Groove Measurement Procedure Outline

(NOTE: Additional methods for obtaining the groove profile and performing the groove measurements are currently being evaluated.)

1. **Tracing the groove profile**
   a. For each club mark a line perpendicular to the grooves on the clubface where the groove trace is to be conducted. Typically, this location should be near the center of the face.
   b. Fixture the clubhead ensuring that the face is level and oriented such that the stylus travel is perpendicular to the length of the groove.
   c. Using the USGA ContouReader™, obtain a tracing of the groove profile along the marked line beginning at the top of the clubface and measuring toward the sole. The number of full land areas traced should be equivalent to the number of grooves being evaluated.
   d. Re-position the clubhead in the fixture and conduct a second tracing of the groove profile along the marked line as closely as possible to the first trace. The second trace shall begin at the sole of the club and proceed along the marked line toward the top of the clubface.

2. **Measuring the grooves from the profile**
   a. Overlay the two tracings to eliminate the offset caused by the stylus chamfer.

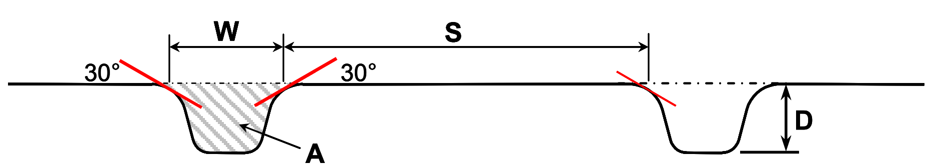

Figure 1

      i. Using the 30° method of measurement (see Appendix A), identify the contact points on the groove. Determine the groove width (W) by measuring the distance between the marked 30° contact points. The width (W) of a groove must not exceed 0.035 inches, using the 30 degree method of measurement.

ii. Using a straight edge, draw a line across the top of the groove connecting the adjacent land areas. Determine the groove depth (D) by measuring the perpendicular distance from the land area extension line down to the lowest point of the groove cross-section. The depth of a groove must not exceed 0.020 inches.

iii. Determine the spacing (S) between adjacent grooves by measuring the distance of the land area between the marked 30° contact points that were used to measure the groove widths. The distance between edges of adjacent grooves (S) must not be less than three times the width of the smallest adjacent groove, and not less than 0.075 inches.

iv. With a circle template, determine whether any portion of the groove edge radius is too sharp using the two circle method (see Appendix B). Groove edges must have an effective radius which is not less than 0.010 inches as determined with the two circle method.

v. Determine the area (A) of each groove by measuring the area on the tracing that is bounded by the groove profile and the line connecting the adjacent land areas that was used to determine depth. Divide this value by the groove pitch (the width (W) of the groove plus the minimum adjacent spacing (S)). The cross-sectional area (A) of a groove divided by the groove pitch (W+S) must not exceed 0.0025 square inches per inch.

APPENDIX A –
30° METHOD FOR MEASURING GROOVE WIDTH

1. SUMMARY

The method for measuring groove width using the 30° method is presented. It is generally understood that the groove in a club face starts where there is a significant departure from the plane of the face (land area). This method specifies where the measurement of the groove width should be taken when the edges of the grooves are rounded.

2. DESCRIPTION OF METHOD

The sidewall of a groove generally meets the face of the club (land area) with a filleted transition. The groove width measurement (W) is made between two points where a line, inclined at 30° to the land area of the club face, is tangent to the radiused edge of the groove. This is shown in Figure 1.

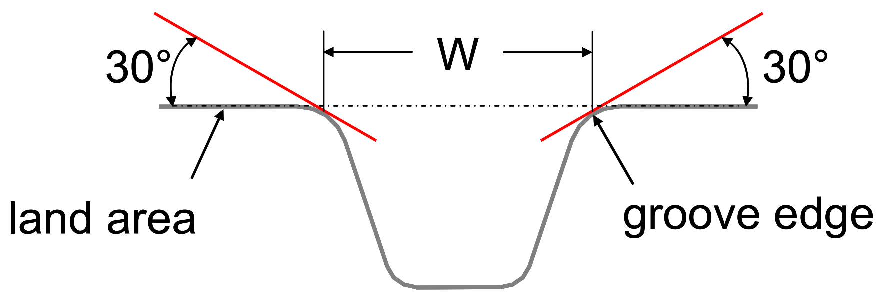

Figure 1: Groove edge radius

If the tangent point using the 30° method occurs at a location that is more than 0.003-in below the land area, then the width measurement shall be made at the points on the groove that are 0.003-in below the land area. (This situation only exists for grooves whose edges have large radii or whose groove sidewalls are very shallow.) This is illustrated in Figure 2.

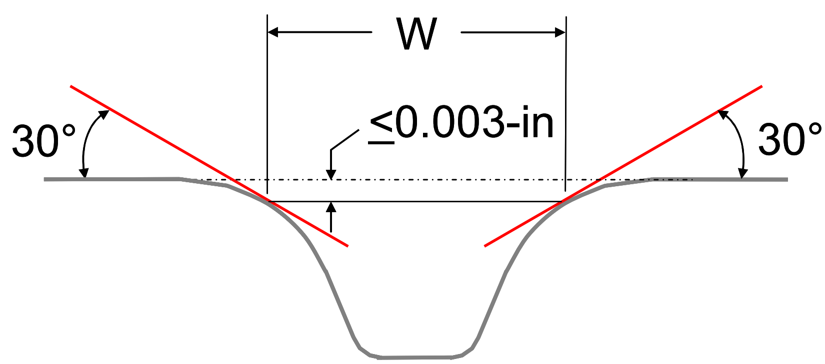

Figure 2: Maximum allowable deviation of the tangent point from the land area

APPENDIX B –
METHOD FOR LIMITING
THE SHARPNESS OF GROOVE EDGES

1. SUMMARY

The method for limiting the edge radius of grooves is presented. This method provides three important features:

- The edge radius limit is implicitly a function of the draft angle of the groove sidewall.
- Allowances for manufacturing variability are incorporated.
- The method is insensitive to small local variations in edge fillet radius

3. THEORETICAL CONSIDERATION

3.1. Analysis of Ideal Grooves

The groove sidewall of a groove meets the land area with a filleted transition. This is shown in Figure 1.

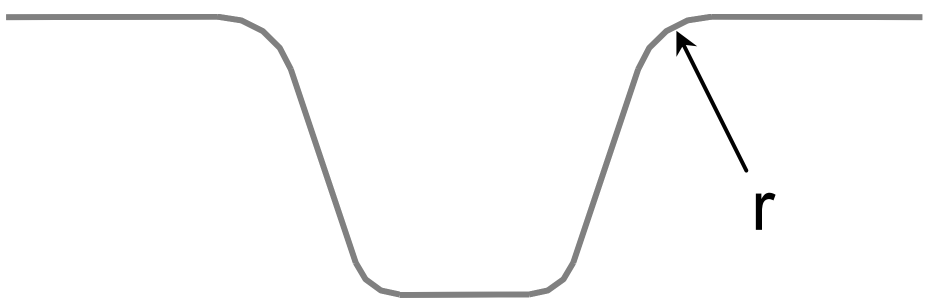

Figure 1: Groove edge radius

The restriction of edge radius depends on the angle of the groove sidewall. That is, the steeper the sidewall (or draft angle), the more dull the edge must be. The simple method described below will implicitly capture the desired draft angle/edge radius relationship eliminating the need to measure the sidewall and the edge radius and prescribe a limit with a functional relationship between the two.

Consider an ideal groove edge having a sidewall angle of β and a filleted edge with a radius, **r**. Further, consider two concentric circles having radii or **R** and **R+t** respectively. The smaller of these two circles is located such that it is tangent to both the groove sidewall and the land area. This arrangement is shown in Figure 2.

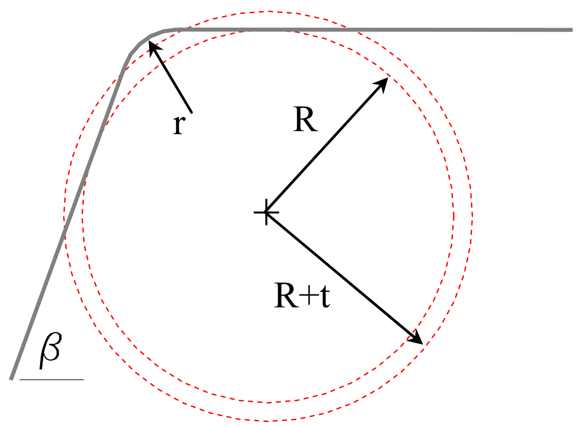

Figure 2: Arrangement of concentric circles

By this method, a groove is deemed non-conforming if any portion of the groove edge protrudes from the outer circle. The groove in Figure 2 is such an example. The groove in Figure 3, on the other hand, is deemed conforming, as the edge does not protrude from the outer circle.

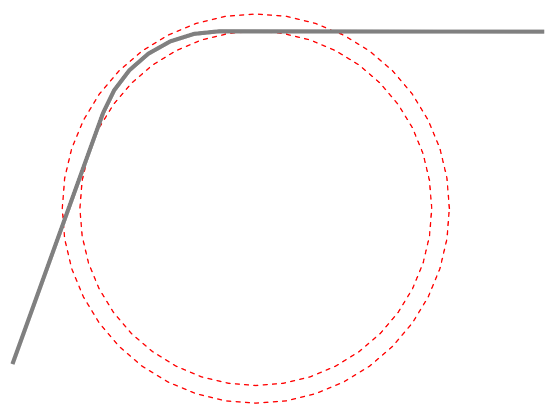

Figure 3: Conforming groove edge

This method is easily applicable to the design of grooves with conforming edge radii. It can be shown that for a given sidewall angle β, an inner circle radius of **R** and an outer circle radius of **R+t**, the allowable edge radius, **r**, is prescribed by:

$$r \geq R + \frac{t}{\left(1 - \frac{\sqrt{2}}{\sin\beta}\sqrt{1-\cos\beta}\right)} \qquad (2.1)$$

Equation 2.1 provides a useful tool for limiting the edge radius. The radius of the inner circle, **R**, provides a constant while the value of **t** determines the magnitude of edge radius change with draft angle.

As an example, Equation 2.1 is plotted in Figure 4 for **R** = 0.010-in and **t** = 0.001-in. Draft angles from 55 degrees (V-groove) to 90 degrees (U-groove) are plotted.

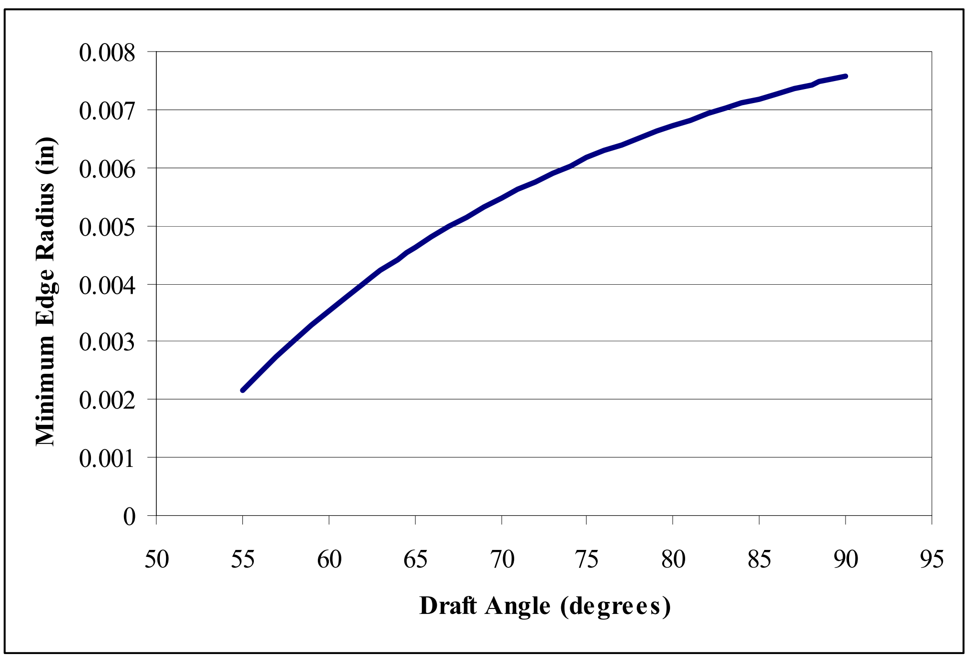

Figure 4: Example edge radius/draft angle relationship (**R**=0.010-in, **t**=0.001-in)

3.2. Examples of Edge Radius Measurement Using Machined Test Plates

Grooved plates were fabricated for spin testing having grooves with a range of draft angles and edge radii. Twelve plate designs, having four different draft angles and four different edge radii were analyzed using the method described in the previous section with **R** = 0.010-in and **t** = 0.001-in. .

3.2.1. U-Groove (90º draft angle)

Figure 5 shows the method applied to ideal U-grooves having edge radii of 0.000, 0.0025, 0.005 and 0.010 inches.

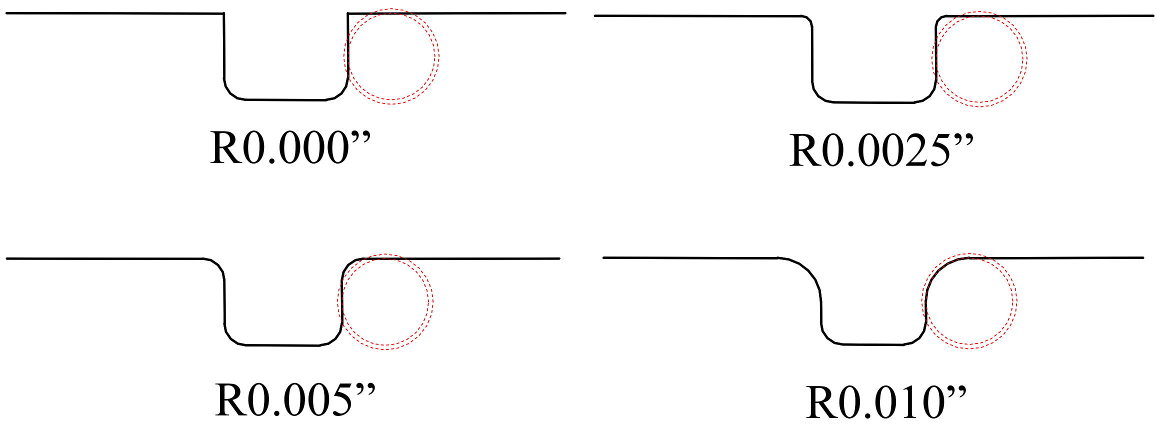

Figure 5: Analysis of U-grooves

It can be seen in Figure 5 that for the 90 degree draft angle, only the 0.010-in edge radius would conform.

3.2.2. Semi U-Groove (75º draft angle)

Figure 6 shows the method applied to ideal semi U-grooves having edge radii of 0.000, 0.0025, 0.005 and 0.010 inches. It can be seen in Figure 6 that as with the 90 degree draft angle, only the 0.010-in edge radius would conform.

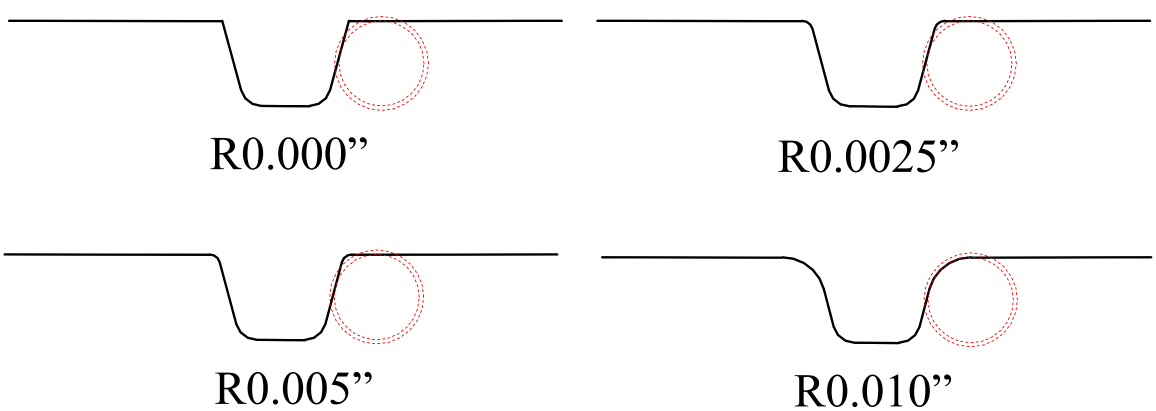

Figure 6: Analysis of semi U-grooves

3.2.3. Semi V-Groove (65º draft angle)

Figure 7 shows the method applied to ideal semi V-grooves having edge radii of 0.000, 0.0025, 0.005 and 0.010 inches.

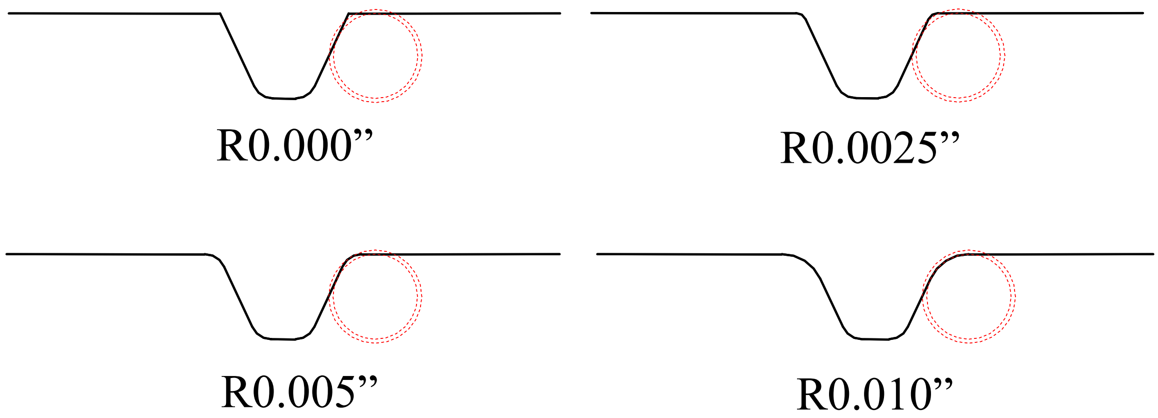

Figure 7: Analysis of semi V-grooves

It can be seen in Figure 7 that both 0.005-in and 0.010-in edge radii would conform at a draft angle of 65 degrees.

3.2.4. V-Groove (55º draft angle)

Figure 8 shows the method applied to ideal V-grooves having edge radii of 0.000, 0.0025, 0.005 and 0.010 inches. It can be seen in Figure 8 that except for a sharp edge, all of the V-groove profiles would conform.

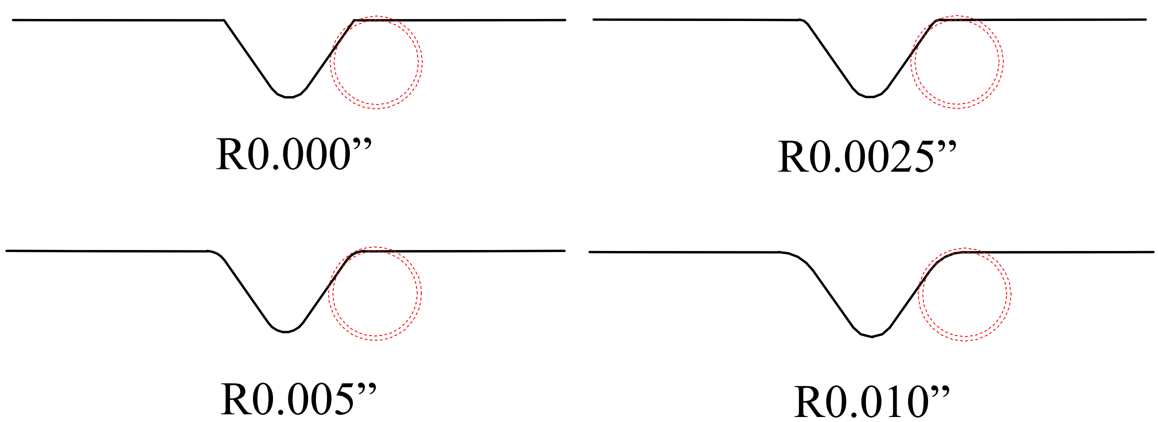

Figure 8: Analysis of V-grooves

4. CONCLUSION

A measurement method for limiting the sharpness of the edge radius of a groove has been detailed. The method provides a radius gauge along with a tolerance on deviations from this gauge. In addition to providing this tolerance, the method implicitly provides (i) a desirable increase in sharpness as groove sidewall draft angle is decreased, (ii) a provision for material removal from the face during post-casting finishing operations, (iii) allowances for manufacturing variability and (iv) an inherent insensitivity to small local variations in edge fillet radius.