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Sandia Corporation

REPRINT

POSITIONAL TOLERANCE TRAINING AIDS

by

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and

R O Dell

AUGUST 1961

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TABLE OF CONTENTS

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Introduction

Positional tolerancing, a post-World War II modification in the dimensioning of engineering drawings, has been used successfully by Sandia Corporation since 1955. Consequently the wide acceptance of the Positional Tolerance Dimensioning System has created a need for an educational program on its meaning and application. This brochure introduces one method employing specially designed training aids to implement such a program.

The training aids described here were prepared for drafting personnel (trainees and new hires) unfamiliar with positional tolerancing; however, they can be equally effective in teaching the system to designers, machinists, and inspectors, but in no sense is this a complete treatment of the subject. A more thorough introduction can be found in "Positional Tolerancing at Sandia Corporation," a Sandia Corporation Reprint (SCR-83A), which could well serve as a basis for a text with these training aids as a supplement.

It should be noted also that the dimensions and tolerances used here have been purposely exaggerated and extreme tolerance conditions are shown to make the principles of the system more readily apparent.

Bilateral Tolerance Method

Chart 1 (Fig. 1) illustrates a plate with a rectangular pattern of four clearance holes located by the bilateral tolerancing method. The design intent is to define a part that may be fastened to an identical plate by 1/2-in. diameter bolts. Misalignment of the edges is permissible.

The inherent ambiguities of the bilateral system, such as the question of the datum for orientation, can be pointed out here. However, the initial purpose of this chart is to show a bilaterally toleranced pattern of holes in order to analyze the locational tolerance zones as they may be verified by fixed-pin type gaging.

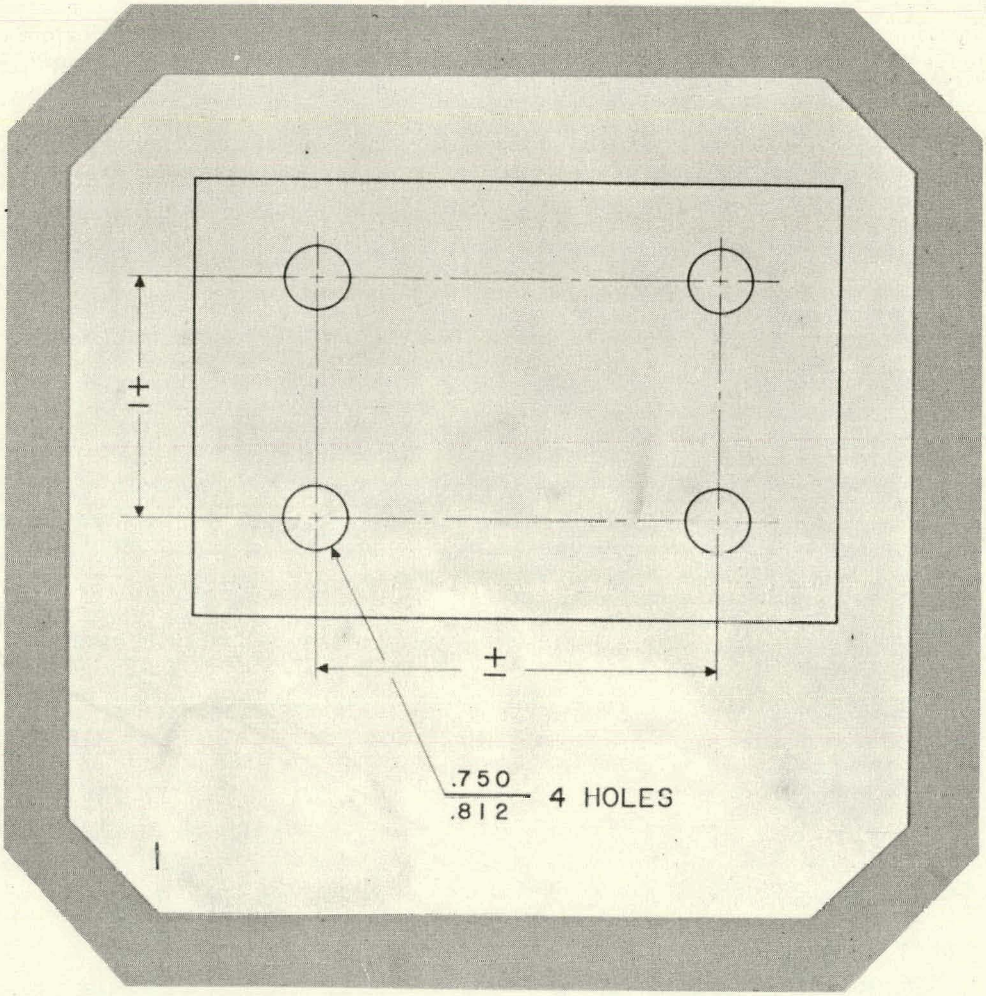

Figure 1

Bilateral Tolerance of Location

Chart 2 (Fig. 2) has a transparent opening and represents one of the holes with its center indicated. Chart 2A represents a round gage pin and, at its center, a square zone is shown which indicates the bilateral (±) tolerance specified for the hole location.

Chart 2 is placed over Chart 2A. By moving Chart 2 horizontally and vertically along the corresponding centerlines of Chart 2A (the maximum amount allowed by the gage pin), it can be observed that this size gage pin appears to verify the location of the hole since the center of the hole falls within the bilateral tolerance zone. However, by moving Chart 2 in any radial direction (again the maximum amount allowed by the gage pin), it becomes clear that the gage pin will accept only those holes whose centers fall within a circular area inscribed in the square zone.

Time consuming open setup inspection would be necessary to verify that the full extent of this square tolerance zone has been utilized.

Since the distance along the diagonal at four places from the desired location is permissible using the bilateral tolerance method, this distance should be acceptable in any radial direction from center. Consequently, a circular zone equal in diameter to the diagonal of the square is used in positional tolerance dimensioning.

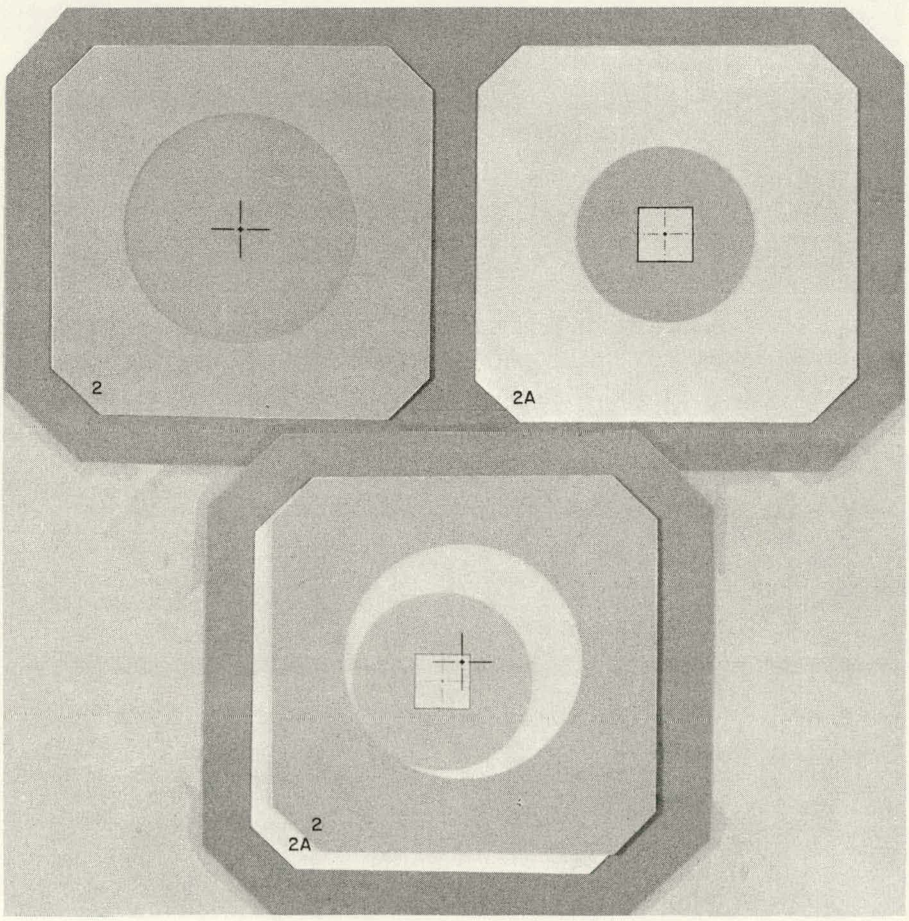

Figure 2

Postional Tolerance

Chart 2 (Fig. 3) is the same as described previously and represents one of the holes. Chart 2B represents a gage pin and, at its center, a circular tolerance zone is shown designating a positional tolerance diameter. Inscribed in this circular zone is a square denoting the same bilateral tolerance mentioned previously.

The gage pin, Chart 2B, is determined by the minimum specified hole diameter less the positional tolerance diameter.

Chart 2 is placed over Chart 2B. The center of Chart 2B denotes the true position (TP) or desired location. The movement of Chart 2 to its extent in any direction will confirm that round fixed-pin type gages will now accept the location of holes whose centers fall anywhere within the specified Positional Tolerance zone.

This method, in addition to being compatible with gaging principles, results in a tolerance increase of about 57% over the bilateral tolerance system and yet meets military requirements of 100% interchangeability of mating parts.

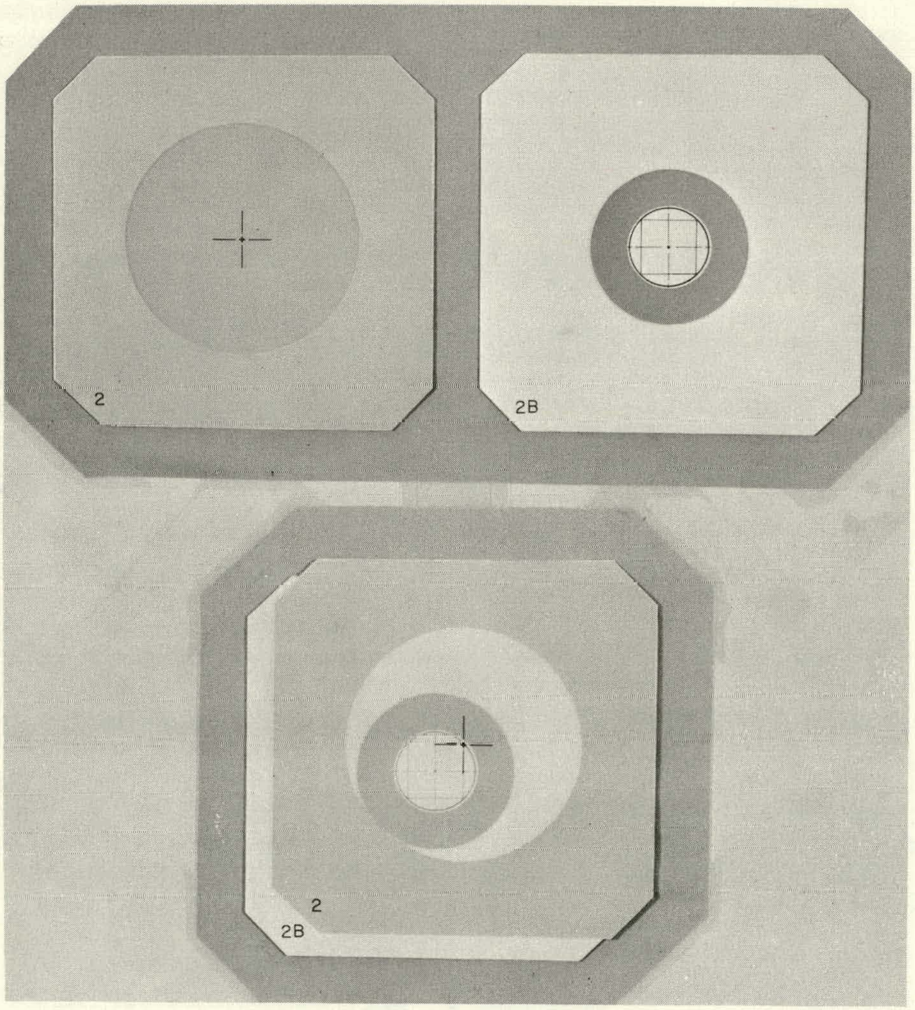

Figure 3

Drawing Illustration Chart

Chart 3 (Fig. 4) illustrates a part drawing with the same pattern of holes as in Figure 1, but is dimensioned by the positional tolerance method.

The assembly consists of two pieces of rigid illustration board. The front section includes the part drawing and a portion of the hole callout. The other section, a movable disk, contains modifications of that callout. The disk is pivoted so that a partial rotation to the next position creates a change in the callout which expresses a specific condition concerning the holes and their related datum.

The conditions displayed by the chart cover the following: (1) location of holes regardless of their size, (2) location of holes at Maximum Material Condition (MMC), (3) datum at MMC, (4) datum tolerance at MMC, and (5) datum at MMC when a feature other than one of the holes is datum.

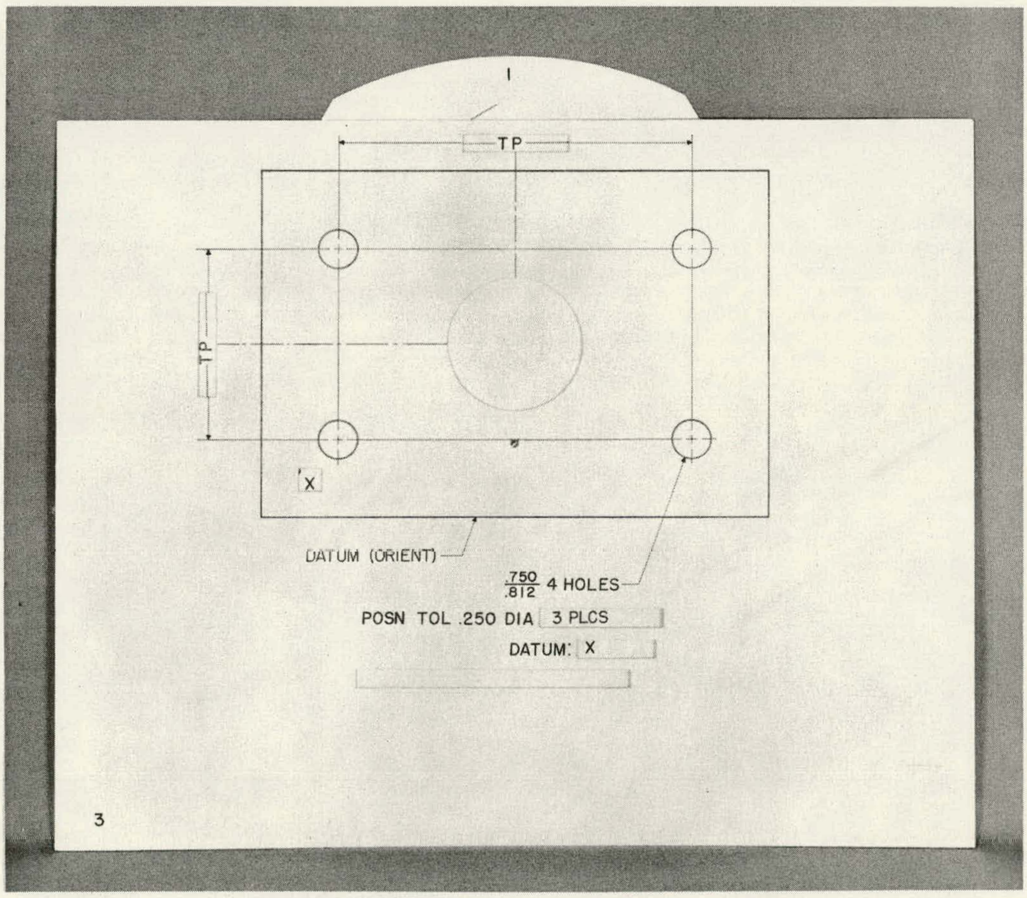

Figure 4

MMC to Position

Chart 4 (Fig. 5) has a transparent opening with its center indicated and three concentric circles representing tolerance zones for various conditions. This chart, combined with Ring 4A, represents one of the holes at minimum size (MMC). Ring 4A indicates the allowable size tolerance of the hole. Chart 2B again represents a gage pin (equal in diameter to the minimum hole size specified less the positional tolerance diameter), and the center circle delineates the positional tolerance specified when the hole is at MMC. Chart 4 with Ring 4A is placed over Chart 2B. The movement of Chart 4 to its extent will show that the center of the hole at minimum diameter (MMC) is within the tolerance of location when checked by the gage pin.

By removing Ring 4A and repeating procedure of placing Chart 4 over Chart 2B, the movement of Chart 4 to its extent will now show that the center of the hole can extend beyond the original zone and still remain functional for the intended design use. Thus, with MMC specified, any increase in the hole size from minimum allows a proportional increase in the tolerance of location.

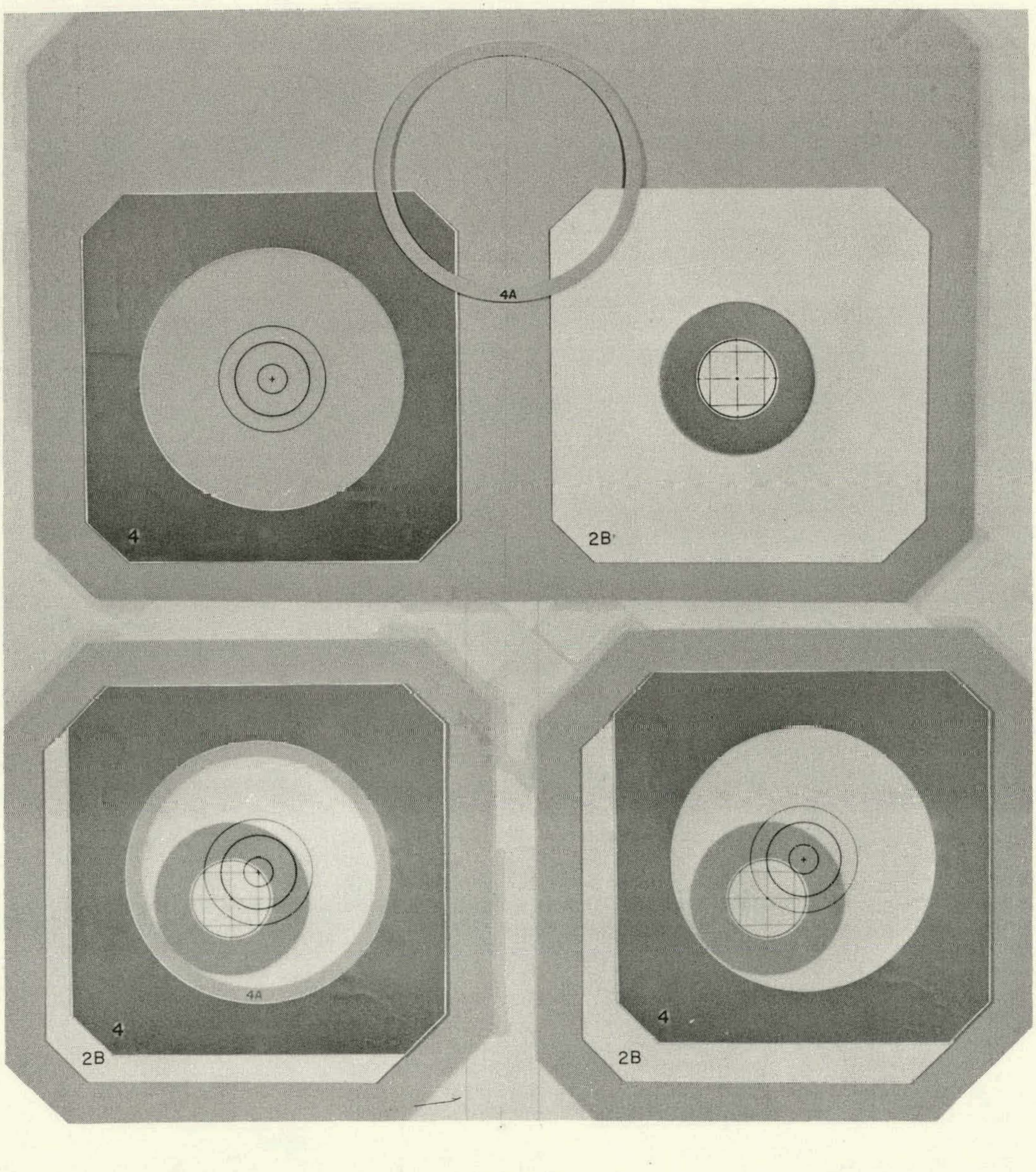

Figure 5

MMC to Datum

Chart 4 (Fig. 6), again in combination with Ring 4A, represents the datum hole at its minimum specified size (MMC). Ring 4A indicates the allowable size tolerance of that hole. Disk 4B represents a fixed gage pin equal in diameter to the minimum hole size specified for the datum.

Chart 4 with Ring 4A is placed over Disk 4B. Since the center of the gage pin coincides with the center of the datum hole, the actual center of the hole becomes the datum or point of origin for True Position (TP) dimensions. Ring 4A is removed to represent the maximum datum hole size, and the procedure repeated by placing Chart 4 over Disk 4B. When Disk 4B is moved its fullest extent in any direction, the datum or point of origin may lie anywhere within a circle concentric with the datum hole center. This circular zone (smallest circle on Chart 4) is equal in diameter to the increase of datum hole size. Thus when datum MMC is specified, any increase in the size of the datum hole from minimum allows the datum or point of origin for TP dimensions to vary a proportionate amount from the actual center of the datum hole.

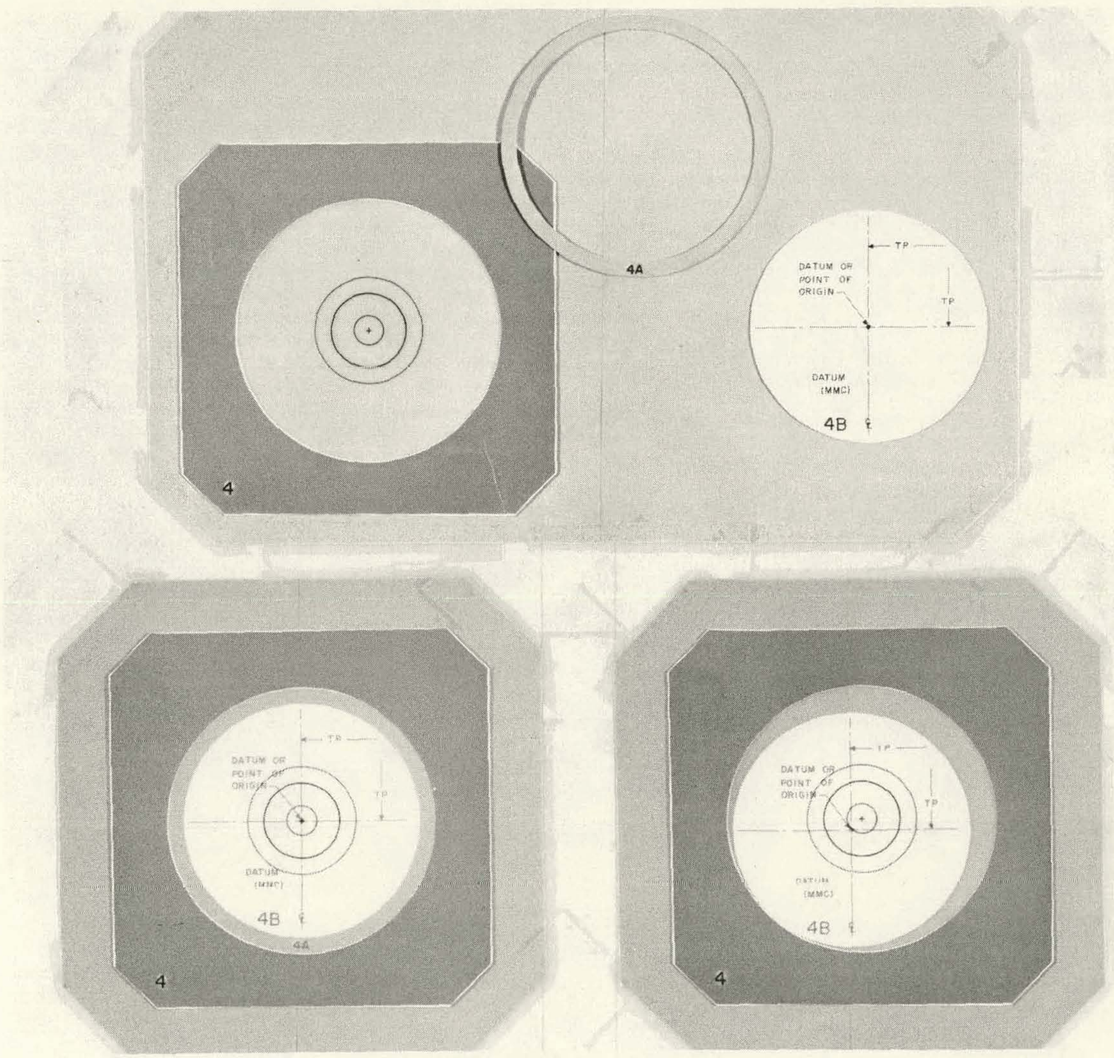

Figure 6

Datum Tolerance at MMC

Chart 4 (Fig. 7), again with tolerance Ring 4A, represents the datum hole at its minimum size (MMC). Chart 4C denotes a fixed gage pin equal in diameter to the minimum hole size specified for the datum less the specified datum tolerance diameter (DATUM TOL. .XXX DIA). Chart 4 with Ring 4A is placed over Chart 4C. The movement of Chart 4 to its extent in any direction shows that the point of origin is allowed to vary from the actual center of the datum hole by the amount of datum tolerance specified at MMC (medium size circle on Chart 4).

By removing Ring 4A and repeating the procedure of placing Chart 4 over Chart 4C, the movement of Chart 4C to its extent shows that the datum or point of origin can now lie within a larger datum tolerance zone.

This zone (largest circle on Chart 4) is equal in diameter to the datum tolerance specified plus any increase of datum hole size. When the datum feature is the same specified size as the other features in the pattern, and the callout "DATUM TOL. .XXX DIA MMC" is specified with a value equal to the positional tolerance of the other features, the maximum tolerance for functional interchangeability is allowed.

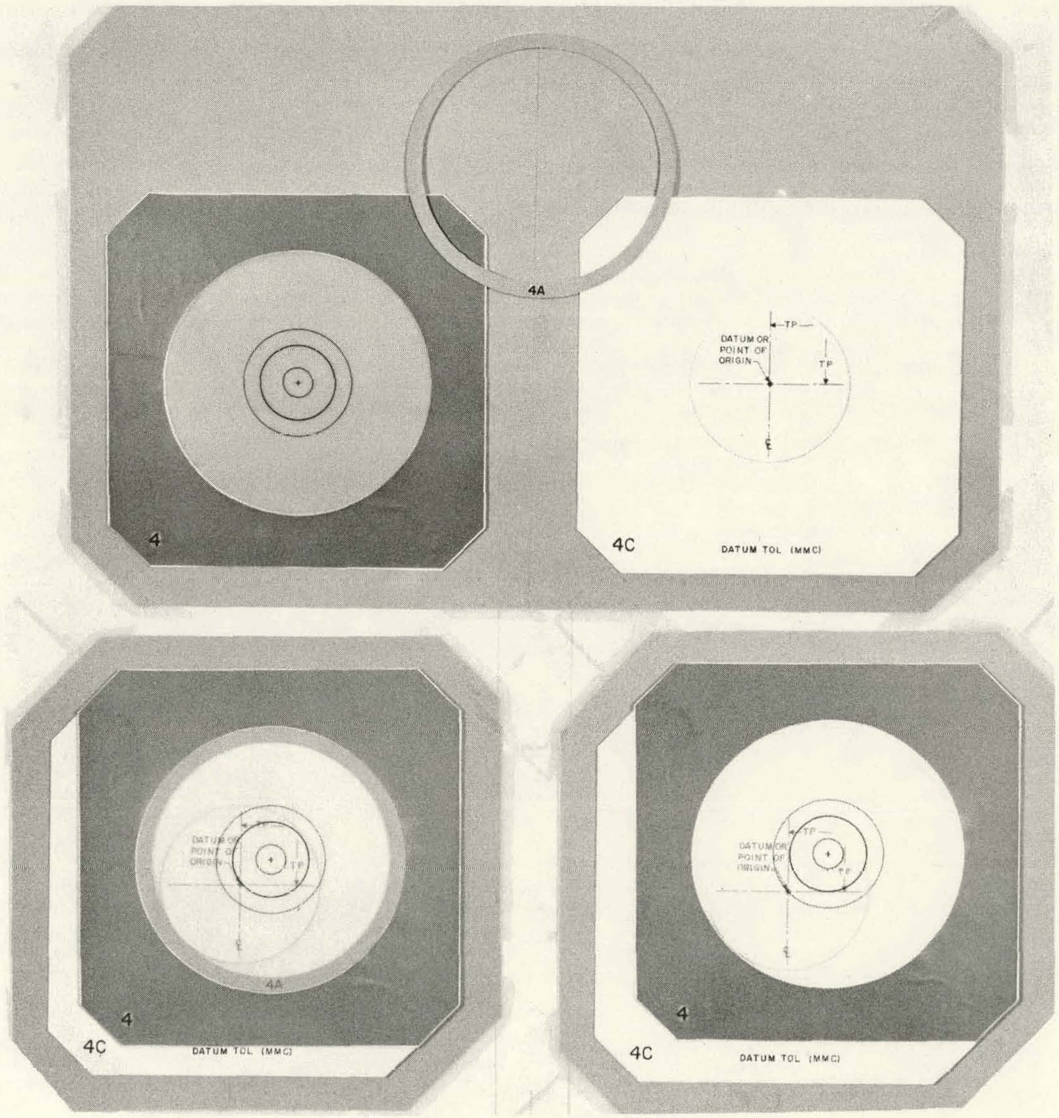

Figure 7

Mechanical Aids

Figure 8 is a package of physical parts which consists of the following:

a. A plain cylindrical "GO-NOT GO" plug gage representative of the common type of gages used in determining whether hole diameters are within the limits specified on the drawing.

b. A simulated location gage consisting of a mounting plate and four (4) round fixed-size pins. These gage pins are the quick-removal type and, therefore, can be conveniently replaced by other size pins to demonstrate specific conditions as stated in the drawing callout (see Fig. 4). The gage mounting plate also has a threaded hole in the center which will readily accommodate pilot studs of different diameters. These pilot diameters are used to represent conditions of the datum callout on the drawing when a datum (different size), other than one of the four pattern holes, is specified.

c. Four 1/2-in. diameter bolts to illustrate assembly conditions.

d. Two typical matching plates and various interchangeable bushings. Both plates have four holes to accommodate equal size bushings. The inside diameter of these bushings represents various size clearance holes and their condition of location which vary in dimension from the bolt diameter to the maximum size specified in Chart 3. Some of the bushings have eccentric holes and, when inserted in the matching plates, exemplify the extreme tolerances of location specified in Chart 3. One of the plates has a larger center hole and, with its related bushing, establishes a datum hole from which the four pattern holes are dimensioned.

Parts in all combinations, but at extreme tolerance limits, are used to illustrate drawing callout requirements on Chart 3. The simulated location gage can be used with either plate to demonstrate acceptance as per the drawing specification (Fig. 9). Also the two mating plates can be assembled together using the four 1/2-in. diameter bolts thus meeting functional end requirements (Fig. 10).

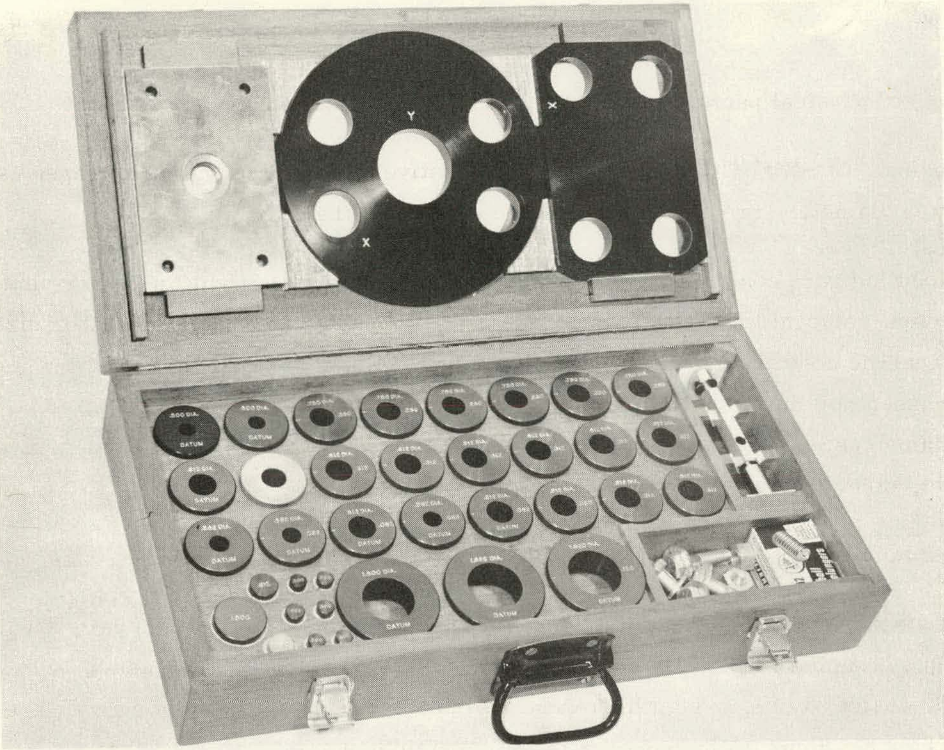

Figure 8

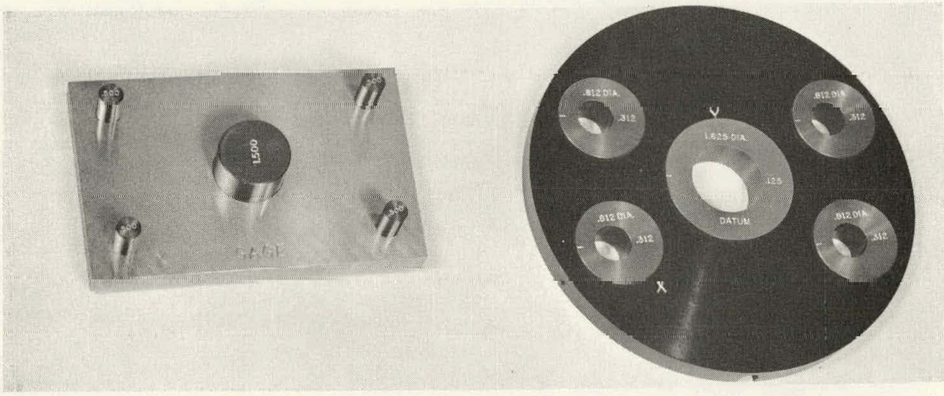

Figure 9

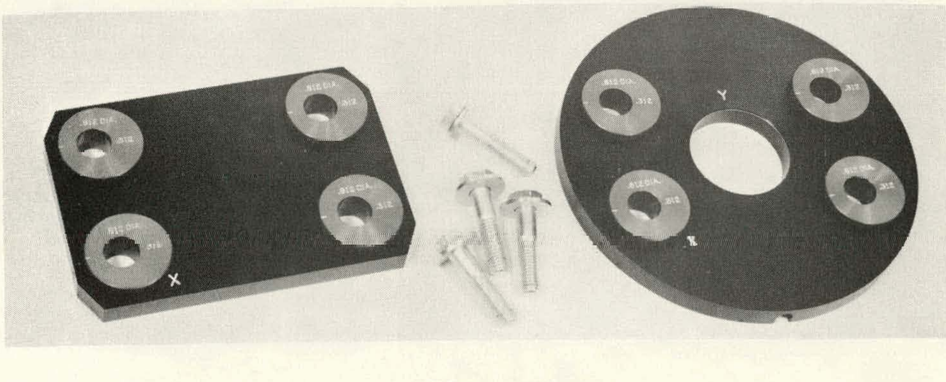

Figure 10