RECOMMENDED PRACTICES FOR CONTROLLING SHOT PEENING PROCESSES
GM 4283-P

SCOPe. This standard covers the practical considerations and procedures involved in setting up and controlling shot peening operations. It includes requirements for the equipment involved (test strips, holding block and gage), recommendations for their use, and standards for designating desired conditions and/or results.

PRINCIPLE OF CONTROL. The control of a peening machine operation is primarily a matter of the control of the properties of a blast of shot in its relation to the work being peened. The basis of measurement of these properties is as follows: If a flat piece of steel is clamped to a solid block and exposed to a blast of shot, it will be curved upon removal from the block. The curvature will be convex on the peened side. The extent of this curvature on a standard sample serves as a means of measurement of the blast. The degree of curvature depends upon the properties of the blast, the properties of the test strip, and the nature of exposure to the blast, as described below:

Properties of the blast are the velocity, size, shape, density, kind of material, and hardness of the shot.

The properties of exposure to the blast are the length of time, angle of impact, and shot flow rate.

The properties of the test strip depend upon the physical dimensions and mechanical properties of the strip.

INTENSITY-MEASURING EQUIPMENT.
A. Test Strips -- Standard test strips "A", "N", and "C", shown in Figure 1, shall conform to the following:

SAE 1070, cold-rolled spring steel; square edge No.1 (on 3-inch edges); flatness (arc height as measured on a standard Almen No.2 gage) plus and minus 0.001 for strips "A" and "N"; plus and minus 0.0015 for strip "C"; blue temper (or bright) finish; uniformly hardened and tempered (heat set between flat plates under pressure for minimum of 2 hours at 775 to 825°F) to Rockwell C44 to 50.

![Figure 1 - Test Strips](image)

The relationship between test strips "A", "N", and "C" is shown by Figure 5. This curve shows strip readings for conditions of identical blast and exposure. The test strip "A" is used for intensities that produce arc heights of 0.006A to 0.024A. For greater intensities of peening the "C" test strip is used. For lesser intensities the "N" strip is used.

B. Holding Fixture -- Test-strip holder shall conform to Figure 2.

![Figure 2 - Assembled Test Strip and Holder](image)

C. Gage -- The gage for determining the curvature of the test strip is shown in Figure 3. The curvature of the strip is determined by a measurement of the height of the combined longitudinal and transverse arcs across standard chords. This arc height is obtained by measuring the displacement of a central point on the non-peened surface from the plane of four balls forming the corners of a particular rectangle. (This gage is commonly referred to as the Almen No.2 Gage. It supersedes the Almen No.1 Gage.) To use this gage, the test strip is located so that the indicator stem bears against the non-peened surface, as shown in Figure 4.

DESIGNATION OF INTENSITY MEASUREMENT. The standard designation of intensity measurement includes the Almen No.2 Gage reading or arc height (in inches) followed by a letter indicating the test strip; for example, "0.013A." This example signifies that the arc height of the peened test strip as measured by the Almen No.2 Gage is 0.013 inch and the test strip used is the "A" size. Another example is: "0.006 to 0.008C." This signifies 0.006 to 0.008 inch gage reading on "C" strip.

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size test strip measured with the same gage. This example is typical of the method used for specifying an arc height tolerance for an application. As shown in both of the examples, the gage or arc height reading is given first and is followed by the test-strip designation.

DIAL INDICATOR (MAX VALUE OF GRADUATION 0.001), COUNTER CLOCKWISE DIAL, BACK ADJUSTABLE BRACKET, LOW FRICTION JEWELLED BEARINGS, EQUIPPED WITH EXTENSION POINT.

CONTACT SURFACE OF ALL BALLS TO BE IN ONE PLANE WITHIN ±0.002

0.08 MIN

0.25 DIA (Guides)

0.62 MAX

L252
L248

0.62 MAX

0.630
0.620

FOUR HARDENED STEEL BALLS 0.188 DIA

0.627
0.623

0.3175
0.3075

0.78

1.56

FIGURE 3 - ALMEN NO. 2 GAGE

PROCEDURE FOR MEASURING BLAST INTENSITY
(Base on Arc Height/Exposure Time Relationship).

A. General Procedure --

1. Fasten the strip tightly and centrally to the test-strip holder as in Figure 2.

2. Expose the surface of the strip to the blast to be measured. Record the time of exposure or its equivalent.

3. Remove the strip from the holder and measure the arc height on the gage. The zero position of the gage must be frequently checked and, if necessary, adjusted.

FIGURE 4 - TEST STRIP POSITION IN GAGE
(SHOWN WITH HOLDING FINGERS)

FIGURE 5 - CORRELATION OF TEST STRIPS "A", "N" AND "C" AS CHECKED ON AN ALMEN NO. 2 GAGE

4. Using different exposure times, repeat Steps 1, 2 and 3 sufficiently to determine a curve similar to Figure 6.

5. The gage reading corresponding with the point

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where the curve flattens out ("A" in Figure 6) is generally taken as the measurement of the intensity of that particular peening. In some cases, this point is difficult to pick out and requires some judgment.

![Graph showing intensity of peening over exposure time](image)

**FIGURE 6 - INTENSITY DETERMINATION CURVE**

B. Production Set-Up Procedure -- (Used in making a production set-up in which a setting of the machine is to be determined for a desired arc height and shot size.)

1. Provide a fixture to support the test strip in a manner to simulate the most critical surface of the part to be peened. In cases where more than one critical surface is to be peened, the fixture should provide for the mounting of the required additional strips.

2. With an estimated setting of the machine (shot flow rate, shot velocity, and type of shot), a series of test strips should be exposed to the blast of shot, each for a different exposure time so that a curve such as shown in Figure 7 may be established.

3. If the intensity measurement obtained from the curve does not fall within the desired limit, machine settings must be changed. If a higher arc height is desired, either higher shot velocity or larger shot is necessary, assuming a given type of shot is used. If lower arc height is desired, a lower shot velocity or smaller shot is needed. These velocity changes may be made by changing wheel speed or air pressure. In certain cases, an adjustment may be made in the direction of the shot stream, but the most efficient peening is obtained with the direction of the main part of the blast stream normal to the critical section of the part being peened.

4. After new settings are made, arc heights are again determined as described in Step 2.

5. Suppose with the first trial, the Curve-B of Figure 7, is obtained, and the desired arc height is indicated by the horizontal broken line. The shot velocity or shot size is accordingly too great and one or both must be reduced. Suppose the second trial results in the Curve-C. Here the shot velocity or shot size is too small. Perhaps the third trial would result in Curve-D, which is the correct one for the required arc height.

6. When the machine settings are found that yield the desired arc height, the time of exposure of the part is also indicated. For example, from Curve-D in Figure 7, the time of exposure (T), corresponding with point Q on the curve, is that which would ordinarily be used.

7. The lowest peening intensity required to produce the desired effect is the most efficient and most economical, because it will require the smallest shot for the least exposure time. The fatigue life of a part subjected to a particular blast intensity will provide the ultimate analysis of the effectiveness of the operation.

![Graph showing intensity determination curves](image)

**FIGURE 7 - INTENSITY DETERMINATION CURVES**

**PROCEDURE FOR MEASURING COVERAGE** (Relationship of Coverage to Exposure Time). There is a definite and quantitative relationship between coverage and exposure time. This relationship may be expressed as follows:

\[ C_n = 1 - (1 - C_1)^n \]

where:

- \( C_1 \) = per cent coverage (decimal) after one cycle
- \( C_n \) = per cent coverage (decimal) after \( n \) cycles
- \( n \) = number of cycles

As this expression indicates, coverage approaches 100 per cent as a limit. It is difficult to obtain accurate measurements of coverage above 98 per cent, but a measurement at a lower degree of coverage will serve...
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as a means of determining the exposure time or equivalent required to obtain any desired coverage. Since coverage approaches 100 per cent as a limit, and since actual measurement can be made up to and including 98 per cent, 98 per cent is arbitrarily chosen to represent full coverage. Beyond this value, the coverage is expressed as a multiple of the exposure time required to produce 98 per cent. For example, 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 per cent coverage. A chart plotted to a convenient exposure time scale is shown in Figure 8.

![Figure 8 - Relationship of Coverage to Exposure Time](image)

**Example:**

\[
\text{LET } C_1 = 45\% \text{ (ONE CYCLE)}
\]

\[
T_1 = 2 \\
\text{FOR 3 CYCLES}
\]

\[
T_3 = 6 \\
C_3 = 82\%
\]

**Figure 8 - Relationship of Coverage to Exposure Time**

Coverage of a blast of shot may be determined in a variety of ways. Three common methods for determining coverage are:

1. Straub Method
2. Valentine Method
3. Surface Replica Method (such as Faxfilm)

Of the three methods, the Surface Replica Method is the only one which can be completely carried out in the shop; the Straub and Valentine Methods require the use of laboratory equipment. The Straub Method is the most commonly recommended.

1. **Straub Method** -- The Straub Method for determining coverage is accurate if Almen test strips are being used properly. If the test strips used for this test are not located properly, this method will be only comparative. However, if the test strips are attached to the work to be shot peened, this method actually determines the area struck by the individual shot particles. The ratio of the indented areas to the total area is the per cent coverage. A true indication of coverage is obtained only if the hardness of the work is the same as the hardness of the test strip. As an alternative, the surface of the part itself could be used.

The materials needed for this test consist of: polished Almen test-strips, test-strip holders, and the use of a metallurgical camera and planimeter.

A. **General Procedure -- Straub Method:**

1. Polish the test strips to obtain a reflecting surface by means of metallurgical polishing cloths, by electrolytic polishing, or equivalent.
2. Fasten to the test-strip holder.
3. Expose the polished surface to the blast under conditions identical to that used in determining the arc height or Almen No.2 Gage reading.
4. Remove the strip from the holder and place it in the field of a metallurgical camera.
5. Using a piece of transparent paper as a ground glass, and with a magnification of approximately 50 diameters, trace the indented areas with a sharp pencil. The indented areas can be identified by the contrast of the polished surface and the inclined surfaces of the indentations.
6. Measure with a planimeter the area of all the indentations enclosed by a circle of known diameter. The ratio of the indented areas to the total area is the percentage coverage.

2. **Valentine Method** -- The Valentine Method of determining coverage is generally used as a qualitative measurement; i.e., to determine if the shot is actually striking certain areas and cold-working the surfaces. The method is particularly applicable to unusual contours which do not lend themselves to any other type of coverage determination. The materials needed for this method consist of: a duplicate of the part made from low carbon steel (SAE 1008) and the use of an annealing furnace and a metallurgical microscope. Since the hardness of the work influences the rate of coverage, it should be recognized that this technique gives a quantitative measure of coverage only if the work is of the same hardness as the duplicate. If the work is harder, coverage develops at a slower rate.

A. **General Procedure -- Valentine Method:**

1. Make a duplicate of the part from low carbon steel (SAE 1008).
2. Normalize at 1650 F.
3. Subject the part to the proposed peening cycle.
4. Anneal at a suitable temperature (1300 F) to produce recrystallization and grain growth.
5. Section the sample through the areas in question and prepare for metallographic examination.
6. Measure the depth of grain growth and compare

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with other areas on the sample and test-strip readings for arc height.

3. Surface Replica (Faxfilm) Method -- The Surface Replica Method is the simplest of the methods for measuring coverage. It is a comparison method and, in general, is not suitable for securing exact measurements of coverage. The test can be applied to practically any area of a part (exclusive of small radii) as well as to the surface of an Almen test-strip.

The materials needed for this test consist of: solvent, film, holders, and projector.

A. General Procedure -- Surface Replica Method:
   1. Select area where coverage is to be measured.
   2. Apply surface replica solvent.
   3. Apply surface replica film to area where solvent has been placed. The film is pressed to the area with thumb pressure for approximately one minute.
   4. Surface replica film is peeled carefully and quickly from surface.
   5. Film is mounted in holder.
   6. Film is then ready for use in suitable projector for viewing and comparison with photomicrographs such as those in Figure 9 showing various degrees of coverage.
   7. After use, the surface replica can be filed for reference.

GENERAL INFORMATION. This standard first published February, 1945; last revised February, 1966.
(Figure 9 on following page)
FIGURE 9 - PHOTOMICROGRAPHS OF FAXFILM IMPRESSIONS OF SPECIMENS SHOWING VARIOUS DEGREES OF COVERAGE MAGNIFICATION X-30