PLATING THICKNESS DISTRIBUTION
AND DEFINITIONS

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**Introduction**

After the choice of a deposit to satisfy a particular manufacturing requirement, the single most important parameter to the metal finisher is the thickness of that deposit. The thickness is defined by several traditional specification protocols. Unfortunately, the understanding of these protocols is neither uniform nor consistent within industry. In addition, electrolytic or electroless deposits produce a non-uniform thickness layer thus exacerbating the problem. The definition of thickness as applied at APC is the purpose of this monograph.

**Plating Thickness**

Deposit thickness applied by barrel or rack techniques and by either of electrolytic or electroless methodologies is normally distributed. The normal distribution curve (Gaussian) is fundamental to understanding the parameter of thickness and to analyze its variance. The curve is defined as

\[
f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}}
\]

(1)

where
- \( \sigma \) is the population standard deviation
- \( x \) is a sample measurement i.e. thickness
- \( \bar{x} \) is the arithmetic mean (average) defined as
- \( \bar{x} = (x_1 + x_2 + x_3 + \ldots + x_n)/n \)
- \( n \) is the number of \( x \) measurements


The shape of the normal distribution curve is as shown in Figure (1).
Equation (1) demonstrates that the thickness is a function of the variation in the plating process (standard deviation) and that the most probable thickness in any set of data is the mean. **However there is a range of thicknesses produced by the plating process with the most numerous measurements clustered about the mean.**

The area under this equation (1) can be found by the techniques of integral calculus. This area can be directly related to the percent of items in the distribution. Thus, the area under the curve from \(-\infty\) to \(+\infty\) represents 100% of all items in the distribution. The area under the curve from \(-\infty\) to the mean (and from the mean to \(+\infty\)) represents 50% of all the items in the distribution. This can be verified by actually calculating the total area under a curve and dividing it into the area under the curve from \(-\infty\) to the mean. Similarly, any area from any value to another value can be calculated and the total area divided into it to get the percent (area or ratio X 100) of items in the distribution between the two values. Then, if the total number of items in the distribution is known, this total can be multiplied by the area (ratio) between the two values to get the actual number of items that lie between these two values.

The percentage of items in a normal distribution that exist between 1, 2 and 3 standard deviations is shown in Figure 2.
At Artistic Plating Company unless otherwise directed all thickness data is used from +3 to –3 standard deviations (6 Sigma). Thickness data at six standard deviations represents 99.7% of the sample population.

If the standard deviation and mean are calculated for a given sample population then the range of all thickness readings can easily be calculated.

The sample population is portion or sample taken from a universe of data to represent the universe. The Greek letter μ is used to represent the true universe mean and \( \bar{X} \) the sample mean. The Greek letter \( \sigma \) represents the universe standard deviation and \( s \) the standard deviation of a sample of the universe. The standard deviation for a sample is

\[
s = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}}
\]  

where

- \( s \) = standard deviation
- \( x \) = an individual value (thickness)
- \( n \) = number of measurements
The mean (average) for a sample is

\[ X = \frac{x_1 + x_2 + x_3 \ldots + x_m}{n} \]  

(3)

The relationship of standard deviation to the slope of the normal distribution curve is shown in Figure 3.

Figure 3. Normal curves with identical means but different standard deviations.

Curve No. 1 in Figure 3 shows a leptokurtic type distribution with its high peak and narrow dispersion (strong central tendency) and curve No. 3 a platykurtic type distribution with its low central peak and wide distribution (weak central tendency). (Kurtic comes from the Greek kurtosis which means peakedness.) Leptokurtic curves have small standard deviations while platykurtic standard deviations which are quite large in comparison. Thus the standard deviation of the normal distribution is variable and slopes the distribution. Therefore the range of plating thickness on an item is a direct function of the standard deviation of the distribution. The goal is to strive for small standard deviations (leptokurtic distributions). This minimizes the spread in the overall range of plating thickness.

**Typical Standard Deviations**

The magnitude of the standard deviation in a particular plating system is altered by numerous factors. These are:

1) Geometry of part being plated (pencil-life objects versus spheres)
2) Ability of product to uniformly tumble in a barrel plating methodology versus nesting.
3) Distribution and orientation of product on plating racks
4) Current density at which product is plated.

5) Overloading of plating units with excessive square footage on either barrels or on racks.

6) Type of plating process
   - Electrolytic or electroless
   - Complexed plating chemistry versus simple ion type

Typical standard deviations are listed in Table I for processes provided at APC.

### Table I: Typical Plating Standard Deviation

<table>
<thead>
<tr>
<th>Process</th>
<th>$s, \mu \text{ in}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright Barrel Nickel (watts)</td>
<td>20 – 25</td>
</tr>
<tr>
<td>Bright Rack Nickel (watts)</td>
<td>25 – 30</td>
</tr>
<tr>
<td>Barrel Silver (cyanide)</td>
<td>15 – 20</td>
</tr>
<tr>
<td>Rack Silver (cyanide)</td>
<td>20 – 25</td>
</tr>
<tr>
<td>Electroless Nickel</td>
<td>5 - 15</td>
</tr>
</tbody>
</table>

If the exact thickness distribution needs to be calculated for a given product, the product is processed in the chemistry of choice with the variables listed above fixed. The distribution curve is plotted and the standard deviation is calculated. With this information the range of 99.7% of all product is known.

**Estimation of Plating Range**

If the estimated range of plating thickness is to be calculated for a deposit take the average thickness (as specified) and add and subtract 3 standard deviations to it from Table I. For example for a bright nickel deposit plated by barrel plating methodology to a 200 $\mu$ in average deposit the range of thickness would be estimated as:
s = 25 μ in
+3s = 75 μ
-3s = 75 μ in
range = 200 - 75 and 200 + 75 μ in
= 125 – 275 μ in

Therefore 99.7% of all readings would be expected to lie within the range of 125 – 275 μ in. This assumes that the measurement location of deposit thickness is consistent from item to item.

**Significant Surface**

In addition to being normally distributed, the deposit thickness is strongly affected by the geometry of the product being finished. This is described in ASTM B 507-86.

Because of this geometry dependence, it is critical to define the exact location on an article where it functions in service and thus the thickness of the deposit is to be measured. This is the **significant surface**. Significant surfaces are defined as those surfaces normally visible (directly or by reflection) that are essential to the serviceability or function of the article, or which can be the source of corrosion products or tarnish films that interfere with the function or desirable appearance of the article. When necessary the significant surfaces shall be indicated on the drawings of the parts or by the provision of suitably marked samples. (ASTM B545-92§3.1.2, ASTM B689-90§3.1.1) This determination is made by mutual agreement between Artistic Plating and the purchaser of our services. If a significant surface is not identified by the purchaser, the deposit thickness may be measured at any convenient location on the product.

**Methods of Defining Thickness**

There are five (5) methods used for defining thickness at APC. They are average, range, minimum, maximum and customer negotiated. These are defined as follows:

- **Average**

Deposit thickness requirements supplied as a single number i.e. nickel plate 0.0002” are average readings. The average deposit thickness on the significant surface if defined shall be 0.0002” ± 0.000075” (200±75uin).
• **Range**

Deposit thickness requirements supplied as a range of numbers i.e. nickel plate 0.0001-0.0003" is the range within which the mean value must lie. If the range is ≤ 0.00015" (150uin) it is treated as a single average with the mid point of the range being the target average and the definition of average thickness above applies.

**Note**

A range specification does not imply that all readings collected on all articles at any location must be within the range.

• **Minimum**

Deposit thickness requirements supplied as a single number with a minimum i.e. nickel plate 0.0002” minimum are defined as all readings measured on the significant surfaces to be greater than 0.0002” (200uin) or any area of the part that can be touched by a 0.75” diameter sphere. Thickness of coating is not controlled in blind or small diameter deep holes or those areas adjacent to metal surfaces which form at angles equal to or less than 135°.

**Note**

There is no upper limit of thickness that applies in this definition. If a significant surface is not defined all readings shall be greater than the specified amount on all surfaces that can be touched by a 0.75” diameter sphere.

• **Maximum**

Deposit thickness requirements supplied as a single number with a maximum i.e. nickel plate 0.0002” maximum are defined as all readings measured on significant surfaces to be less than 0.0002” (200uin). If a significant surface is not defined all readings shall be less than 0.0002” (200uin) on any area of the part that can be touched by a 0.75” diameter sphere.
Note

There is no lower limit of thickness that applies. Any measurable deposit thickness is acceptable.

• Customer Negotiated Specifications

When a customer has a defined specification or sites commonly referenced specifications i.e. ASTM, MIL SPEC, AMS etc. They shall be followed.

When a specification is developed with the approval of and in conjunction with a customer it shall be followed. This unique specification is maintained in the Quality Control laboratory and is referenced on the appropriate process routing instructions. This document will be the ruling document as to significant surfaces, thickness interpretation and target thickness.