty includes all factors that lead to differences between an actual part distance and the measurement value obtained for that part distance. These factors may include gage accuracy, gage precision, dust, humidity, operator error, temperature, vague drawing specifications, and numerous other factors. Obtaining a specific uncertainty value for all of these is virtually impossible; however, the

[Summer 2003 issue.](#)

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## ETI Products



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most significant contributing factors can be quantified. Generally in industry, there are well known methods for determining gage error, accuracy, and operator error, which usually accounts for the greatest portion of uncertainty.

### Paragraph 2.4 of Y14.5 - Often Viewed with Two Paradigms

Paragraph 2.4 of ASME Y14.5 - 1994 discusses the interpretation of tolerance limits. Furthermore, it addresses conformance to limits. The conformance portion of Paragraph 2.4 is where our attention will be focused. The paragraph states:

"To determine conformance within limits, the measured value is compared directly with the specified value and any deviation outside the specified limiting value signifies nonconformance with the limits."

This passage seems simple enough; however, as with many passages in the standard, the interpretation depends upon an individual's organizational background. The product engineer may have an entirely different view than the manufacturing engineer. We will explore how these differences can create a poor business condition.

### Product Engineering Paradigm

Product engineers work under the belief that production parts will be within drawing specifications. They tend to focus on the first portion of Paragraph 2.4, which states:

"All dimensional limits are absolute. . ."

This leads to an understanding that the actual part produced will never physically exceed the limits specified on a drawing. When a system approach to tolerancing is used, the system's functional requirements are determined, and the allocation of tolerances in the system is facilitated by tolerance analysis. The maximum tolerance that allows the system to function as intended is specified to reduce cost and provide manufacturing with maximum flexibility. This approach is robust only when the produced parts do not exceed specified tolerance limits. If parts exceed the specified limits, the system may not function as intended.

The product engineering paradigm bases the part tolerance specification on the functional requirements of the system. The manufacturing organization determines the gage error value for the measurement system that is used to verify a part tolerance. The gage error is then subtracted from the specified limits to determine the acceptance limits. (See Figure 1.) For example, if a hole diameter specification is 9 - 10 and the gage error is 0.26 (0.13 for each end of the specification), the acceptance limits would be 9.13 - 9.87. When using this approach, product tolerance analysis, engineering analysis, and tolerance allocation practices ensure that the actual parts produced within these limits will function properly. However, reducing the functional specification limits by the gage error to establish the acceptance limits may increase manufacturing cost.

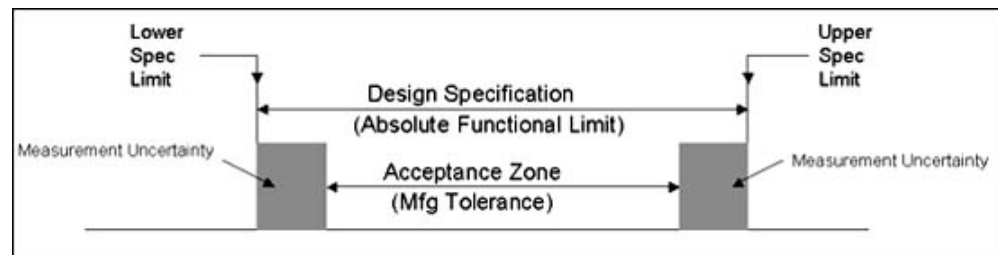


Figure 1

### Manufacturing Engineering Paradigm

Manufacturing engineers believe they can simply compare the measured value with the drawing specifications. They tend to focus on the last portion of Paragraph 2.4, which states:

". . . the measured value is compared directly with the specified value. . ."

This leads to an understanding that gage error is additive to the specified value. Manufacturing measurement systems are generally evaluated for reproducibility and repeatability of measurement with respect to gage variation. A value is obtained that predicts-with a high degree of confidence-how much measurement error can be attributed to the gage.



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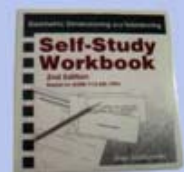
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The most common manufacturing practice used in industry today is to compare the gage error to the tolerance value on the part print tolerance that the gage element is designed to measure. If the gage error is within a predetermined percentage of the print tolerance, the measurement device is approved. After the gage is approved, it is used to determine acceptance or rejection of production parts. The most commonly accepted practice for % error is 25-33%. (See Figure 2.) For example, if a hole diameter specification is 9 - 10 and the gage error is 0.26 (0.13 for each end of the specification), the acceptance limits could be 8.87 - 10.13.

This approach decreases manufacturing costs; however, if a resulting measurement approaches the limits of the print specification, there is an increasing probability that the approved part is actually out of the specification limit. When using this approach, the product engineering tolerance analysis used to determine product tolerances does not reflect the tolerances produced on the finished part.

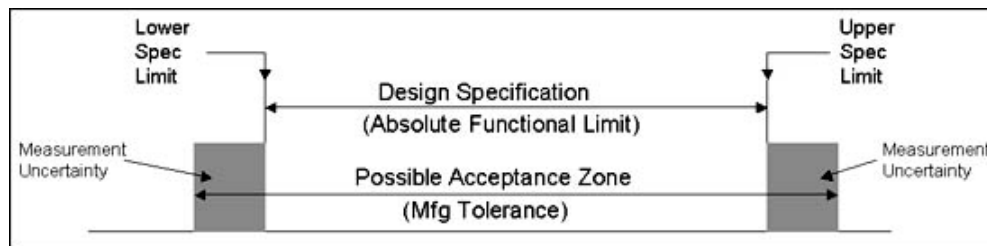


Figure 2

**What to Do?**

First, an organization must have a common approach to tolerance verification that is clearly documented and understood by all. It should be communicated in company policy manuals and included in training programs. The decision about which approach is used must include a cost vs. risk analysis with a sharp eye on the customer's needs.

If the product engineering paradigm is used, the product function is protected. However, manufacturing must use a measurement acceptance zone that is smaller than the print specification. When purchasing production and measurement equipment, the systems must be designed appropriately.

If the manufacturing paradigm is used, the product function is at risk. Product engineering must account for additional tolerance in the tolerance analysis to account for measurement uncertainty. In order to satisfy the system function requirements, product engineering must adjust tolerances down to account for measurement uncertainty allowances.

If the goal of an organization is to achieve Tolerancing Heaven, then how measurement uncertainty is accounted for must be understood, documented and communicated.

<b>Controlling Measurement Uncertainty</b>	
<b>Product Engineering Approach</b>	<b>Manufacturing Approach</b>
<b><i>Manufacturing must. . .</i></b>	<b><i>Product engineering must. . .</i></b>
Use caution purchasing production and measurement equipment	Account for additional tolerance in the tolerance analysis to account for gage error
Design measurement systems appropriately	Adjust tolerances down to account for manufacturing gage allowances
Carefully consider scrap rates	Not increase gage error percentage

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allowances to account for tighter tolerances

*Michael A. Murphy is a Design Supervisor at a major automotive manufacturer with over twenty years' experience. He received his undergraduate degree from Central Michigan University and has completed graduate work at Oakland University. As an ASME certified senior level GDTP, Mike is an independent consultant who provides dimensional management and GD&T training throughout the US and Europe. He is a member of the ASME Y14.41 and ASME Y14.5M committees, and has worked extensively with a major CAD manufacturer.*

*Mike chairs a corporate Geometric Tolerancing Task Team and is a member of other corporate and ASIG/JAD (Aircraft SIG/Joint Application Development). He is a member of the USCAR GD&T standards committee and recently served as a consultant on a national science foundation project where the principal object was to improve the quality of entry level design engineering courses at universities throughout the United States.*

We welcome your feedback. Send comments about this article to [ETIemailbag](#). Your opinions will be posted in the next issue.

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## Standards in the News

ETIEmail's Standards in the News takes a look at real-life issues involving standards. This month: A history lesson about standards.



Excerpts from the [Wired Magazine Website](#)

### STANDARDS: A HISTORY LESSON

*Standards in the News usually looks at current issues regarding the use of standards —and the problems that result from their misuse. This issue deviates a bit from the norm and highlights an article by New Yorker financial columnist James Surowiecki. He gives us an interesting look at the beginnings of standardization with the 1864 speech by a legendary tool builder named William Sellers that started our nation on its track towards nationalizing standards and making our economy better and our country safer.*

Today, according to the National Institute of Standards and Technology, there are close to 800,000 global standards. But go back a century and a half and you find an American economy in which there were literally none. On April 21, 1864, a man named William Sellers began to change that. Sellers initiated the first successful standardization fight in history, over the humble screw. That struggle was not just about a particular standard. It was about the importance of standardization itself. To win, Sellers relied on technical savvy - as well as political connections, clever strategy, and a willingness to put progress ahead of the self-interest of his own friends and colleagues.

On that April evening, a crowd of Philadelphia engineers and machinists gathered in the lecture hall of the Franklin Institute, the professional society to which they belonged. Sellers was the institute's new president, and they were there to hear him speak publicly for the first time. In the world of these men, Sellers was a legend, the finest tool builder of his time. After starting as an apprentice machinist at 14, Sellers had his own shop by the age of 21, and a decade later he was the head of the most important machine-tool shop in Philadelphia, the city at the center of America's machine-tool industry. If Sellers was going to insist that national standards were necessary, then it was definitely an idea worth taking seriously.

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The speech, "On a Uniform System of Screw Threads," played against the backdrop of war between North and South, which added resonance to Sellers' call for a national standard. "In this country," Sellers noted, "no organized attempt has as yet been made to establish any system, each manufacturer having adopted whatever his judgment may have dictated as the best, or as most convenient for himself." At the time, American screws, nuts, and bolts were custom-made by machinists, and there was no guarantee that bolts made by shops on different streets, let alone in different cities, would be the same. "So radical a defect should exist no longer," Sellers proclaimed.

[Full story](#)

Excerpted from the article, "Turn of the Century," by James Surowiecki, in the January 2002 issue of [Wired News](#) online.



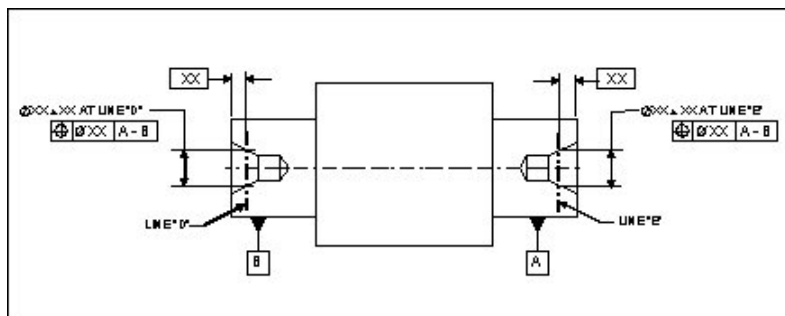
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**The ETI Mailbag**

Alex,  
We frequently make cylindrical parts with a center drill on both ends. We use the center drill holes to finish grind the outside diameter. What is the correct method to specify that the center drill must be in relationship with the outside diameter. Can a control be placed on the angle of the center drill hole? What is correct???

Scot Sittler  
CITCO Operations



**Yes. This is a good question. Unfortunately, the Y14.5 standard doesn't cover this type of application. Since it is not covered in Y14.5, you may get a number of different solutions based on whom you ask. Based on the drawing in the attached sketch, here is one possible way to specify the relationship of a center drill hole to the outside diameter of a cylindrical part.**

**Apply a position tolerance to a circular element of the conical surface of each center drill hole as shown in the attached sketch. The tolerance zone for the circular element of the**

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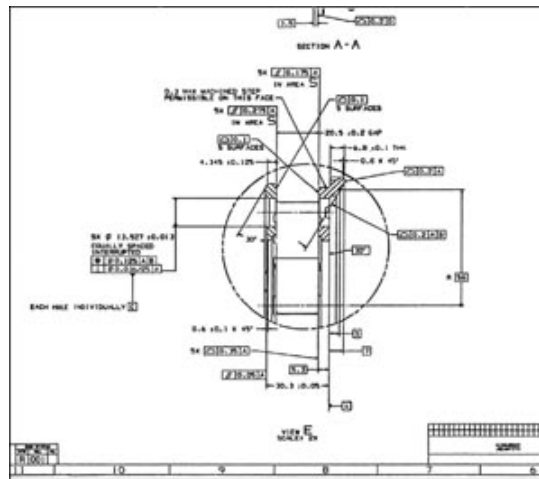
cone can be used to determine the relationship of the axis of the cone relative to the datum axis. (The size and orientation of the center drill holes still need to be defined).

I have described one method to handle your application. Keep in mind, there are a number of ways this application could be tolerated.

Alex



*My question is about a GD&T callout on an automotive component drawing. It is for a hole's axis to be "perpendicularity +  $\text{Ø}0.036 / 25$  + plane datum A."*



*Click on drawing for larger view.*

*I am not sure the meaning of the part of "--/25". Is it "projected to 25 mm" (but no P accommodated) or "per 25 mm length of axis"? Where could I find the explanation regarding this?*

Regards,

*Xibo Liu  
Manufacturing Engineer  
Quadrad Mfg. Ltd., A Linamar Company*

**I think this may be an application (or misapplication) of a unit per unit callout as described in Y14.5 in figure 5-4 on page 160. The standard shows the concept of unit per unit length used on straightness. Some companies have expanded the concept to other geometric controls.**

**One way to interpret the callout is for each twenty five mm from datum A, the hole axis can be out of perpendicularity by .036. For example, if the part was 50mm wide, the hole could be out of perpendicular by .072.**

Alex

*ETI appreciates your questions and comments.  
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The GD&T Trainer (5) GD&T Trainer Discussion Area - Includes Trainers, Updates, etc.
Geometric Dimensioning and Tolerancing
Prior GD&T Questions This Discussion Group contains questions that are small mail, etc.
ASME Y14.5M Discussion Group for questions/comments on represented in the ASME Y14.5M standard
Tolerance Analysis

### ETI'S Discussion Board

ETI's website has an interactive forum that's easy to access and may give you a broader knowledge of GD&T-related topics. Drop by the Interact section of our website and take a look at the Discussion Board.

To visit the board, [click here](#).

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### Quality Quote



### Alex's Tech Tip

*From teaching ideas to new products that will assist you in training or on the job, the ETImail Tech Tip will keep you informed about new technology and training trends. This month's Tech Tip: Systems to help organize electronic drawings and documents.*

#### GET THE MOST OUT OF ELECTRONIC FILES

Document-management systems help engineers keep track of drawings, documents such as specifications, and all the parts and assemblies that comprise 2D and 3D CAD files. However, as engineers find themselves working with colleagues in many different locations, systems that let them share their work with others are essential to productivity. What's more, vendors are also working on new features for programs that allow companies to distribute files and data to other users in the organization.

Companies are constantly improving their systems. MatrixOne Inc., for example, recently updated its newly released Matrix10 with a file-collaboration server that speeds the response of distributed file systems by reducing the amount of data sent over the network when a user initially requests a file.

Most systems use a single transaction to verify a user's identity, locate a file, and download it. This transaction can be time-consuming and may require multiple calls to the database, file vault, and application. MatrixOne's server uses a multi-step process, first confirming that the user is allowed access to the file, and then sending a "ticket," or encrypted Extensible Markup Language (XML) file, containing descriptive data about the file to the vault closest to the engineer's computer. The file is then downloaded over a local area network. [Read entire article](#)

Excerpt from "Get the Most Out of Electronic Files," by Joost Dull, VP Support & Services, Cyco Software. Full article is from the October 2003 [DE Online](#) [[www.deskeng.com](http://www.deskeng.com)].



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### ETImail Feedback

*Have comments about anything you've read in ETImail? ETI will post your comments here and provide a forum for more discussion about GD&T topics.*

#### Comments on the 'Tao of Tolerancing'

An excellent article that I will be sharing with my team at DaimlerChrysler.

My main comment is that I got halfway through the article before you made the clear distinction between variation (the thing that actual parts do) and tolerance (the thing people include in designs to accommodate the thing that parts do). Some of my audience don't yet have a grasp of the difference.

Also, I was hoping you would include a matrix relating functional tolerances to process capability: If capability is far tighter than functional tolerances then quality is good but



*Quality is the degree to which a specific product conforms to a design or specification.*

—Harold Gilmore

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product costly (choose cheaper process). If capability is slightly tighter than functional tolerances then quality is good and good value (optimum situation). If functional tolerance is slightly tighter than capability then quality is slipping (value MAY still be there) and if functional tolerance is far tighter than capability then quality is poor (find new process or redesign to increase tolerance to variation).

Thanks,

Mike Matusky



*ETI would like to hear from you. If you have an opinion about any ETIEmail article or feature, please write to our [ETIEmailbag](#).*

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