APPLIED GEOMETRIC TOLERANCING IN ACCELERATOR COMPONENT DESIGN*

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Abstract

This paper discusses how the ANSI Y14.5M 1982 Standard for Dimensioning and Tolerancing applies to the fabrication of components for cryogenic accelerators. It includes information on selecting datums and assigning positional tolerances that ensure stress-free mechanical mating conditions as well as interchangeability of parts. In addition, modifiers can be used in the feature-control frames that specify allowable deviations from nominal geometry; their use reduces the cost of fabrication without compromising ease of mechanical assembly. The physics requirements unique to the design of linear accelerators also call for the prudent application of some seldom-used modifiers that reduce the need for alignment of initial assemblies to optimize accelerator performance.

I. INTRODUCTION

The ANSI Y14.5M 1982 Standard for dimensioning and tolerancing provides a common basis for interpreting engineering drawings of mechanical parts and assemblies. Correct application of the ANSI standard helps designers define their tooling and inspection gages and provides more flexibility in selecting fabrication facilities. The ten radio-frequency (rf) cavities of the drift-tube linac (DTL) and other components of the Ground Test Accelerator (GTA) are currently being fabricated. We have seen significant benefits to this effort from using the ANSI standard.

The scope of this paper does not allow us to explain the ANSI standard in detail to those who are not familiar with it. Rather, we hope that the examples shown will illustrate its effectiveness to other designers.

II. DATUM SELECTION

Figure 1 shows a cross section through one of the copper rf cavities of the drift- tube linac. The primary datum used to locate the rest of the geometry within the cavity is the center bore. This datum selection ensures that the axes of the intersecting features, such as holes required for the drift tubes, post couplers, and tuners, are located in accord with the accelerator's physics requirements rather than as dictated by non-physics-related parameters (such as ease of machining setup).

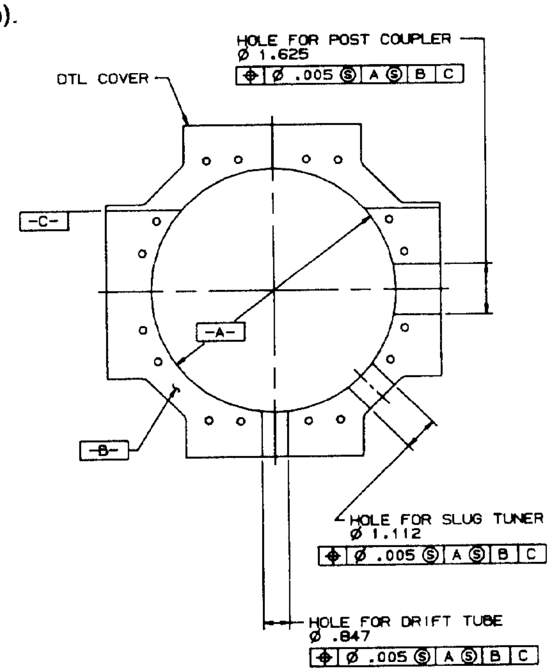

Fig. 1 - Locating Features On A DTL Cavity

Computer-aided fabrication and inspection systems make it feasible to select and use functional part features for datums that otherwise might require an inordinate amount of setup time for the fabricator. As an example, Fig. 2 shows a cross section through a nonconvoluted radio-frequency quadrupole (RFQ) vane, with features of the vane tip specified as the primary and secondary datums for controlling the profile of other features within the vane. Datum "A" is the theoretically perfect plane that lies at the midpoint of the space between the two planes established by the sides of the vane at minimum separation. Datum "B" is the theoretically perfect plane perpendicular to Datum "A" that contains the line established by the two highest points on the apex of the vane tip. The vane is readily machined by a numerically controlled system, and inspected with a computer-assisted coordinate measuring machine.

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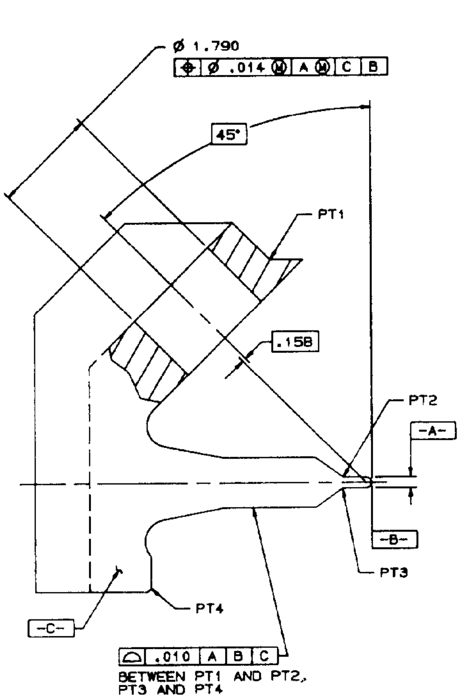
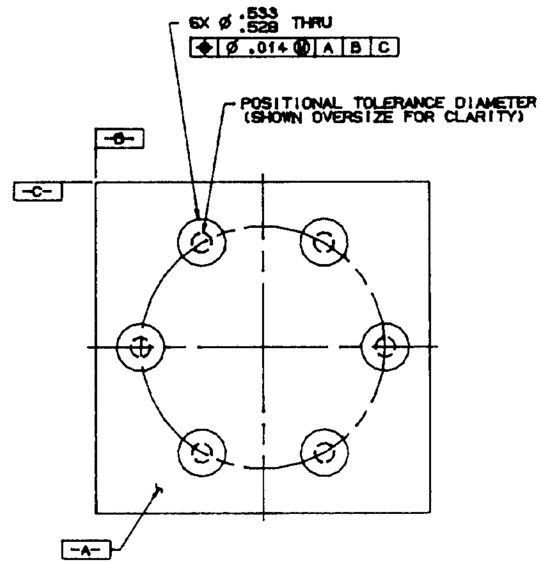


Fig. 2 - Datam References On An RFQ Vane



HOLE DIAMETER	POSITIONAL TOLERANCE DIAMETER ALLOWED
.528	.014
.529	.015
.530	.016
.531	.017
.532	.018
.533	.019

Fig. 3 - Specification Of MMC In A Bolted Flange

III. MODIFIERS

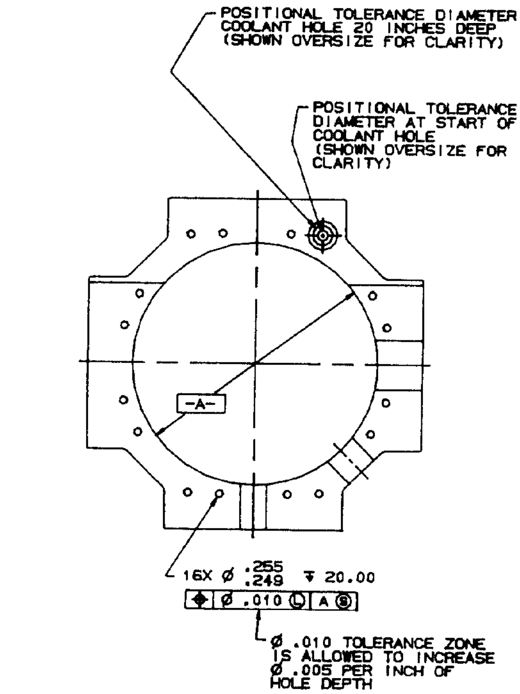
The ANSI standard allows deviations from the specified upper or lower limits of the size of internal features (such as holes) and external features (such as cylindrical protrusions). When stress-free mechanical mating is of prime importance, the fabricator is allowed to take advantage of "bonus" positional tolerance provided that Maximum Material Condition (MMC) or Least Material Condition (LMC) exists in the particular feature or datum. The specification of these two modifiers provides for 100% part interchangeability and facilitates gage definition. Such parts can be inspected "in an open setup", generally considered a more economical inspection method.

Maximum Material Condition has been specified for features and datums in many areas of our design work. It was used extensively for positional tolerances related to the location of bolt circles on components such as mounting flanges for the drift tubes, post couplers, slug tuners, and monitor loops. Figure 3 shows the possible results for MMC specification in this type of application.

We applied the LMC specification to tolerances for the location of the twelve approximately 1/4-in.-diameter coolant holes surrounding the bore of each of the cryogenically cooled DTL modules. To cool the accelerator effectively, the holes must be close to the inner surface of the cavity. Each drift-tube cavity is approximately 40 inches in length; drilling therefore had to be done by a technique called "deep-hole drilling" (similar to "gun drilling"). Each hole was drilled to a depth of just over half the module length, from each end, so that they would meet at approximately the midpoint of the cavity. Least Material Condition was specified for the positional tolerance of each hole, together with a diametrical tolerance zone whose size varied with the depth of the hole at any given location. By keeping the size of the drilled hole toward the smaller diameter allowed by the tolerance, the fabricator could take advantage of the maximum available positional deviation. Figure 4 shows an example of LMC and the variable diametrical tolerance zone applied to the coolant holes in the DTL cavities.

A modifier must be used when a geometrical feature that is subject to variations in size is specified to be a datum. "Regardless of Feature Size" (RFS) is the modifier that was used in positioning the drift-tube and post-coupler holes in the DTL cavities. This ensures that the axes of the holes intersect the axis of the cavity to the precision specified by the diameter of the tolerance zone, regardless of the diameter of the cavity. Although RFS requires that these features be inspected separately on each of the ten cavities, it also assures that the initial assembled positions of the drift tubes and post couplers will be closer to the position required to optimize accelerator performance. In addition, the range of adjustment for these components will be more equally distributed about their nominal locations. To illustrate this difference,

Fig. 5 shows the maximum allowed positional deviation for the MMC vs the RFS specification for the drift-tube holes.



COOLANT HOLE Ø	POSITIONAL TOLERANCE Ø AT 0.00 DEEP	POSITIONAL TOLERANCE Ø AT 20.00 DEEP
.255 (LMC)	.010	.110
.249 (MMC)	.016	.116

Fig. 4 - LMC With A Variable Diametrical Tolerance Zone

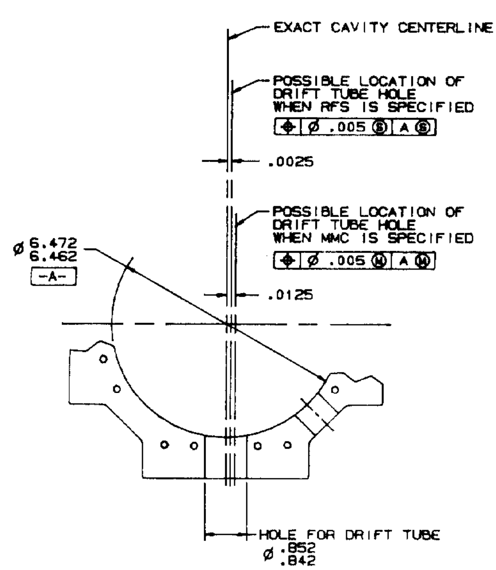


Fig. 5 - Possible Results From Using RFS VS MMC

Application of the ANSI standard is effective for assigning tolerances when minimum clearances as well as stress-free mechanical mating conditions are required for function. The stems of each of the 130 post couplers in the DTL consist of two coaxial tubes that form an annular space through which cryogen flows. Adequate distribution of cryogen through the annulus was ensured by applying the rules governing form and positional tolerances in the ANSI standard. A minimum diameter of .301 inch and a positional tolerance of .006 inch in diameter at MMC was specified for the inside of the outer tube; and a maximum diameter of .253 inch and a positional tolerance of .004 inch in diameter at MMC was specified for the outside of the inner tube. This ensured that, at the worst condition of form and position allowed, a minimum of .019 inch annular flow space would result. Figure 6 shows a cross section through the post-coupler stem and the possible results expected from these specifications.

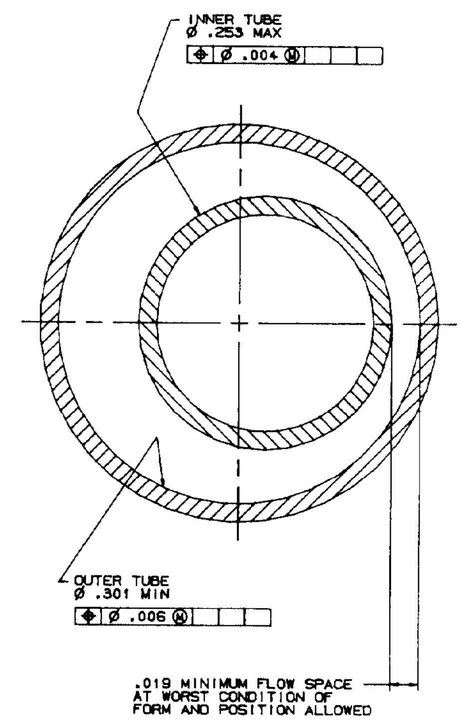


Fig. 6 -Cross Section Thru Post Coupler Stem

IV. CONCLUSION

Close adherence to the rules set forth in the ANSI Y14.5M 1982 standard has proven effective as we continue fabrication and assembly of the components of the Ground Test Accelerator. Not only has the ANSI standard provided a common reference for interpreting engineering drawings, it has also provided a means for locating individual components closer to the positions dictated by the physics requirements of cryogenic linear accelerators.