ACADEMIC STUDY
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Verification of Peening Intensity

INTRODUCTION

Verification of peening intensity is described in SAE J443 using just the three paragraphs of section 3.5. This article attempts to provide a much fuller explanation of the basic issues involved when attempting verification. These issues are summarized in fig.1. In tackling these issues we have first to consider just what (or which) defined peening intensity has to be verified. Different problems arise depending on if a single strip holder is being used or if multiple holders are involved. For the latter case, SAE J443 introduces the concept of a "Target Arc Height".

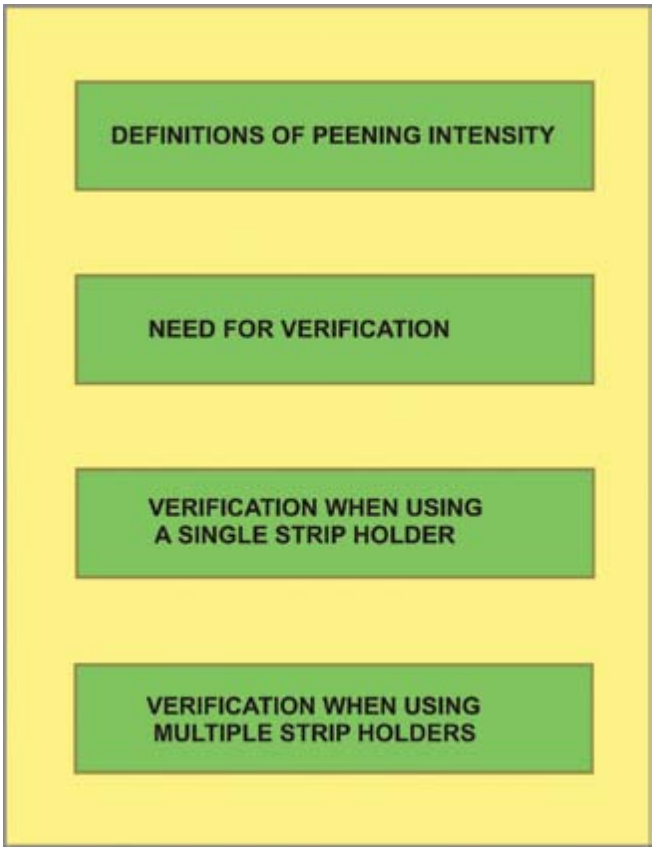

Fig.1. Basic issues involved in verification of peening intensity.

DEFINITIONS OF PEENING INTENSITY

Three different definitions of peening intensity are currently in use. These are not clearly named but are named here as: "10% rule", "10% or less" and "Type 2".

1. "10% Rule"

This is currently defined, in SAE J443, as the point on a saturation curve for which the corresponding arc height increases by precisely 10% when the peening time is doubled. SAE J2597 details appropriate computer techniques.

Fig.2 illustrates the use of computer curve-fitting and analysis when applied to SAE J2597 Data Set No.8. The derived peening intensity value, **H**, occurs at a peening time (or its equivalent) of **T**. This value increases by precisely 10% (to **1.1H**) when the peening time is doubled (to **2T**). **H** occurs at a point on the fitted curve (**H,T**) – not at a data point.

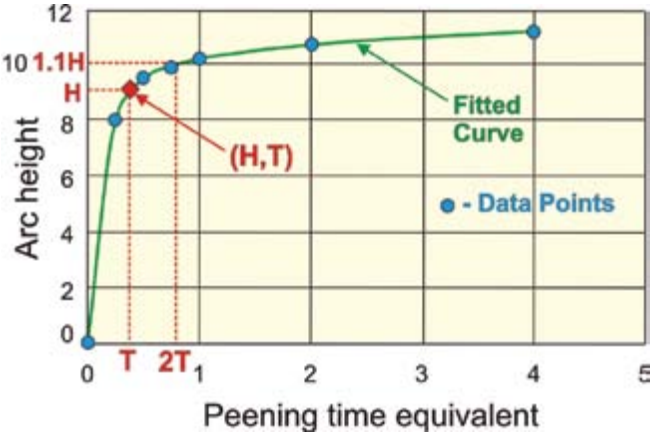

Fig.2. SAE Data Set No.8 plotted using "10% rule" to derive unique Peening Intensity, H.

The great advantage of this definition of intensity is that it is unambiguous. When allied to a computer curve fitting program the derived intensity, **H**, and the corresponding peening time, **T**, are unique, i.e., everyone will obtain the same values from a given set of data points.

2. "10% or less Rule"

This rule pre-dates the current 10% rule – being included for the first time in the 1984 version of SAE J443. It was an improvement on the previous "point on the knee of the saturation curve". It is, however, obsolescent - but "old habits die hard". It is not capable of providing a unique value for

either peening intensity or the corresponding peening time. That is because intensity is defined here as "that point on the curve beyond which the arc height does not increase more than 10% when the peening time is doubled".

Fig.3 illustrates the range of peening intensity and time values that could be reported for a particular shot stream. The reported values depend upon how an individual interprets data and also on how the data points are positioned relative to the minimum ($\mathbf{h_{MIN}}$). Both peening intensity, **h**, and corresponding time, **t**, are now variable quantities. Lower case is used here to follow accepted engineering/scientific practice for naming variables. The basic problem is that any point on the curve from the point $\mathbf{h_{MIN}}$ / $\mathbf{t_{MIN}}$ upwards satisfies the '10% or less Rule'.

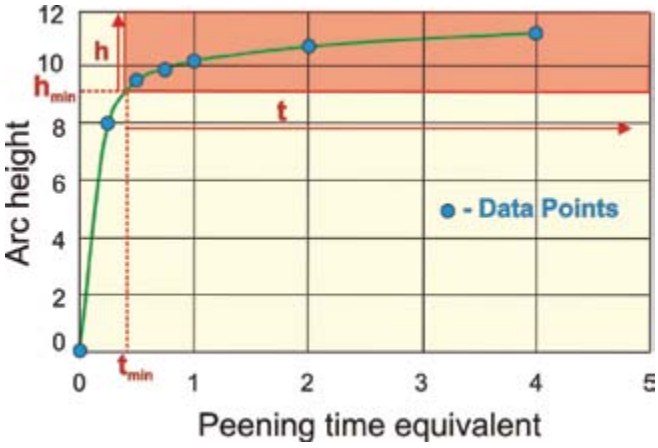

Fig.3. "10% or less Rule" applied to SAE Set No.8.

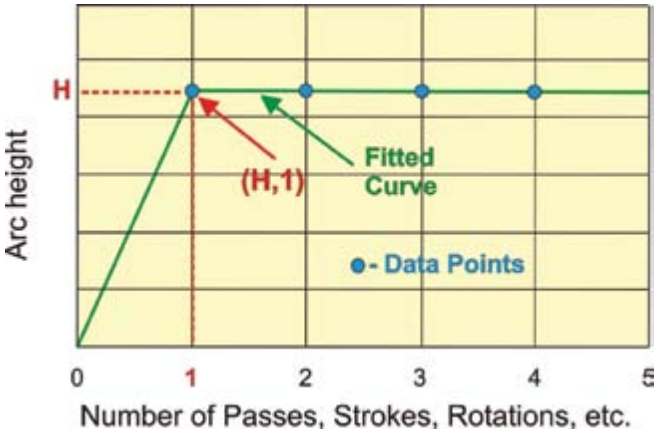

Fig.4. SAE J443 "Incremental based saturation curve (Type 2)".

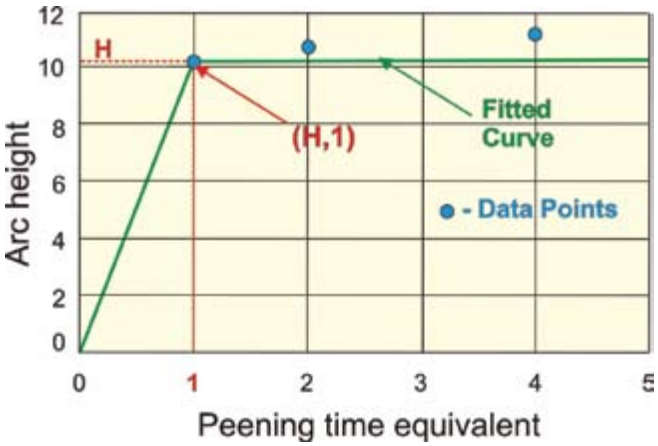

Fig.5. "Type 2" saturation curve for real data set.

3. "Type 2 Rule"

This rule is not commonly used, but is included in SAE J443. It is allowed because: "In some cases, saturation curves can appear as exemplified in Figure 2 (Type II) and occurs only when process variables do not permit the attainment of earlier data points". The SAE's illustrative figure, reproduced as fig.4 with minor modifications, is somewhat misleading as it includes simply four data points of exactly equal arc height. That situation never occurs in practice (except as a fluke of measurement variability).

For 'Type 2 Rule' situations, SAE J443 states that: "the intensity is defined as the arc height value of the first data point (i.e., at the minimum possible exposure time, T) provided that the arc height increases by no more than 10% when the exposure time is doubled to time 2T." This statement is at variance with its own fig.4. A possible real situation is illustrated in fig. 5 which uses the last three data points of SAE J443 Data Set No.8.

It follows that this rule permits a range of intensity values to be reported for a given shot stream (as does the '10% or less Rule'). The situations that it covers arise, presumably, when the components being peened are much harder than Almen strips. Alternatives that would allow the '10% Rule' to be applied include the use of high-hardness Almen strips and masks. For the mask alternative, different fractions of a standard Almen strip could be exposed to the shot stream – simulating fractions of a single pass.

NEED FOR VERIFICATION

SAE J443 rightly requires that verification be carried out in order to ensure consistent peening intensity. "The frequency of intensity verifications shall be no longer than eight hours of operation". This requirement recognizes the fact that peening intensity, for fixed machine settings, can vary after a substantial time of plant operation.

Peening variables have two effects on a peening intensity curve. First is their effect on peening intensity arc height, H. Second is their effect on the peening intensity time, T. Within a specified eight-hour period the major variable affecting H will be the shot velocity whereas feed rate is the major factor affecting T. The two effects are not independent of one another. For example: A change in feed rate will normally induce a change in H as well as T.

This is illustrated in fig.6 where the overlap indicates interaction.

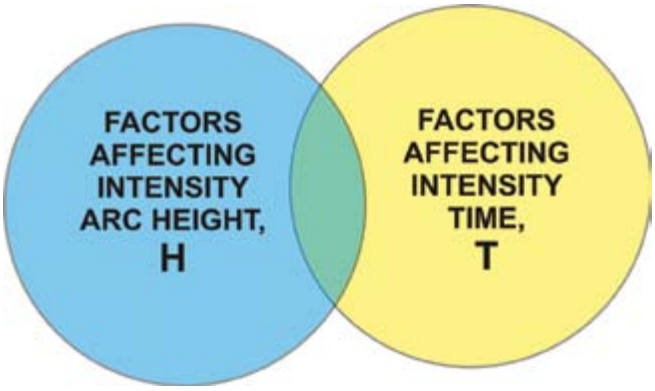

Fig.6. Interaction of factors affecting peening intensity point, H, T.

VERIFICATION WHEN USING A SINGLE STRIP HOLDER

The relevant section in SAE J443 is as follows:

> "When using a single holder on a fixture, a single strip may be used to verify intensity. This strip should, ideally, be exposed for the time T derived from the saturation curve and its arc height shall be within the stated tolerance. In practice, this is not always possible (for example, when integral values of strokes or rotations are used). When that condition occurs, the nearest practical time to T should be used. The arc heights obtained must repeat the value from the saturation curve ± 0.038 mm (0.0015 in) or other value acceptable to the responsible authority."

Fig.7 illustrates the SAE J443 requirements for verification. These involve 'either/or".

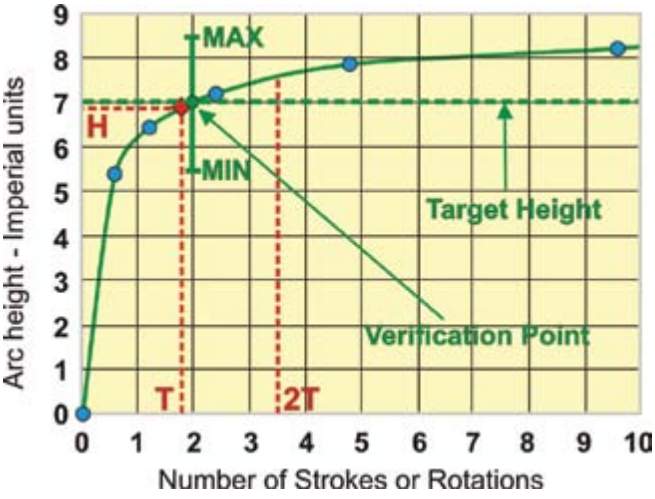

Fig.7. SAE J443 verification alternatives when using a single holder.

For the ideal situation, the single strip would be exposed to peening for the time,T, shown in fig.7. The arc height of this peened strip "shall be within the stated tolerance". Verification therefore only requires that the arc height of the single peened strip falls within the tolerance band e.g. 6 – 9 using imperial units. The tolerance is presumably that stated by the customer and is not specified within SAE J443.

When integral values of strokes or rotations are being employed SAE J443 is quite unambiguous. For example, if the established peening intensity curve was that shown in fig.7 then the single strip must be peened for 2 strokes/rotations. The resultant arc height must repeat the value from the saturation curve ± 1.5 (imperial units). This "value from the saturation curve" is shown in fig.7 as the verification point, (7, 2), which lies on the curve. Hence the requirement is that the arc height shall be 7 ± 1.5. Put another way we now have a "target height" of 7 when the strip is peened using 2 strokes/rotations. That target must not be missed by more than 1.5.

The SAE J443 verification for single holders embodies an important principle. This is that the intensity of a shot stream is defined just as well by other points on the saturation curve as it is by just the one, critical, point on that curve (H, T). Hence any point on the saturation curve that is reasonably close to T can be employed as a verification point. This verification point has what is commonly called a "'Target Height" – meaning that it is a target to be aimed at, see fig.7.

VERIFICATION WHEN USING MULTIPLE STRIP HOLDERS

The objective in this section is to expand on and clarify the SAE J443 multi-holder verification requirement. The SAE requirement is stated as follows:

> "Using multiple holders on a fixture will result in various exposure times for T. To simplify the verification procedure, a single verification exposure time or equivalent may be selected. The verification time selected shall not be less than the shortest exposure time no greater than the longest exposure time of the group of holders. New strips shall then be placed on the holders and exposed for this verification time. The resulting arc height readings of these strips shall be recorded as target arc heights and subsequent verification test results shall then repeat these arc height values within ±0.038 mm (0.0015 in). The resultant arc height readings do not have to be within the intensity tolerance band since the single verification time at a given location can be substantially less than or greater than verification time T. The purpose of the verification test is to confirm that the arc height at a particular location is consistent. The ability of the test strip to exhibit similar curvature for similar exposure time is sufficient evidence of consistency."

In trying to achieve the stated objectives, consider the following hypothetical conversation between Joe and Fred (a visiting peening expert and long-time friend of Joe's).

Joe's Big Problem

Joe: Hi Fred. Thank goodness you are here. I've got a big peening problem that is giving me headaches.

Fred: Hi Joe. What's the problem?

Joe: In a word, "verification".

Fred: Tell me more.

Joe: I am using up to 24 holders on a big component. I've managed to arrange the set-up so that every holder produces a saturation curve with a peening intensity within my customer's tolerance band. I am using a computer to help me produce curves and intensity values following the "10% Rule". My problem is that I have to verify all of these intensities at least every 8 hours of peening plant operation – according to SAE J443. I don't know if my method of verification is correct – it certainly takes me so long that I am losing orders.

Fred: It certainly shouldn't take so long but you are certainly obtaining intensity values properly. Let us take multi-holder verification one step at a time. As a first step have a drawing made of six typical saturation curves from six holders – 24 curves on one graph would look like a bowl of spaghetti! Just the curves and the peening intensity points – there's no need to include the data points. Ideally put the graph on a thumb drive so that I can edit it on my laptop

Joe: O.K. I must have read your mind. Here it is:

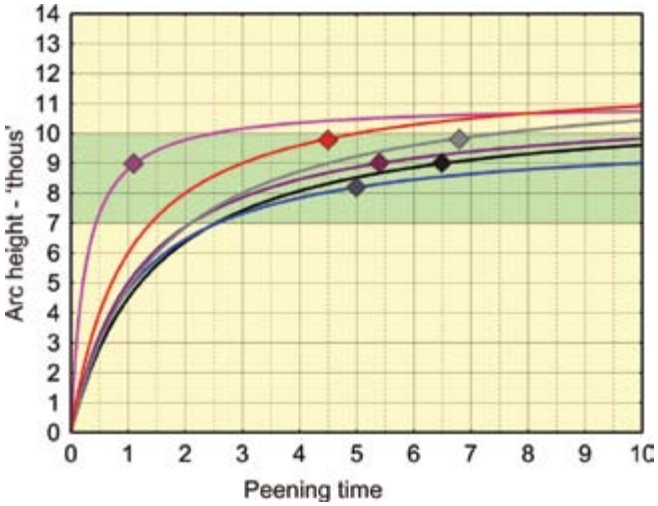

Fig.8. Saturation curves from six holders peened on the same component.

As you can see, the six peening intensity times, T, vary from 1.1 to 6.8. The corresponding intensities are all within the customer's tolerance band – which I've marked as a green box. Where do I go from here?

Fred: As step 2 I'll load the graph onto my laptop, erase your green box, minimise the marking of the peening intensity points and insert minimum and maximum limits for any allowable verification peening time. Here we go:

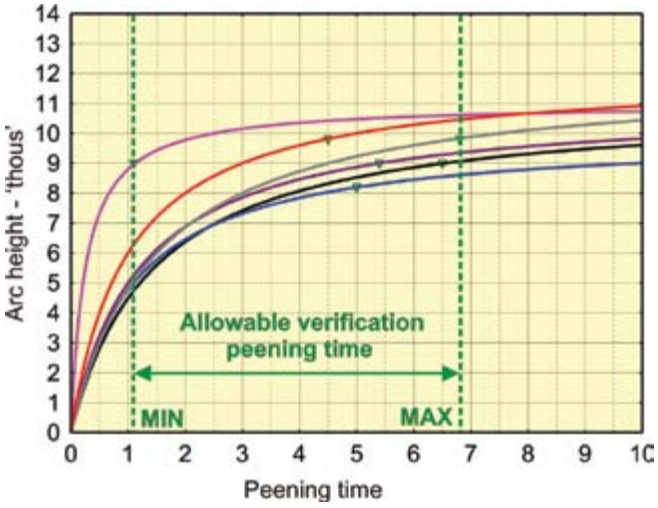

Fig.9. Range for allowable verification peening time using multi-holder setup.

Joe: Surely you've made a mistake by implying just one verification peening time?

Fred: No. SAE J443 clearly states: "To simplify the verification procedure, a single verification exposure time or equivalent may be selected." It also specifies that this single verification time must be between the shortest and longest from the full set of holders. That means that you are free to choose any time between the minimum and the maximum from your set of holders – to suit your convenience. Let us pick 6 as an allowable verification time. As step 3 I'll mark it on the graph. Here we go:

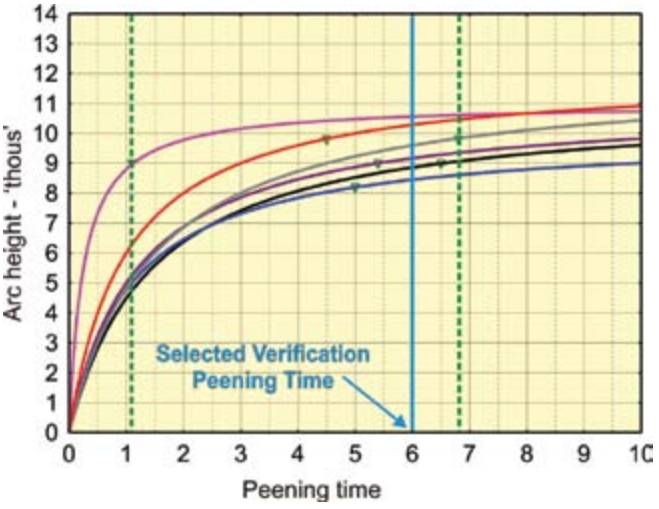

Fig.10. Selection of a single Verification Peening Time when using multi-holder setup.

Joe: What should I do next, Fred?

Fred: All you have to do is to find the six points where the selected verification peening time intersects the six saturation curves. We call these the "target heights". These are the arc heights that we have to aim at during verification. As step 4 I'll mark them on the graph, cut-and-paste, and then zoom in on my laptop so that you can see the target heights more clearly. I've just marked one target height of 9.6, but you can easily read off the other five from the graph. The smallest one is 8.5 and the largest one is 10.6.

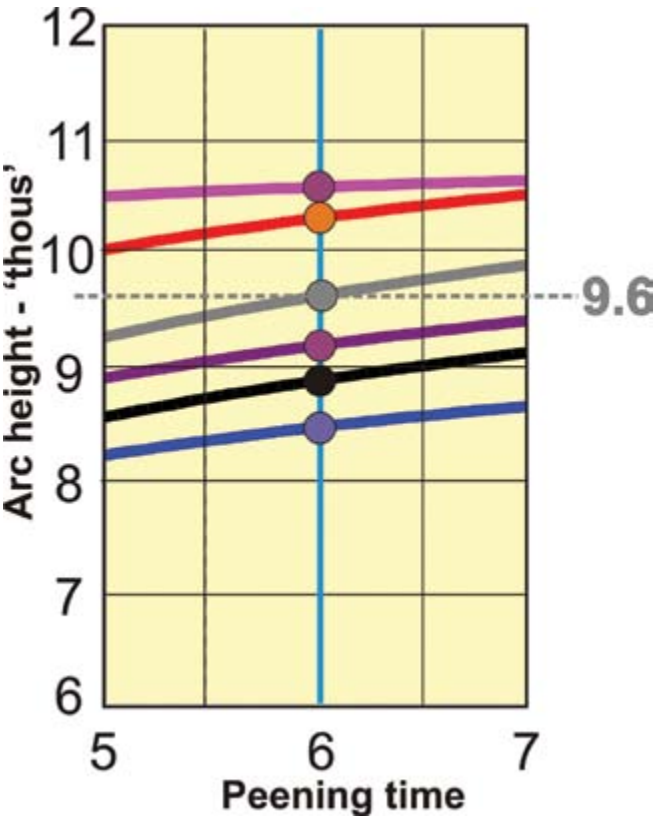

Fig.11. Target heights for a multi-holder set-up and a peening time of 6.

Joe: Yes, but the largest one is above my customer's tolerance band limit.

Fred: That doesn't matter. SAE J443 states that "The resultant arc height readings do not have to be within the intensity tolerance band."

Joe: That's O.K. but do I have to achieve all 6 target heights exactly?

Fred: No. You just have to put one strip in each holder and peen all of them for a time 6. If the measured arc heights after peening are within ± 0.0015" of the corresponding target height you are O.K. For example, at the target height of 9.6 that means that the verification requirement is satisfied if the deflection is anywhere between 11.1 and 8.1.

Joe: Wow that seems simple enough, why was I getting so confused?

Fred: Some of the wording in the current version of SAE J443 doesn't help. By the way what I have told you applies for any number of holders in your set-ups. Here is a checklist - before we go for that pint that you promised me.

Multi-Holder Peening Intensity Verification Checklist

STEP 1: Make a list of the peening intensity times, T, obtained for all of your holders and have all of the saturation curves to hand.

STEP 2: Tick the shortest and longest of list of peening intensity times. Pick just one convenient peening time anywhere between the shortest and longest of these times.

STEP 3: Mark where this selected verification peening time intersects each of the saturation curves. List each intersection as a "Target Height" corresponding to each of your holders.

STEP 4: Put one strip in each holder and peen all of them for your selected verification peening time. Measure the arc heights after peening and compare each of them with your target arc heights. Verification is achieved if each one is within ±0.038 mm (0.0015 in) of the corresponding target height.

SUMMARY

Periodic verification of shot stream peening intensity is a necessity. Variability of this intensity can never be completely removed, even with the use of every available control device.

Specified procedures for verification are not always completely clear and may require interpretation.

Verification when using a single holder can be specified in a relatively straightforward manner. The use of just a single strip is specified in SAE J443 and may be carried out at either the peening intensity point (H, T) on the saturation curve or at a nearby peening time that has a corresponding "Target Height" – which differs from H. The arc height obtained for the peened strip must lie within ±0.038 mm (0.0015 in) of the corresponding target height.

Verification when using multiple holders is specified in SAE J443 and requires one strip for each holder. To simplify verification, these strips can be peened using a single, common, verification peening time. This selected time can lie anywhere between the shortest and the longest peening intensity point times obtained for the set of holders. The arc heights obtained for the peened strips must lie within ± 0.0015" of a corresponding target height. This target arc height is the intersection of the common peening time with the saturation curve for that holder.