ASTM D1998-97 Section 9.1.3
Thickness Requirements (An Explanation)

In the following technical bulletin, we will explain ASTM D 1998 – 97, Section 9.1.3.

First, let's divide the upright closed top tank into (3) components and define the components, design thickness, and average thickness for each component:

Top Head:

The top head consists of a partial spherical shell (dome), the upper knuckle, and any features (gutters, runways, castles, etc.).

Top Head Design Thickness (t_{TH}) applies uniformly to the entire top head as implied. Average thickness (typical) is found by summing the readings and dividing by the number of readings (called the "arithmetic mean").

Cylindrical Shell:

The cylindrical shell is the open-ended cylinder between the upper and lower knuckles.

Cylindrical Shell Design Thickness (t_{CS}) is constant on circumferential lines of constant elevation. For some tanks, design thickness at one elevation may be the same as another. This is based on tank geometry and thickness requirements. Each elevation has its own average thickness. When the entire cylindrical shell has a constant design thickness, then and only then could the average thickness be based on all of the cylindrical shell readings.

Bottom Head:

The bottom head consists of a flat circular plate and the lower knuckle.

The constant value for the lower knuckle is called the Lower Knuckle Design Thickness (t_{KR}). For the bottom plate, Bottom Plate Design Thickness (t_{BP}) is constant on concentric lines of constant radius. For some tanks, one concentric ring may have the same design thickness as another based on tank geometry and requirements. There is an average thickness for the lower knuckle and an average thickness for each bottom plate concentric ring. When the bottom plate has a constant design thickness, then and only then could an average thickness be based on all of the bottom plate readings. For this case, the lower knuckle design thickness would equal that of the bottom plate.
Now, let's relate the above discussion to the statements of ASTM D1998 - 9.1.3:

9.1.3 – 1st Sentence / 1st requirement / Interpretation:

The average thickness for any region cannot be less than 90% of the design thickness for that region. For some tanks, this "region" could be the entire tank if the entire tank has constant design thickness.

9.1.3 – 2nd Sentence / 2nd Requirement / Interpretation:

No individual reading can be less than 80% of the design thickness for that region. This establishes the tolerance low limit to be 20% less than design.

At this point, it would appear that ALL readings for a region could be, say, between 90% and 92% percent of the design thickness. This would indicate an average thickness of roughly 91% of design, which would meet the 1st requirement of 9.1.3. Also, the 2nd requirement would be met since no individual reading would be less than 80% of design.

However, the 3rd sentence of 9.1.3 puts a limitation on the amount of shell that can be below design (called "low side of the tolerance" in ASTM / where "tolerance" is the range between design and the 20% low limit). This limitation is stated in terms of "area on the low side" compared to "total area" rather than in terms of occurrence of reading values.

The first two sentences mention something we can relate to – concepts of average and occurring readings. However, we cannot reasonably measure the "area on the low side." The goal is to determine if any thin points exist on the shell through representative thickness readings, noting that thin spots may be missed in the reading process. After all, does a tank fail because an "area" of the tank is too thin? No. The tank fails because a single point is too thin.

The key here is to relate readings to a representative area. When we take a thickness reading, we are seeing ONE value and then assuming that value to be constant for the surrounding AREA, or portion of circumference for the cylindrical shell. Thus, thickness readings are a type of sampling. It must be noted that for a tapered cylindrical shell, the "area" where a design thickness exists only runs in the horizontal direction and therefore, the "area" for an applicable design thickness really doesn't exist. "Portion" or "segment" of circumference is more reasonable.

Therefore, we must assume shell thickness in a region to be represented by the readings in that region. Some have said that the "area on the low side" is to be compared to the total area of the tank. At 10% allowable, this would mean that over (2) entire foot-wide bands going all the way around on a 12000-gallon tank could be below design. Why would one elevation be allowed to go below design but not another? It makes more sense to limit "area on the low side" to 10% of the area where the thickness requirement exists.

Continuing with the idea of sampling, if 10% of a region, part, etc. truly falls below design, then we would expect 10% of the readings uniformly taken in that area to be below design. For this reason, we recommend that the last statement of 9.1.3 be interpreted as follows:

9.1.3 – 3rd Sentence / 3rd Requirement / Interpretation:

No more than 10% of the readings taken on a particular region fall below the design thickness for that region.

This will generally govern over the 1st sentence requirement, which allows average thickness to be less than design. In meeting the 1st sentence, 50% of the readings might turn out to be below design since the average could be 10% below design.

Summary / What does all this mean?

The three sentences of 9.1.3 each prescribe requirements for not only a tank region's thickness but for its thickness distribution. Limitations are placed on average thickness, individual thickness, and the variability in thickness readings is taken into account.

Variability is imposed, in our case, by the rotational molding process. ASTM doesn't provide distribution characteristics for molded tanks. That is up to us. It is common knowledge that these distributions will vary from tank to tank, from one point to another point on the same tank, and even the same point on the same tank may vary from day to day. Thickness variability is hard to control but easy to calculate. It is an important component in the calculation and control of powder weights in an effort to efficiently mold properly designed storage tanks.