SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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Shot Peening Coverage Determination

RATIONALE

As part of the required Five-Year Review, the document is being revised to improve clarity.

1. SCOPE

This SAE Recommended Practice provides procedures for determining shot peening coverage and relating coverage to part exposure to the media stream. Effectiveness of shot peening is directly dependent on coverage. Inadequate or excessive coverage can be detrimental to fatigue strength and component life.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J442 Test Strip, Holder, and Gage for Shot Peening

SAE J443 Procedures for Using Standard Shot Peening Almen Test Strip

3. COVERAGE

Coverage is the extent of peening as shown by the percentage of the surface exhibiting a uniform impact pattern of overlapping indentations. Coverage of exactly 100% exists only as a theoretical limit that is neither measurable nor achievable. Coverage is considered full coverage (aka complete coverage) when 98% or more of the surface is indented. It is difficult to visually distinguish differences in coverage above 98%.

Coverage, up to 100%, is defined as the percentage of a surface that has been impacted at least once by the peening media. Typically, coverage estimates are obtained by optically-aided visual inspection of the peened part. Estimates of coverage by visual observation are unavoidably subjective, particularly when full coverage is being approached.

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https://www.sae.org/standards/content/J2277_202301/

4. COVERAGE INSPECTION

Individual unimpacted islands can exist at full coverage and are permitted provided they are randomly distributed on an otherwise uniformly dimpled surface. The largest dimension of any single island should be less than the typical indentation diameter. The minimum peening time required to achieve full coverage is determined by incrementing the peening time until full coverage is achieved. Coverage greater than 100% coverage, when required, is a multiple of the time to reach “full coverage.” Coverage greater than 100% cannot be verified by examining the peened surface.

Coverage inspection shall be performed to verify full coverage on, at a minimum, representative areas of the peened surfaces. Sampling plans and frequency of coverage inspection should be documented in the supporting technical plan or quality procedure(s). These areas should include recesses and shaded regions that are difficult to access. Sampling of peened parts shall be as required by the shot peen process specification or as agreed upon between the provider and the customer. Coverage customarily is determined by visual inspection; however other methods may be employed.

Coverage inspection methods depend upon many factors primarily the size of the indentations resulting from the peening process. Large indentations can sometimes be inspected with no optical magnification while small indentations can require 10 to 30X or higher magnification. Coverage inspection methods are classified as direct and indirect.

4.1 Direct Inspection Methods

4.1.1 Optically Aided Visual

The most common method for coverage inspection is the use of a hand magnifier or microscope capable of 10 to 30X magnification. Lower magnification even down to 1X can be possible when peening indentations are large enough to clearly differentiate full from partial coverage. For purposes of this recommended practice, the starting size of the indentations required to verify using 1X magnification has not been defined since there are multiple factors effecting the resulting indentation size such as intensity, media size, and material hardness to name a few. When the indentations cannot be otherwise evaluated, magnifications greater than 30X can be necessary. Options for optical evaluation continue to evolve with the advent of USB based microscopes and boroscopes. Alternative methods and magnifications should be documented in the technical plan or respective quality documents unless otherwise agreed to by both the customer and the provider.

4.1.2 Optical Analyzers

Optical analysis instruments may be used for coverage estimation. Such systems must, however, be “trained” in specific situations to provide true coverage estimation because differences in surface roughness, reflectivity, and geometry which can affect instrument output.

4.2 Indirect Methods

The following methods may be used when agreed between the customer and the provider.

4.2.1 Fluorescent Tracers

Fluorescent tracers are coatings applied to parts before shot peening. The amount of coating removal is intended as a visual aid in the determination of the coverage.

4.2.1.1 Prior to peening, coat a representative area of a part or a coupon according to the tracer manufacturer's recommended practice. After peening, inspect the peened surfaces with 10X minimum magnification to verify the required level of coverage. Then view the same surfaces under ultraviolet light in a darkened area to determine the amount of tracer removal.

4.2.1.2 The amount of coating removal on subsequently peened parts shall be compared with the amount of coating removal from the sample prepared in 4.2.1.1. Parts exhibiting more residual fluorescence than the sample piece are inadequately covered and shall be visually examined for coverage using 10 to 30X magnification.

4.2.1.3 Complete tracer removal does not necessarily coincide with full visual coverage.

4.2.2 Dye Marker Inks

Dye marker inks are used in the same manner described for fluorescent tracer with white light inspection.

4.2.3 Replicas

A replica of the surface can be made and used for clarification of coverage. This technique results in an inverse image and is commonly used for recessed areas that cannot be inspected using normal techniques.

4.2.4 Coverage Coupon

A less common method is referred to as a coverage coupon. It utilizes a sample with similar material properties and hardness to the part to the part to be peened to evaluate coverage. For high hardness parts, low intensity peening, or other situations where peening impressions are small and difficult to discern, striations may be added to the coupon by grinding or sanding the prior to peening to facilitate coverage evaluation.

It is important to verify that the coverage rate of the coupon is comparable to the coverage rate of the part to be peened. It should be noted that the rate of work-hardening affects the rate of coverage. The rate of work-hardening depends on metallurgical characteristics such as crystal structure, number of phases, etc. For example, austenitic steels generally work-harden more rapidly than ferritic steels. Coupon testing should be restricted to the establishment of the minimum peening time required to achieve a nominal full coverage. It is not a substitute for component coverage inspection.

4.3 Part Peening Time Determination

Peening time to reach full coverage of parts is not related to the intensity/saturation times referenced in SAE J443 for Almen strips. This is because parts generally have different shapes, hardnesses, and strain hardening characteristics from those of Almen strips. For example, with all other factors remaining unchanged, softer parts will require less exposure time to achieve full coverage than Almen strips or parts with higher surface hardness.

5. NOTES

5.1 Revision Indicator

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

5.2 Coverage can be affected by any combination of factors including the duration of part exposure to the media stream, hardness of the part, hardness of the media, media flow rates, peening intensity, and other process factors.

5.3 Relationship of Coverage to Exposure Time

Equation 1 expresses a relationship between coverage and time of exposure that can be useful for relating coverage to exposure time.

$$C_n = 1 - (1 - C_1)^n \quad \text{(Eq. 1)}$$

where:

C_1 = percent coverage (decimal) after 1 cycle

C_n = percent coverage (decimal) after n cycles

n = number of cycles (number of passes, number of rotations, or uniformly chosen increments of time)

As this expression indicates, coverage approaches 1.0 (100%) as a limit. It is difficult to accurately assess the amount of coverage as coverage approaches 100%. Thus, 98% has been chosen to represent full coverage. Beyond this value, the coverage is expressed as a multiple of the exposure time required to produce 98% coverage. For example, 150% or 1.5 coverage represents a condition in which the specimen has been exposed to the blast 1.5 times the exposure required to obtain 98% coverage. A chart plotted to a convenient exposure time scale is shown in Figure 1.

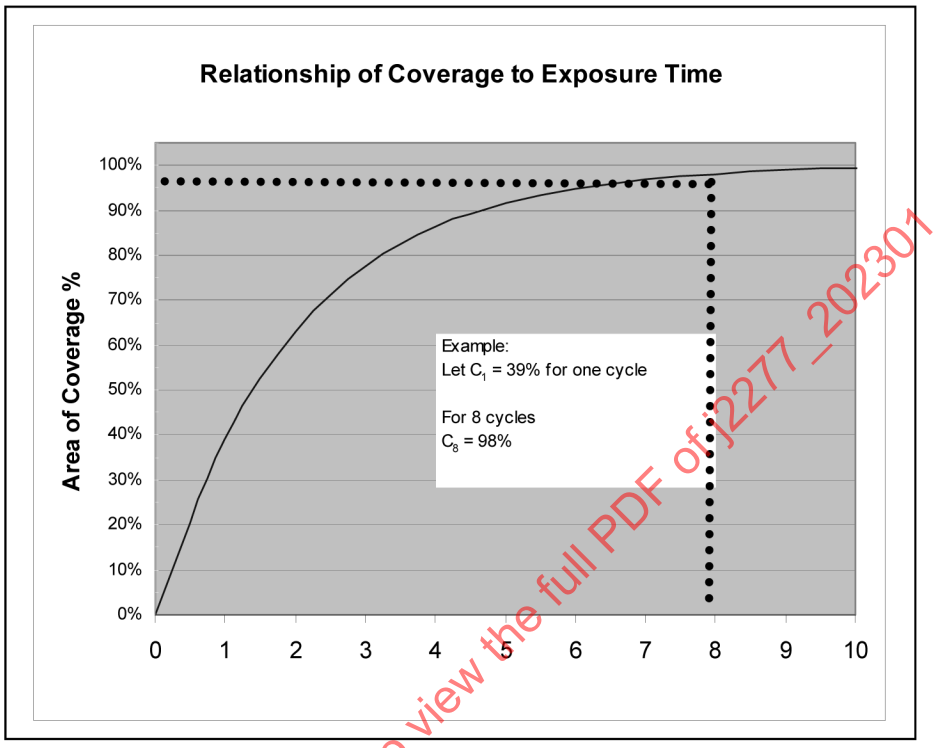
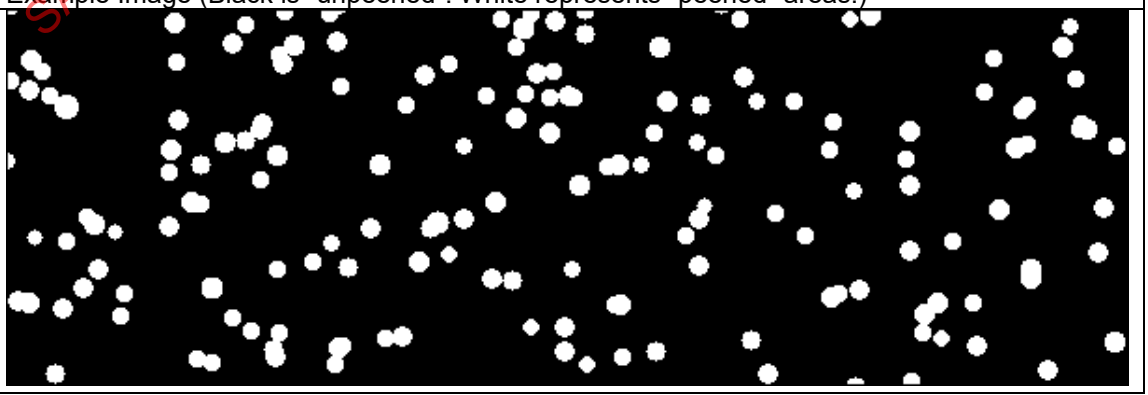
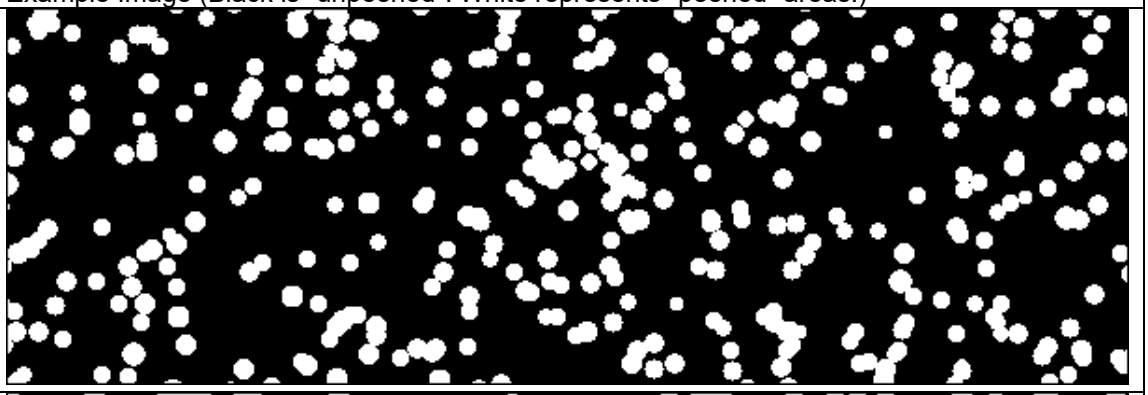
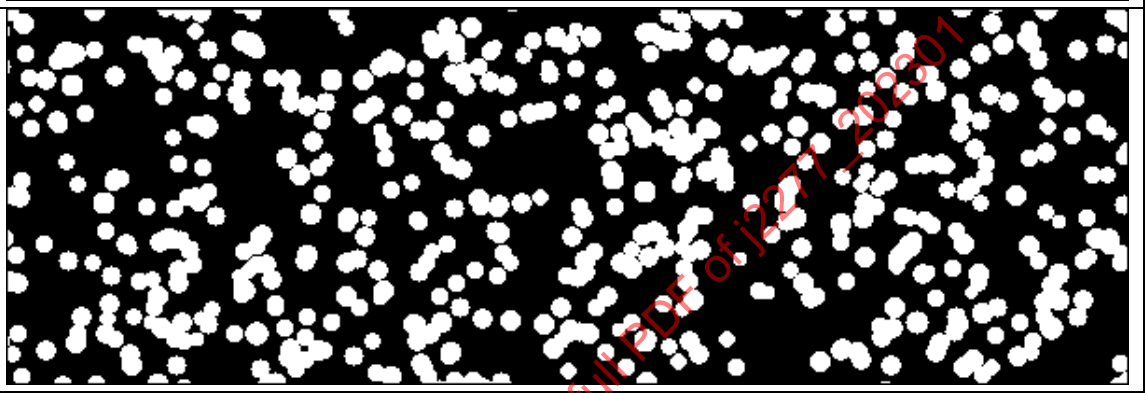
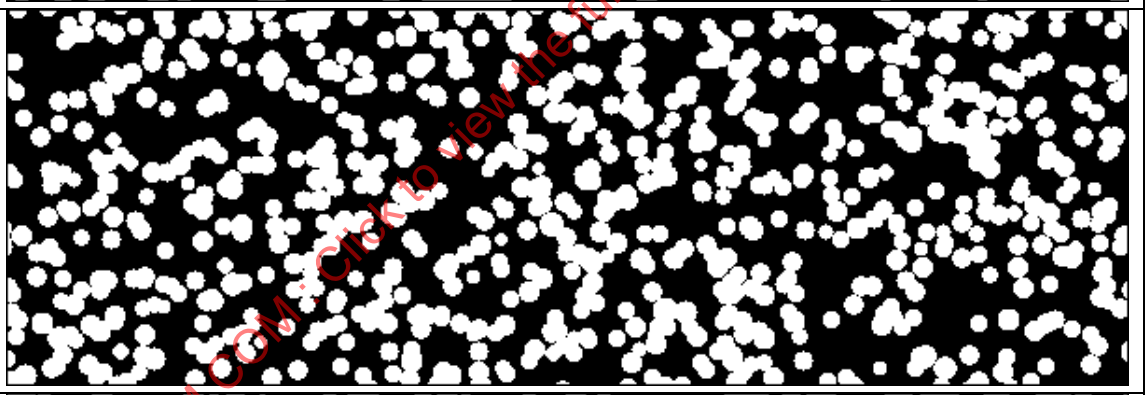
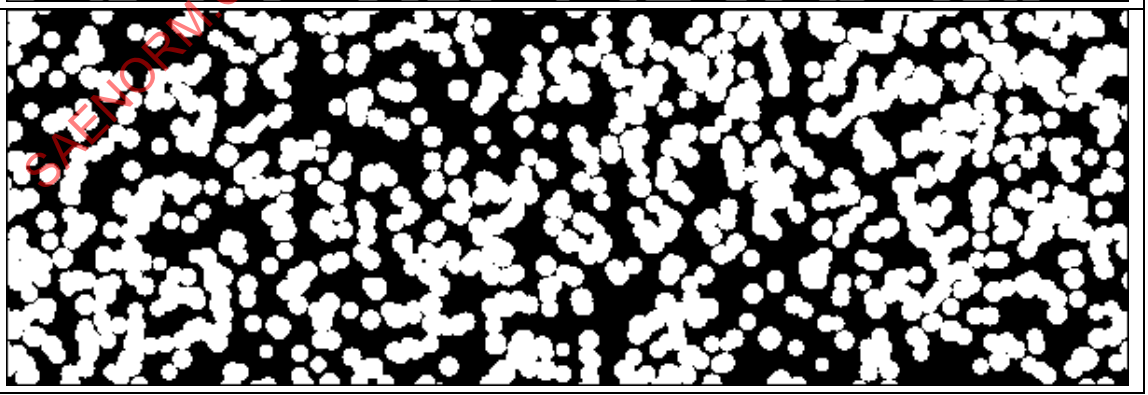


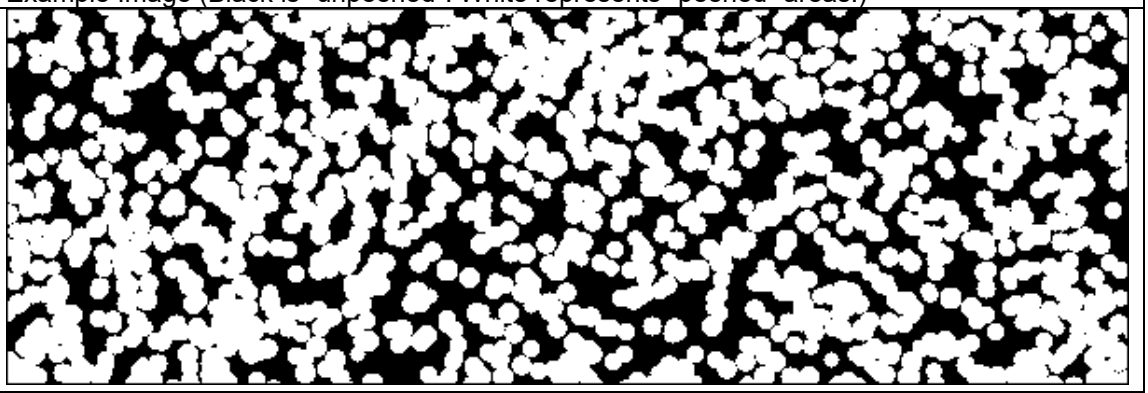
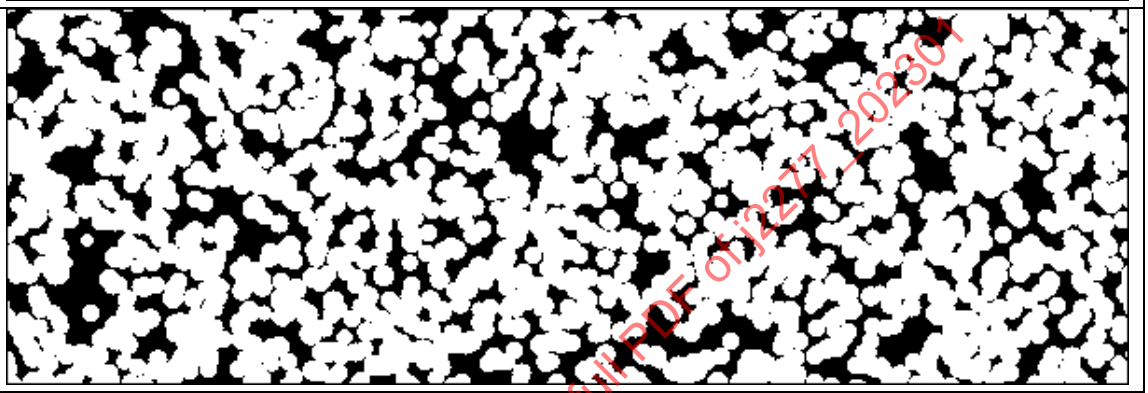
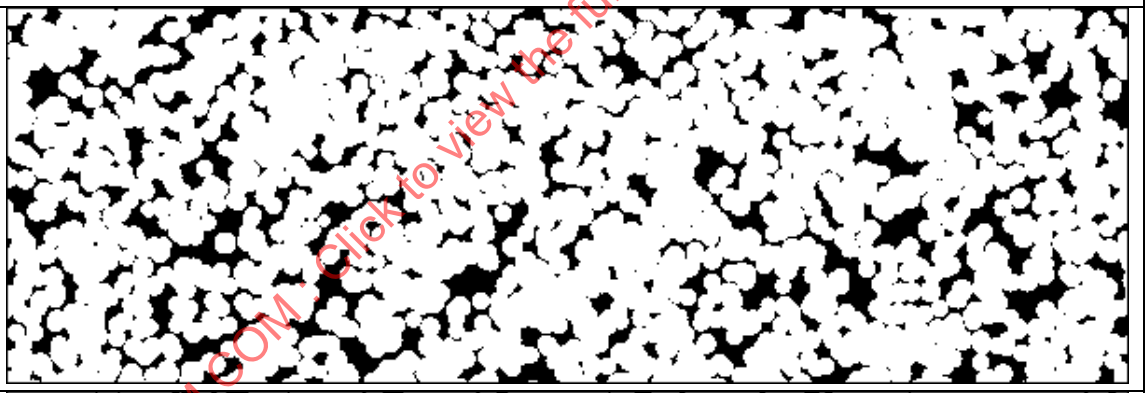
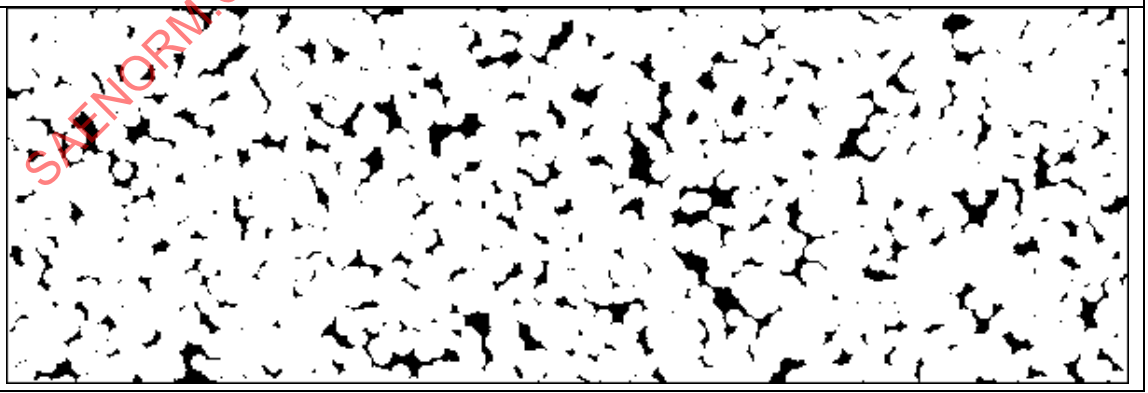
Figure 1 - Factor of exposure time, t

5.4 Shot Peen Coverage Visual Reference Examples

For illustration purposes only. The white zones shown below are random digital representations of peening dimples on an ideal black background. The coverage percentages were calculated from the ratio of white area to black area in the images. Actual 3D effects that happen on real surfaces (e.g., curvature, texture, or interactions in dimples, etc.) were not simulated.

Coverage	Example Image (Black is "unpeened". White represents "peened" areas.)
10%	

Coverage	Example Image (Black is "unpeened". White represents "peened" areas.)
20%	
30%	
40%	
50%	

Coverage	Example Image (Black is "unpeened". White represents "peened" areas.)
60%	
70%	
80%	
90%	

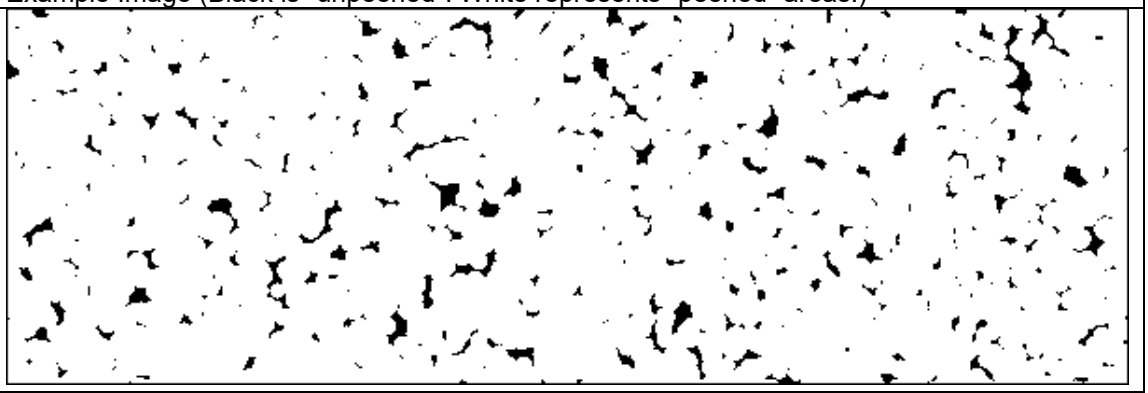
Coverage	Example Image (Black is "unpeened". White represents "peened" areas.)
95%	
98%	
99%	

Figure 2 - Images of Coverage
(Courtesy of GE Aviation, Dale Lombardo)