**Chapter 20**

**20–1** Refer to the first paragraph of Sec. 20–1, p. 970.

*iv Ans.*

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**20–2** Refer to the first paragraph on p. 974, and the first paragraph in Sec. 20–4 on p. 981.

The size dimension of a feature of size should be directly toleranced.  *Ans.*

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**20–3** Refer to the last paragraph on p. 972.

*ii Ans.*

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**20–4** Refer to the first paragraph on p. 973.

Feature of size *Ans.*

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**20–5** Refer to the first paragraph on p. 973.

size, location, orientation, and form *Ans.*

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**20–6** Refer to the *Form Controls* sub-section on p. 985.

straightness, flatness, circularity, and cylindricity *Ans.*

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**20–7** Refer to the *Orientation Controls* sub-section on p. 987.

angularity, parallelism, and perpendicularity *Ans.*

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**20–8** Refer to the *Location Controls* sub-section on p. 990.

position, concentricity, symmetry, position *Ans.*

The position control is the most prominently used. *Ans.*

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**20–9** Refer to the *Basic Dimensions* sub-section on p. 983.

*ii Ans.*

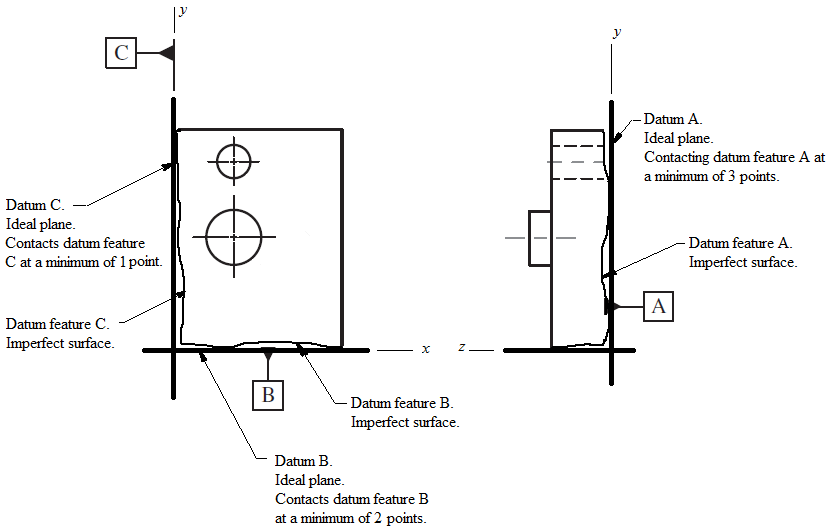
­­­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**20–10** All of the features with a +/– tolerance are features of size. *Ans.*

These include boss, hole, plate thickness, plate width, and plate height. The combined thickness of the plate and the boss (70 +/– 0.1) technically satisfies the definition, though it is not a typical feature of size.

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**20–11** The datum features are the physical surfaces of the plate. The datums are the theoretically perfect planes corresponding to the datum feature simulators of the physical surfaces. The datum reference frame is the *xyz* coordinate axis corresponding to the three datum planes.



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**20–12** For the first two questions, refer to the first two paragraphs in the *Position* sub-section on p. 990. Also refer to step 4 of Ex. 20–1, p. 998.

*iv Ans.*

*iii Ans.*

For the third question, refer to the first full paragraph on p. 977.

*v Ans.*

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**20–13** (*a*) The boss is a feature of size, so it is directly toleranced.

The maximum and minimum diameters allowed are 50.3 and 49.7, respectively. *Ans.*

(*b*) The position tolerance affects the location and orientation of the center axis of the boss, but does not affect the diameter of the boss.

No effect. *Ans.*

(*c*) The position tolerance always defines the allowed location and orientation of an axis, center line, or center plane of a feature of size. Refer to the *Position* sub-section on p. 990. For a strict definition of the axis, refer to the *Actual Mating Envelopes* sub-section on p. 979.

The center axis of the boss, as determined by the related actual mating envelope, must be within the tolerance zone. *Ans.*

(*d*) Note that the position tolerance is specified at maximum material condition. If the boss is produced at a diameter of 50.3, which is the maximum material condition, then the specified tolerance applies.

The tolerance zone diameter is 0.2. *Ans.*

(*e*) If the boss is produced at a diameter of 49.7, which is 0.6 less than the maximum material condition, the tolerance zone diameter is the sum of this 0.6 and the specified tolerance of 0.2.

The tolerance zone diameter is 0.8. *Ans.*

(*f*) The part is stabilized with respect to datums A, B, and C, in that order, then the central axis of the tolerance zone is oriented perpendicular to datum A*,* and located from datums B and Cby the basic dimensions. *Ans.*

(*g*) The position control defines a tolerance zone that defines the allowed location and orientation of the axis of the boss. Refer to the first paragraph of the *Position* sub-section on p. 990. Depending on the amount of deviation from the maximum material condition, the tolerance varies from 0.2 at MMC to 0.8 at LMC.

*ii* *Ans.*

(*h*) Cylindricity is a characteristic of form. Since a specific cylindricity form control is not specified, Rule #1 applies as the default form control for a feature of size. Refer to the second full paragraph on p. 982.

*iii Ans.*

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**20–14** (*a*) The hole is a feature of size, so it is directly toleranced.

The maximum and minimum diameters allowed are 30.1 and 29.9, respectively. *Ans.*

(*b*) The position tolerance affects the location and orientation of the center axis of the hole, but does not affect the diameter of the boss.

No effect. *Ans.*

(*c*) The position tolerance always defines the allowed location and orientation of an axis, center line, or center plane of a feature of size. Refer to the *Position* sub-section on p. 990. For a strict definition of the axis, refer to the *Actual Mating Envelopes* sub-section on p. 979.

The center axis of the hole, as determined by the related actual mating envelope, must be within the tolerance zone. *Ans.*

(*d*) Note that the position tolerance is specified at maximum material condition, which for the hole is 29.9. If the hole is produced at a diameter of 30.1, which is 0.2 greater than the maximum material condition, the tolerance zone is the sum of this 0.2 and the specified tolerance of 0.3.

The tolerance zone diameter is 0.5. *Ans.*

(*e*) If the hole is produced at a diameter of 29.9, which is the maximum material condition, then the specified tolerance applies.

The tolerance zone diameter is 0.3. *Ans.*

(*f*) The part is stabilized with respect to datums A, B, and C, in that order, then the central axis of the tolerance zone is oriented perpendicular to datum A*,* and located from datums B and Cby the basic dimensions. *Ans.*

(*g*) The position control defines a tolerance zone that defines the allowed location and orientation of the axis of the boss. Refer to the first paragraph of the *Position* sub-section on p. 990. Depending on the amount of deviation from the maximum material condition, the tolerance varies from 0.3 at MMC to 0.5 at LMC.

*ii* *Ans.*

(*h*) Cylindricity is a characteristic of form. Since a specific cylindricity form control is not specified, Rule #1 applies as the default form control for a feature of size. Refer to the second full paragraph on p. 982.

*iii Ans.*

­­­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**20–15** Refer to the *Actual Mating Envelopes* sub-section on p. 979.

An actual mating envelope is determined by fitting the largest gauge pin (or an expanding mandrel) into the hole, just touching the high points of the hole. The center axis of the gauge pin is defined to be the center axis of the hole. *Ans.*

­­­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**20–16** Refer to the second full paragraph on p. 982.

*iii Ans.*

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**20–17** Refer to the first full paragraph on p. 982.

Shaft diameter at MMC = 20.2 *Ans.*

Shaft diameter at LMC = 19.8 *Ans.*

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**20–18** Refer to the first full paragraph on p. 982.

Hole diameter at MMC = 19.8 *Ans.*

Hole diameter at LMC = 20.2 *Ans.*

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**20–19** Refer to the second full paragraph on p. 982. The surface of the hole is limited by an envelope of perfect form at MMC. There is no limiting envelope defined at LMC.

The diameter of the limiting envelope is 19.8. *Ans.*

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**20–20** Refer to the second full paragraph on p. 982. The surface of the shaft is limited by an envelope of perfect form at MMC. There is no limiting envelope defined at LMC.

The diameter of the limiting envelope is 20.2. *Ans.*

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**20–21** Refer to Sec. 20–6, p. 994.

(*a*) Since no material condition is specified, the tolerance zone diameter is the specified 0.1 at all produced diameters of the boss.

0.1, 0.1, 0.1 *Ans*.

(*b*) Since the maximum material condition is specified, the tolerance zone diameter is the specified 0.1 when the boss is produced at the MMC of 25.2, and increases by the amount of deviation from the MMC.

0.5, 0.3, 0.1 *Ans.*

(*c*) Since the least material condition is specified, the tolerance zone diameter is the specified 0.1 when the boss is produced at the LMC of 24.8, and increases by the amount of deviation from the LMC.

0.1, 0.3, 0.5 *Ans.*

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**20–22** Refer to Sec. 20–6, p. 994.

(*a*) Since no material condition is specified, the tolerance zone diameter is the specified 0.3 at all produced diameters of the hole.

0.3, 0.3, 0.3 *Ans*.

(*b*) Since the maximum material condition is specified, the tolerance zone diameter is the specified 0.3 when the hole is produced at the MMC of 32.0, and increases by the amount of deviation from the MMC.

0.3, 0.5, 0.7 *Ans.*

(*c*) Since the least material condition is specified, the tolerance zone diameter is the specified 0.3 when the hole is produced at the LMC of 32.4, and increases by the amount of deviation from the LMC.

0.7, 0.5, 0.3 *Ans.*

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**20–23** Refer to the *Cylindricity* sub-section on p. 987.

cylindricity *Ans.*

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**20–24** Refer to the third paragraph on p. 989.

profile of a surface *Ans.*

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**20–25** Refer to the *Form Controls* sub-section on p. 985.

The form controls (straightness, flatness, circularity, and cylindricity) never reference datums. They only relate to the form of the individual feature, and are independent of the feature’s location. *Ans.*

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**20–26** (*a*) Refer to the first paragraph of Sec. 20**–**6 on p. 994 for the two primary modifiers, and the last paragraph on p. 995 for the default material condition.

­MMC, LMC, and RFS *Ans.*

(*b*) Refer to the last paragraph on p. 995.

RFS *Ans.*

(*c*) Refer to the last paragraph on p. 994 and the third paragraph on p. 995.

MMC and LMC *Ans.*

(*d*) Refer to the last sentence on p. 994.

*iv*  *Ans.*

(*e*) Refer to the first paragraph of Sec. 20**–**6.

*iii* *Ans.*

(*f*) Refer to the first paragraph on p. 995.

MMC *Ans.*

(*g*) Refer to the first partial paragraph on p. 996.

RFS *Ans.*

(*h*) Refer to the third paragraph on p. 995.

LMC *Ans.*

­­­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**20–27** (*a*) The countersink diameter is specified as 12 ± 0.2.

The minimum countersink diameter is 11.8. *Ans.*

(*b*) The countersink depth is specified as 3 ± 0.1.

The maximum countersink depth is 3.1. *Ans.*

(*c*) The bolt holes are specified as 6 +0.1/**–**0.0. The maximum material condition for a hole is the smallest hole diameter.

The diameter of the bolt holes at MMC is 6.0. *Ans.*

(*d*) Refer to the second paragraph on p. 973.

The features of size are all hole diameters and counterbore diameters, the slot width, the base widths, the base thickness, and the center protrusion width. *Ans.*

(*e*) The default surface profile tolerance in the note provides a tolerance zone around all surfaces of 0.5, centered on the surface. This gives a tolerance of 0.25 outside the base dimension on each edge, for a total of 0.5. Therefore, the minimum and maximum allowed base dimensions are 59.5 and 60.5. *Ans.*

(*f*) Datum feature Ais the bottom surface. Its datum is a theoretical plane corresponding to a datum feature simulator (such as a machine table). Datum feature B is the surface of the hole. Its datum is the center axis corresponding to a datum feature simulator, such as the largest gauge pin just touching the high points of the hole, while being held perpendicular to datum A. Datum feature C is the surface of the slot. Its datum is the center plane corresponding to a datum feature simulator, such as the largest gauge block just touching the high points of the slot, while being held perpendicular to datum A. *Ans.*

The datum reference frame is made of three mutually perpendicular planes, with the origin of the coordinate axes at the bottom center of the datum B hole. *Ans.*

The part is stabilized for manufacture or inspection by applying the datums in the following sequence: Constrain the base to be in contact with a datum feature simulator (an essentially flat surface) corresponding to datum A; constrain the translation of the part on datum A with a gauge pin in the datum feature B hole; constrain the final rotation of the part (around datum B) with a gauge pin or block in the groove. *Ans.*

The purpose of the fixture is to locate and orient the large bore. This bore is located with respect to the bottom surface (datum A), the pin hole (datum B), and the groove (datum C). The edges of the base will not be touching anything for alignment, and can consequently have much looser tolerances. It is usually easier and cheaper to precisely locate a part with respect to locating pins than with respect to the edges of the part. *Ans.*

(*g*) Since no material condition modifier is specified for the tolerance zone associated with the hole, its tolerance zone is RFS (regardless of feature size). The specified tolerance zone diameter is the specified 0.05 whether the hole diameter is 6.00, or 6.05, or anything between.

0.05, 0.05 *Ans.*

(*h*) The top line of the position control of the bolt holes specifies the PLTZF tolerance of 0.3 at MMC (maximum material condition). For the bolt holes, when manufactured at the MMC of 6.0, the diameter of the PLTZF tolerance zone is 0.3. When manufactured at the LMC of 6.1, the diameter of the PLTZF tolerance zone is 0.4, i.e. the sum of the specified tolerance plus the “bonus” tolerance of 0.1 due to the deviation of the hole from its MMC.

0.3, 0.4 *Ans.*

(*i*) The second line of the position control of the bolt holes specifies the FRTZF tolerance of 0.1 at MMC (maximum material condition). For the bolt holes, when manufactured at the MMC of 6.0, the diameter of the FRTZF tolerance zone is 0.1. When manufactured at the LMC of 6.1, the diameter of the FRTZF tolerance zone is 0.2, i.e. the sum of the specified tolerance plus the “bonus” tolerance of 0.1 due to the deviation of the hole from its MMC.

0.1, 0.2 *Ans.*

(*j*) MMC ensures a minimum clearance for the bolts in their holes, but allows greater deviations from ideal if the holes are produced larger. *Ans.*

(*k*) Orientation and straightness of the axis are controlled by the position tolerance zone which is specified in the feature control frame directly under the diameter dimension for the bore. The position tolerance specifies a cylindrical tolerance zone that the axis of the hole must be within, thus controlling its orientation and straightness. *Ans.*

Cylindricity is a control of the surface of the bore, so is not controlled by the position tolerance zone which controls the axis of the bore. Since there is not an explicit control of the cylindricity specified, it could be controlled either by the default profile of a surface control, specified with the note at the bottom of the drawing, or by Rule #1. In this case, Rule #1 has the tighter tolerance, so it controls the cylindricity of the bore.

Rule #1 provides for the cylindricity of the surface of the bore to be within an envelope of a perfect cylinder at MMC diameter of 14.9. *Ans.*

(*l*) All exterior surfaces except for the bottom are controlled only by the default surface profile tolerance, so as-cast is sufficient for them. *Ans.*

If the edges of the base were used as datum features, these surfaces would need to be controlled more tightly in order to locate the critical holes from them. The edges of the base could not be left as-cast. *Ans.*

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**20–28** (*a*) A datum feature is the physical surface that will be used to define the theoretical datum. The datum B tag is associated with a control frame that is pointing to the datum feature. The datum feature is best described by answer *iv* The outer surface of the protruding cylinder. *Ans.*

(*b*) 10.1 *Ans.*

(*c*) Maximum material condition for a hole is when it is at its smallest allowed diameter (maximum material), thus 10.0. *Ans.*

(*d*) The tolerance block indicates zero tolerance at maximum material condition, plus a bonus of any amount that the hole is larger than maximum material condition. At a diameter of 10.1, the hole is 0.1 larger than maximum material condition. Thus the diameter of the tolerance zone is 0.1. *Ans.*

(*e*) The tolerance block indicates a 0.3 diameter tolerance zone, regardless of size. Thus, the tolerance zone has a diameter of 0.3. *Ans.*

(*f*) The universal profile tolerance of note at the bottom of the drawing applies to all basic dimensions that aren’t otherwise toleranced. Thus, a profile tolerance of 0.2 is centered on the basic dimension of 90. The diameter may vary between a minimum of 89.9 and a maximum of 90.1. *Ans.*

(*g*) The tolerance zone is located ideally by basic dimensions. The non-ideal center axis of the hole must lie entirely within the tolerance zone. The center axis of the hole is defined by its actual mating envelope. This is best describe by answer *i,* the largest gauge pin that fits into the hole. *Ans.*

(*h*) There is not an explicit cylindricity control given, but the surface of the hole, including its cylindricity, must stay within the ideal cylinder defined by the hole’s maximum material condition. This is best described by answer *iii.* The envelope of a perfect cylinder with diameter of 19.95. *Ans.*

(*i*) The tolerance for the holes is defined with the modifier for maximum material condition. Therefore, the center axes of the bolt holes (defined by their actual mating envelope) must be perfectly located if the holes are manufactured at maximum material condition. If the holes are manufactured larger than maximum material condition, then the tolerance zone size increases and the holes do not need to be perfectly located. *Ans.*