



Designation: B851 – 04 (Reapproved 2020)

# Standard Specification for Automated Controlled Shot Peening of Metallic Articles Prior to Nickel, Autocatalytic Nickel, or Chromium Plating, or as Final Finish<sup>1</sup>

This standard is issued under the fixed designation B851; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers the requirements for automated, controlled shot peening of metallic articles prior to electrolytic or autocatalytic deposition of nickel or chromium, or as a final finish, using shot made of cast steel, conditioned cut wire, or ceramic media. The process is applicable to those materials on which test work has shown it to be beneficial within given intensity ranges. It is not suitable for brittle materials. Hand peening and rotary flap peening are excluded specifically.

1.2 Shot peening induces residual compressive stresses in the surface and near-surface layers of metallic articles, controlling or limiting the reduction in fatigue properties that occurs from nickel or chromium plating of the article, or the fatigue properties of unplated articles.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

**B183** Practice for Preparation of Low-Carbon Steel for Electroplating

**B242** Guide for Preparation of High-Carbon Steel for Electroplating

**B320** Practice for Preparation of Iron Castings for Electroplating

**B322** Guide for Cleaning Metals Prior to Electroplating

**B607** Specification for Autocatalytic Nickel Boron Coatings for Engineering Use

**B650** Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Substrates

**B656** Guide for Autocatalytic (Electroless) Nickel-Phosphorus Deposition on Metals for Engineering Use (Discontinued 2000) (Withdrawn 2000)<sup>3</sup>

**B689** Specification for Electroplated Engineering Nickel Coatings

**B733** Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal

**E11** Specification for Woven Wire Test Sieve Cloth and Test Sieves

**E165** Practice for Liquid Penetrant Testing for General Industry

**E709** Guide for Magnetic Particle Testing

### 2.2 Federal Standards:<sup>4</sup>

**QQ-N-290** Nickel Plating (Electrodeposited)

**QQ-C-320** Chromium Plating (Electrodeposited)

### 2.3 Military Standards:<sup>4</sup>

**MIL-S-851** Steel Grit, Shot, and Cut Wire Shot, and Iron Grit and Shot Blast Cleaning and Peening

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.02 on Pre Treatment.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



MIL-S-13165 Shot Peening of Metal Parts  
MIL-C-26074 Coating, Electroless Nickel  
MIL-STD-45662 Calibration System Requirements

## 2.4 SAE Standards:<sup>5</sup>

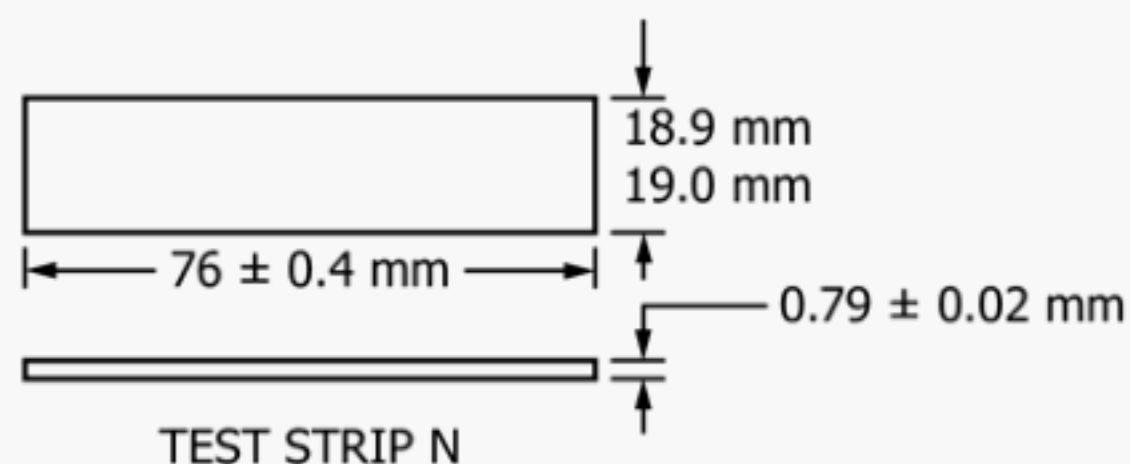
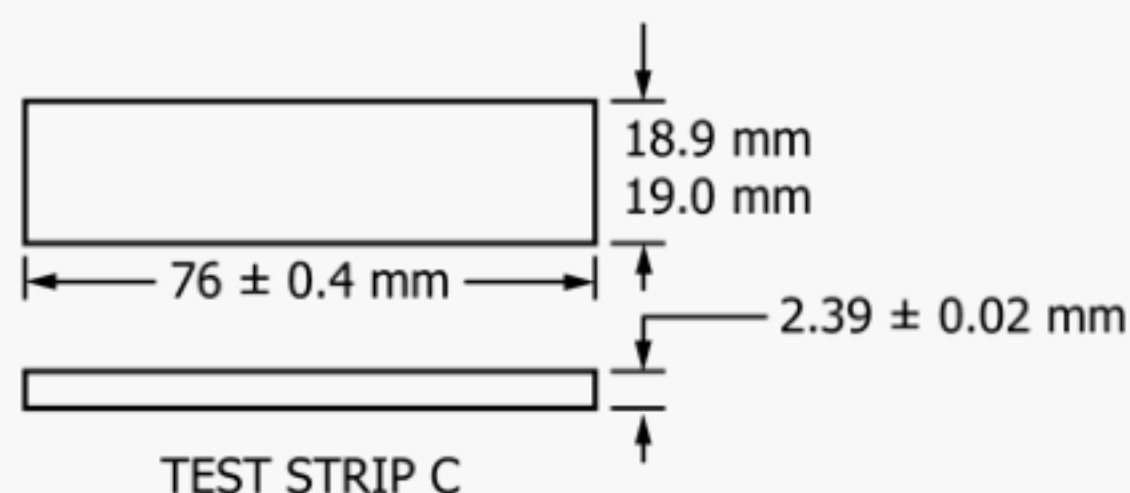
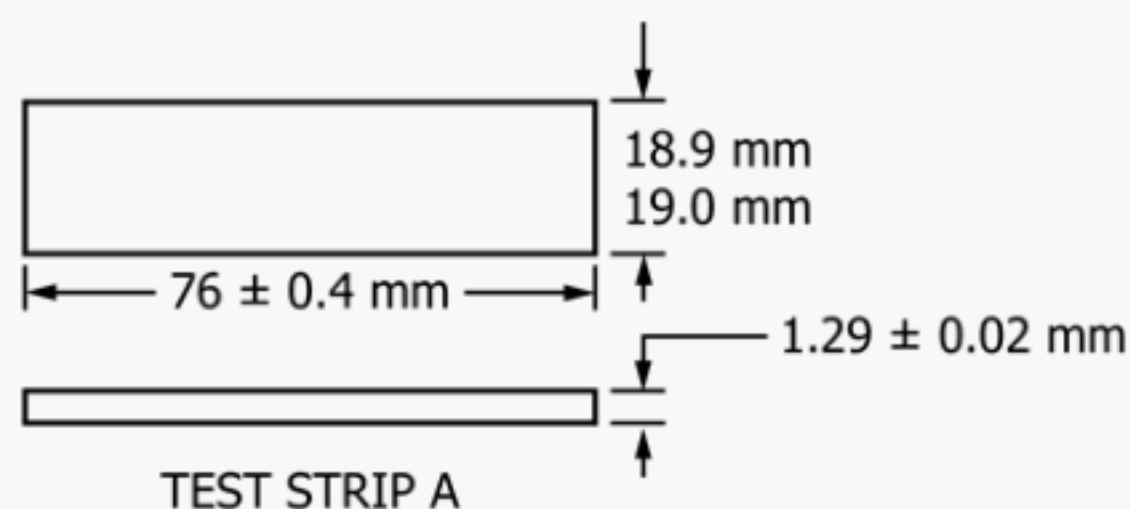
SAE J441 Cut Steel Wire Shot  
SAE J442 Test Strip, Holder and Gage for Shot Peening  
SEA J827 Cast Steel Shot  
SAE J1830 Size, Classification and Characteristics of Ceramic Shot for Peening

## 3. Terminology

### 3.1 Definitions:

3.1.1 *Almen strip*—UNS G10700 carbon steel specimens that are used to calibrate the energy of a shot peening stream (see Fig. 1).

<sup>5</sup> Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.



TEST STRIP SPECIFICATIONS

Analysis of stock - UNS G10700  
Cold rolled spring steel  
Square edge number one (on 76.2 mm edge)  
Finish - blue temper (or bright)  
Uniformly hardened tempered to 44 - 50 HRc  
Flatness C  $\pm 0.038$  mm arc height  
Flatness N and A  $\pm 0.025$  mm arc height

FIG. 1 Almen Test Specimen

3.1.2 *Almen strip holding fixture*—a fixture for holding Almen strips in suitable locations that represent the position and angular orientation of the surfaces of a part where intensity is to be determined and verified (see Fig. 2).

3.1.3 *arc height*—flat Almen strips, when subjected to a stream of shot moving at an adequate velocity, bending in an arc corresponding to the amount of energy transmitted by the shot stream. The height of the curved arc measured in millimeters is the arc height, measured by an Almen gage (see Fig. 3).

3.1.4 *automatic equipment*—shot peening equipment in which parts, fixtures, nozzles, and peening parameters are preset by hand or by locating fixtures and verified by inspection personnel. The peening time is monitored automatically, and the air pressure or wheel speed is set manually.

3.1.5 *compressive stresses*—cold working or stretching the surface beyond the elastic limit by shot peening, creating a layer in compression below the surface. The depth of compressive stresses is measured by the crown of the dimple to the depth.

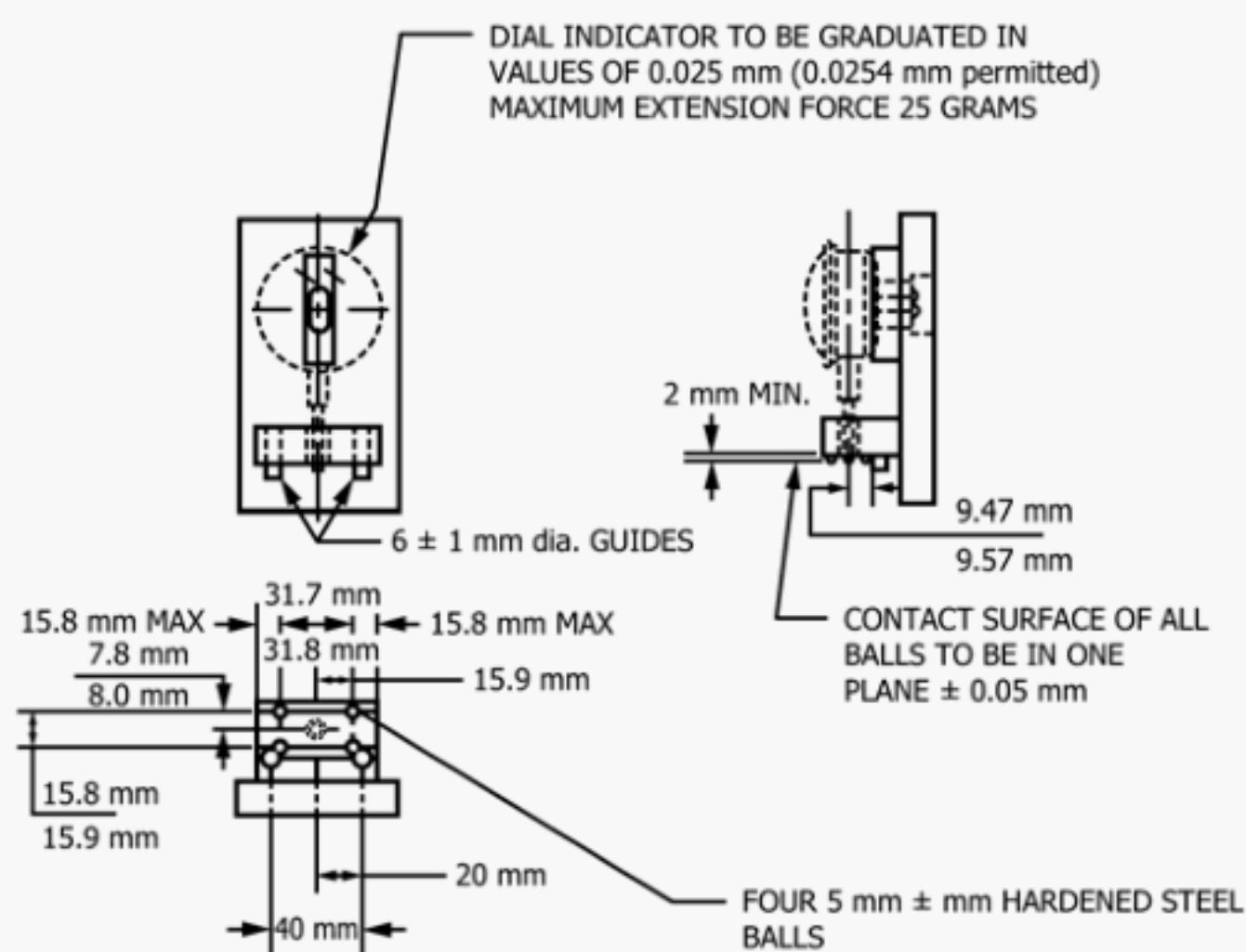
3.1.6 *coverage*—the extent of obliteration of the original surface by dimples produced by impact from individual shot particles and expressed as a percentage. See Note 1.

3.1.7 *depth of compressive stresses*—where the stress profile passes through 0 stress.

3.1.8 *intensity*—the Almen strip arc height at saturation. Arc height is not termed intensity correctly unless saturation is achieved.

3.1.9 *liquid tracer system*—a liquid coating material bearing a pigment that fluoresces under an ultraviolet light and removes at a rate proportioned to peening coverage.

3.1.10 *microprocessor-controlled equipment*—peening equipment that has nozzle holding fixtures and is computer controlled for processing, monitoring, and documentation of the peening parameters critical to process certification.





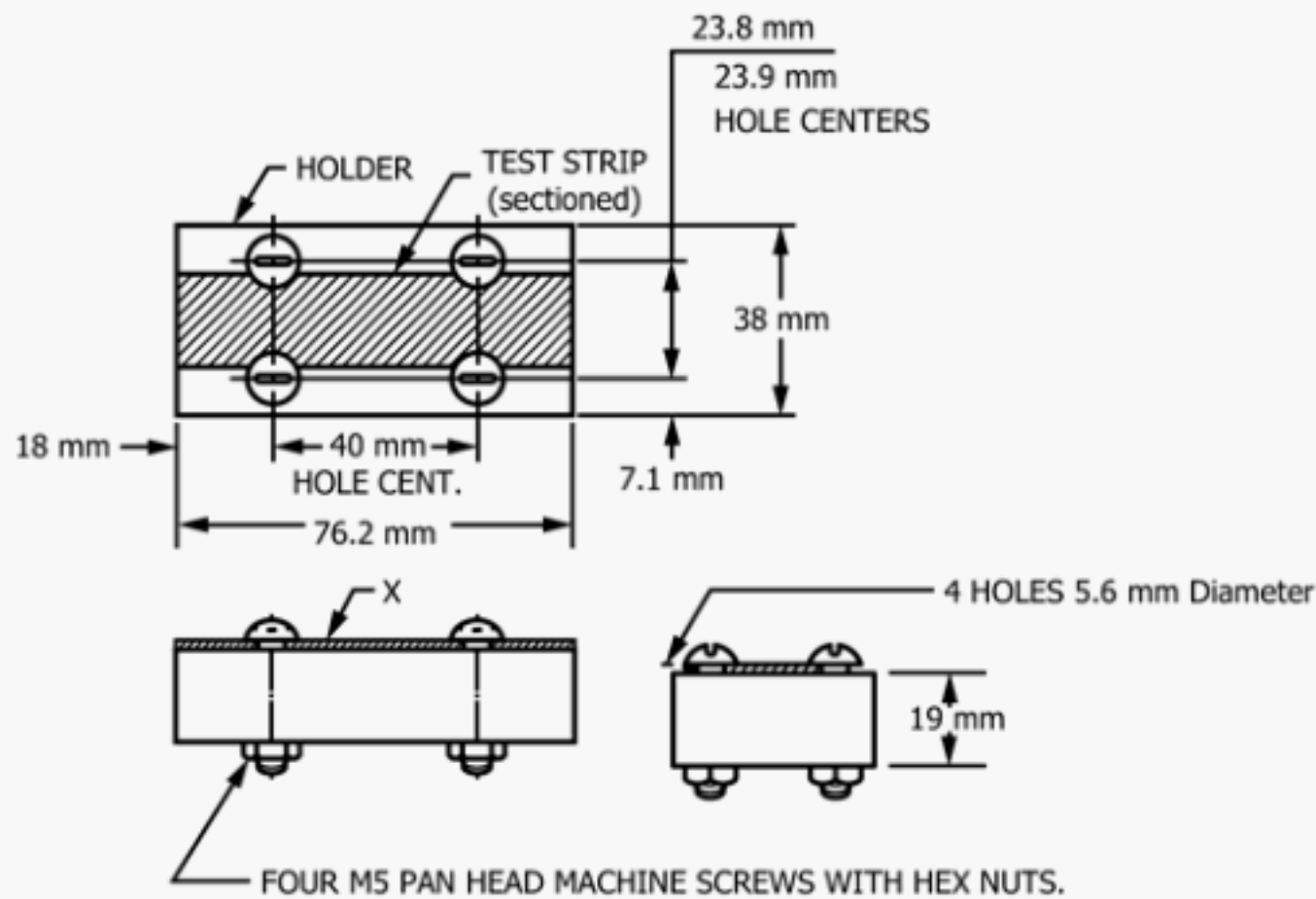


FIG. 3 Almen Gage

3.1.11 *nozzle holding fixture*—a fixture that holds the nozzles at the required location, distance, and angle in a locked position during the peening operation.

3.1.12 *process interrupt parameters*—for critical peening operations, parameters such as shot flow, air pressure, part r/min, oscillation rate, and cycle time that must be monitored within process requirements.

3.1.13 *saturation*—the minimum duration of peening necessary to achieve the desired Almen intensity which, when doubled, does not increase the Almen strip arc height by more than 10 %.

3.1.14 *saturation curve*—a curve that plots peening time on the Almen strip (abscissa) versus Almen strip arc height (ordinate) achieved for the peening time (see Fig. 4).

3.1.15 *surface obliteration*—the condition of a peened surface in which 100 % of the surface has been dimpled with shot impressions.

NOTE 1—A 100 % coverage is defined as that leaving unpeened 2 % or less of the original surface because the estimation of coverage of the impressions is difficult when this is approximately 98 % of the total surface. The 100 % coverage is a theoretical limiting value. Hence, the term complete coverage is preferred. Complete coverage usually requires increasing the base time, that is, the time of peening to reach 98 % coverage, by 15 to 20 %. Values of 200 %, 300 %, etc. are obtained by multiplying this run time by 2, 3, etc.

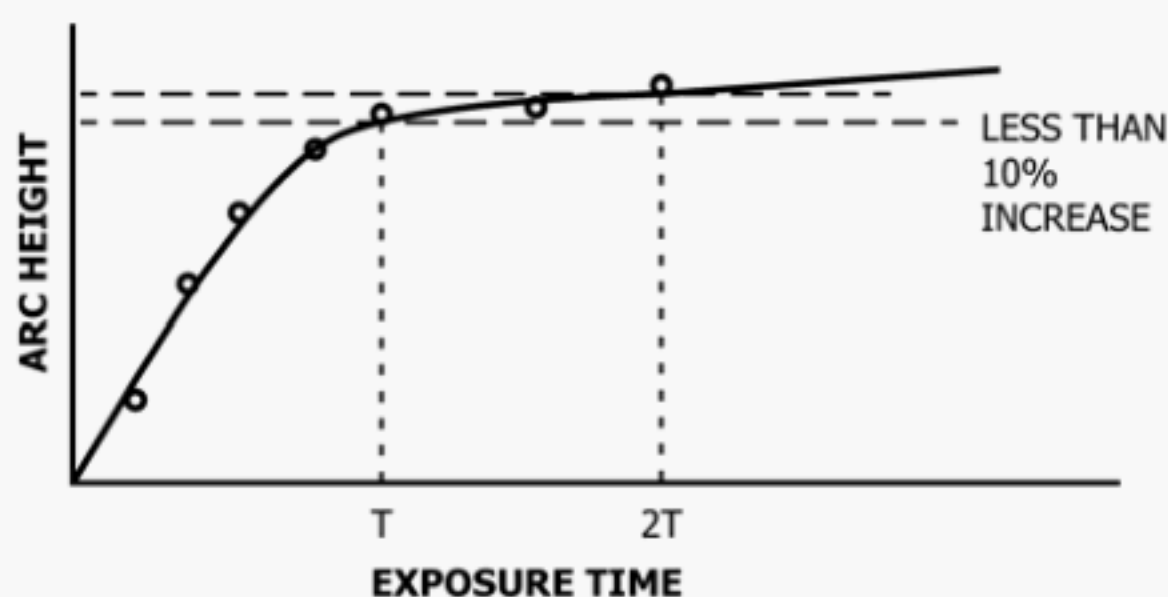


FIG. 4 Saturation Curve

## 4. Ordering Information

4.1 When ordering articles to be shot peened, the purchaser shall state the following:

4.2 ASTM designation.

4.3 Type, size, and hardness of shot to be used (see 6.1).

4.4 Number and frequency of the determinations of shot size and uniformity required, if other than those specified in 8.1.1.

4.5 Peening intensity to be used at each location (see 8.2).

4.6 Number, frequency, and locations of Almen test specimens to be provided for intensity verification and monitoring of the process if other than those specified in 8.2, 8.2.1, and 8.2.2.

4.7 Areas on the part that are to be shot peened and those to be protected from the peening (see 7.5).

4.8 Whether magnetic particle or penetrant inspection is required before peening (see 7.2).

4.9 Amount (percent) of coverage required in the areas to be peened. A complete coverage is the minimum requirement (see 3.1.6 and 8.3).

4.10 Method for measuring coverage (see 8.3.1).

4.11 Type of equipment to be used, automated or computer-monitored microprocessor (see 6.3 and X1.10 – X1.12).

4.12 Details of any post treatment such as corrosion protection (see 9.5).

4.13 Requirements of certification and test records, as specified in Section 10.

## 5. Significance and Use

5.1 Shot peening is a process for cold working surfaces by bombarding the product with shot of a solid and spherical nature propelled at a relatively high velocity. In general, shot peening will increase the fatigue life of a product that is subject to bending or torsional stress. It will improve resistance to stress corrosion cracking. It can be used to form parts or correct their shapes. See Appendix X1 for additional information.

5.2 It is essential that the shot peening process parameters be controlled rigidly to ensure repeatability from part to part and lot to lot.

5.3 This specification covers techniques and methods necessary for proper control of the shot peening process.

## 6. Materials and Equipment

6.1 *Shot Material Composition:*

6.1.1 *Cast Steel*—Cast steel shot shall conform to the requirements of SAE J827.

6.1.2 *Cut Wire*—Cut wire shot shall be made from cold finished, round wire, conforming to SAE J441.

6.1.3 *Ceramic Shot*—Ceramic beads shall conform to the chemical composition given in Table 1 and to SAE J1830.

6.1.4 *Shot Form and Shape:*

6.1.4.1 *Cast Steel*—Cast steel shot shall be spherical in shape and free of sharp edges, corners, and broken pieces. It



TABLE 1 Composition of Ceramic Shot

| ZrO <sub>2</sub> , % | SiO <sub>2</sub> , % | Al <sub>2</sub> O <sub>3</sub> , % | Fe <sub>2</sub> O <sub>3</sub> , % | Free Iron, % | Specific Gravity, g/cm <sup>3</sup> |
|----------------------|----------------------|------------------------------------|------------------------------------|--------------|-------------------------------------|
| 60.0–70.0            | 28.0–33.0            | 10.0 max                           | 0.1 max                            | 0.1 max      | 3.60–3.95                           |

shall conform to the acceptable shapes given in Fig. 5. The number of nonconforming shapes (see Fig. 6) shall not exceed the values given in Table 2.

6.1.4.2 *Cut Wire*—Cut wire shot shall be spherical in shape. It shall be free of sharp edges, corners, and broken pieces. The number of nonconforming shapes shall not exceed the values given in Table 2.

6.1.4.3 *Ceramic Shot*—Ceramic shot shall be spherical in shape and free of sharp edges, corners, and broken pieces. The number of nonconforming shapes shall not exceed the values given in Table 2.

6.1.5 *Hardness*—The hardness of the media shall exceed that of the material to be processed.

6.1.5.1 *Cast Steel*—Cast steel shot shall have a hardness of HR<sub>c</sub> 45 to HR<sub>c</sub> 55. Special hard cast steel shot shall be used on products harder than HR<sub>c</sub> 50 and shall have a hardness of HR<sub>c</sub> 55 to HR<sub>c</sub> 65.

6.1.5.2 *Cut Wire*—Cut wire shot shall have a hardness equal to or greater than that given in Table 3.

6.1.5.3 *Ceramic Shot*—Ceramic shot shall have a minimum hardness of 560 HV<sub>30</sub> (30 kgf).

6.1.6 *Size*:

(1) The size of the media shall be capable of producing the required intensity in the required time.

(2) If a peened surface contains a fillet, the nominal size of the shot shall not exceed one-half of the radius of the fillet.

(3) If the shot must pass through an opening, such as a slot, to reach a peened surface the nominal diameter of the shot shall not exceed one-fourth of the width or the diameter of the opening.

6.1.6.1 *Cast Steel*—Cast steel shot charged into a machine shall conform to the screen requirements given in Table 4 for the nominal size selected. When a machine has a completely new charge of cast steel shot, conditioning shall be conducted, to remove the oxide layers on the shots, by bombarding onto a hardened steel surface for a minimum of two passes. Conditioning may not be required if the addition to the charge already in the machine is below 25 %. If the addition of over 25 % is made to the charge, conditioning is required.

6.1.6.2 *Cut Wire*—The diameter of cut wire shot charged into a machine shall conform to the requirements given in Table 4. Cut wire shot shall conform to the requirements of length and cumulative weight given in Table 5. It is mandatory that only preconditioned cut wire shot be used.



Not necessarily spheres but all corners rounded.

FIG. 5 Acceptable Shapes

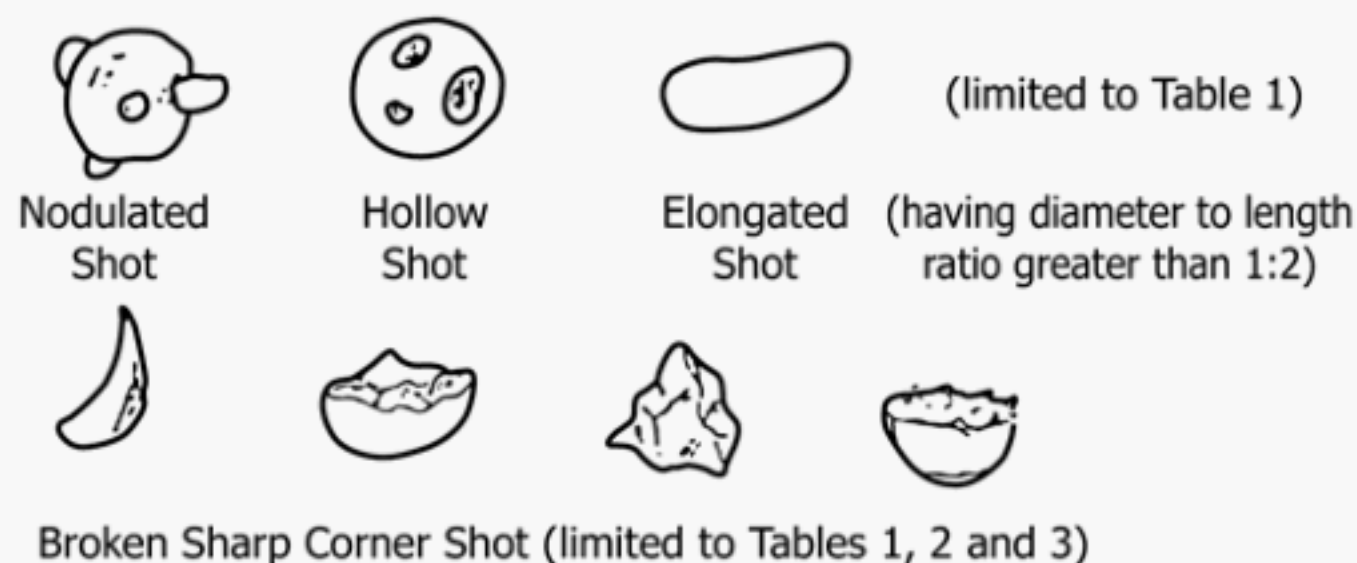


FIG. 6 Unacceptable Shapes

TABLE 2 Maximum Allowable Nonconforming Shapes—Cast Steel, Cut Wire, and Ceramic Shot (in accordance with Fig. 6)

| Cast Steel Size | Cut Wire Size | Ceramic Size | Maximum Allowable Nonconforming Shapes per area 1 cm × 1 cm |
|-----------------|---------------|--------------|---|
| 930             |               |              | 5   |
| 780             |               |              | 5   |
| 660             | CW62          |              | 12  |
| 550             | CW54          |              | 12  |
| 460             | CW47          |              | 15  |
| 390             | CW41          |              | 80  |
|                 | CW35          |              | 80  |
| 330             | CW32          | Z850         | 80  |
| 280             | CW28          |              | 80  |
| 230             | CW23          | Z600         | 80  |
| 190             | CW20          |              | 80  |
| 170             |               | Z425         | 80  |
| 130             |               |              | 480   |
| 110             |               | Z300         | 640   |
| 70              |               | Z210         | 640   |

TABLE 3 Hardness Cut Wire Shot

| Cut Steel Wire Shot (Shall Have the Following Minimum Hardness) |                              |
|---|------------------------------|
| Shot Size   | Minimum Hardness, Rockwell C |
| CW 62   | 36                           |
| CW 54   | 39                           |
| CW 47   | 41                           |
| CW 41   | 42                           |
| CW 35   | 44                           |
| CW 32   | 45                           |
| CW 28   | 46                           |
| CW 23 and finer   | 48                           |

6.1.6.3 *Ceramic Shot*—Ceramic shot charged into the peening machine shall conform to the screen requirements of Table 6.

6.2 *Almen Strips, Blocks, and Gages*—Almen strips, blocks, and gages used shall meet the requirements of SAE J442.

6.3 *Equipment*—Shot peening shall be conducted in a machine that is designed for the purpose, propels shot at high speed against the product, moves the product through the shot stream in a way that ensures complete and uniform peening, and screens the shot continuously to remove broken or defective shot.

## 7. Pre-Peening Treatment

7.1 *Prior Operations*—Areas of parts to be shot peened shall be within dimensional requirements before peening. Except as otherwise permitted, all heat treatment, machining,



TABLE 4 Screen Size Cast Steel Shot (in accordance with Fig. 6)

| Peening Shot | All Pass U.S. Screen Size (mm) | Maximum 2 % on U.S. Screen (mm) | Maximum 50 % on U.S. Screen (mm) | Cumulative Min 9 % on U.S. Screen (mm) | Maximum 8 % on U.S. Screen (mm) | Maximum Number of Deformed Shot Acceptable per area 1 cm × 1 cm |
|--------------|--------------------------------|---------------------------------|----------------------------------|--|---------------------------------|---|
| 930          | 5 (4.000)                      | 6 (3.350)                       | 7 (2.800)                        | 8 (2.360)                              | 10 (2.000)                      | 5   |
| 780          | 6 (3.350)                      | 7 (2.800)                       | 8 (2.360)                        | 10 (2.000)                             | 12 (1.700)                      | 5   |
| 660          | 7 (2.800)                      | 8 (2.360)                       | 10 (2.000)                       | 12 (1.700)                             | 14 (1.400)                      | 12  |
| 550          | 8 (2.360)                      | 10 (2.000)                      | 12 (1.700)                       | 14 (1.400)                             | 16 (1.180)                      | 12  |
| 460          | 10 (2.000)                     | 12 (1.700)                      | 14 (1.400)                       | 16 (1.180)                             | 18 (1.000)                      | 15  |
| 390          | 12 (1.700)                     | 14 (1.400)                      | 16 (1.180)                       | 18 (1.000)                             | 20 (0.850)                      | 20  |
| 330          | 14 (1.400)                     | 16 (1.180)                      | 18 (1.000)                       | 20 (0.850)                             | 25 (0.710)                      | 80  |
| 280          | 16 (1.180)                     | 18 (1.000)                      | 20 (0.850)                       | 25 (0.710)                             | 30 (0.600)                      | 80  |
| 230          | 18 (1.000)                     | 20 (0.850)                      | 25 (0.710)                       | 30 (0.600)                             | 35 (0.500)                      | 80  |
| 190          | 20 (0.850)                     | 25 (0.710)                      | 30 (0.600)                       | 35 (0.500)                             | 40 (0.425)                      | 80  |
| 170          | 25 (0.710)                     | 30 (0.600)                      | 35 (0.500)                       | 40 (0.425)                             | 45 (0.355)                      | 80  |
| 130          | 30 (0.600)                     | 35 (0.500)                      | 40 (0.425)                       | 45 (0.355)                             | 50 (0.300)                      | 480   |
| 110          | 35 (0.500)                     | 40 (0.425)                      | 45 (0.355)                       | 50 (0.300)                             | 80 (0.180)                      | 640   |
| 70           | 40 (0.425)                     | 45 (0.355)                      | 50 (0.300)                       | 80 (0.180)                             | 120 (0.125)                     | 640   |

Sieves shall be in accordance with Specification E11.

TABLE 5 Cut Wire Shot—Size Length and Weight

| Shot Number | Wire Diameter, mm | Length of Ten Pieces, mm <sup>A</sup> | Weight of Fifty Pieces <sup>B</sup> , g |
|-------------|-------------------|---------------------------------------|---|
| CW-62       | 1.587 ± 0.051     | 15.75 ± 1.02                          | 1.09 to 1.33                            |
| CW-54       | 1.372 ± 0.051     | 13.72 ± 1.02                          | 0.72 to 0.88                            |
| CW-47       | 1.194 ± 0.051     | 11.94 ± 1.02                          | 0.48 to 0.58                            |
| CW-41       | 1.041 ± 0.051     | 10.41 ± 1.02                          | 0.31 to 0.39                            |
| CW-35       | 0.889 ± 0.025     | 8.89 ± 1.02                           | 0.20 to 0.24                            |
| CW-32       | 0.813 ± 0.025     | 8.13 ± 1.02                           | 0.14 to 0.18                            |
| CW-28       | 0.711 ± 0.025     | 7.11 ± 1.02                           | 0.10 to 0.12                            |
| CW-23       | 0.584 ± 0.025     | 5.84 ± 1.02                           | 0.05 to 0.07                            |
| CW-20       | 0.508 ± 0.025     | 5.08 ± 1.02                           | 0.04 to 0.05                            |

<sup>A</sup> Shot particles to be checked for length shall be mounted and ground and polished to expose a central longitudinal section. The combined length of ten randomly selected particles shall be within the tolerance shown above.

<sup>B</sup> At the option of the contractor, the particles may be weighed instead of mounted and measured as stated in the above note. When weighed, the total weight of 50 randomly selected particles shall be within the limits specified above.

and grinding shall be completed before shot peening. All filets shall be formed, all burrs removed, and all sharp edges and corners that require peening provided with sufficient radii prior to peening, in order to result in complete coverage without any distortion, chipping, or rollover.

**7.2 Flaw and Crack Testing**—When required, magnetic particle, penetrant, ultrasonic, or other flaw or crack detection processes shall be completed prior to peening. See Test Method E165 and Guide E709.

**7.3 Corrosion and Damage**—Parts shall not be peened if they show evidence of invasive corrosion or mechanical damage on the surface.

**7.4 Cleaning**—Cleaning prior to peening shall be accomplished by vapor degreasing, solvent wiping, warm solvent spray, or an acceptable water-base nonflammable product, as required, to remove all soils, scale, and coatings from the surface areas to be peened. See Practices B183, B242, B320, and B322.

**7.5 Masking**—Surfaces designated on the drawing to be free of shot peening marks shall be masked or otherwise protected from the shot stream or indirect impingement by shot.

**7.5.1** Suitable masking materials are adhesive tape, sheet rubber, etc. If adhesive tape is used, it shall be coated on one

face with adhesive, and when the tape is removed from the surface it shall not show any evidence of corrosion or leave any residue on the surface. Areas not requiring peening and not required to be masked shall be considered optional.

## 8. Procedure

**8.1 Shot**—Shot charged into the peening machine shall be as specified by the purchaser and meet the requirements of 6.1 for the particular type, size, and material required. Unless otherwise specified, all shot shall be maintained in the machine so that it conforms to the requirements of Table 7.

**8.1.1 Uniformity Determination**—At least one determination for shot size and uniformity in accordance with Table 7 shall be made before and after each production run and after each 8 h of production on long runs, when using cast or cut wire steel shot. Ceramic shot size distribution shall be verified at least every 4 h of production and before and after each production run.

**8.2 Peening Intensity**—The peening intensity should be that specified by the purchaser as the arc height produced by the peening process at saturation, as measured on Almen strips placed in the required locations. Unless otherwise specified on the drawing or in the contract, the intensity of peening shall be as specified in Table 8 for the thickness involved.

**8.2.1 Saturation Curve**—For initial process development, a saturation curve shall be generated for each location where intensity is to be verified.

**8.2.2 Intensity Determination**—At least one intensity determination for all required locations shall be made immediately before and after each production run and at least every 8 h of continuous running. The intensity determination is also required after any replacement of shots, a new setting, or any other change of setting of the machine, as well as after any event that may affect the shot peening operation.

**8.3 Peening Coverage**—Peened surfaces shall be uniform in appearance and completely dented so that the original surface is obliterated entirely. The extent (in percent) of coverage shall be specified by the purchaser. Complete coverage is full and complete obliteration of the original surface.



**TABLE 6 Fused Ceramic Beads for Peening—Sizes (mm) (in accordance with Fig. 6).<sup>A</sup>**

| Designation  |           | Nominal Size, mm |       | Sieve Number and Screen Opening Size, mm |                |                |                | Min % Beads with Sphericity ≥0.8 (% of True Spheres) | Max No. of Beads with Sphericity <0.5 Acceptable per Area | Max No. of Broken or Angular Beads Acceptable per Area |
|--------------|-----------|------------------|-------|--|----------------|----------------|----------------|--|---|--|
| Ceramic Size | Shot Size | Min              | Max   | Max 0.5% Retains                         | Max 5% Retains | Max 10% Pass   | Max 3% Pass    |  |   |  |
| 1 cm × 1 cm  |           |                  |       |  |                |                |                |  |   |  |
| Z 850        | 330       | 0.850            | 1.18  | 14<br>(1.400)                            | 16<br>(1.100)  | 20<br>(0.850)  | 25<br>(0.710)  | 65   | 4   | 2  |
| Z 600        | 230       | 0.600            | 0.850 | 18<br>(1.000)                            | 20<br>(0.850)  | 30<br>(0.600)  | 40<br>(0.425   | 65   | 8   | 4  |
| Z 425        | 170       | 0.425            | 0.600 | 25<br>(0.710)                            | 30<br>(0.600)  | 40<br>(0.425)  | 50<br>(0.300)  | 70   | 14  | 8  |
| Z 300        | 110       | 0.300            | 0.425 | 35<br>(0.500)                            | 40<br>(0.425)  | 50<br>(0.300)  | 60<br>(0.250)  | 70   | 27  | 15   |
| Z 210        | 70        | 0.212            | 0.300 | 45<br>(0.335)                            | 50<br>(0.300)  | 70<br>(0.212)  | 80<br>(0.180)  | 80   | 45  | 20   |
| Z 150        | GP60      | 0.150            | 0.212 | 60<br>(0.250)                            | 70<br>(0.212)  | 100<br>(0.150) | 120<br>(0.125) | 80   | 300   | 65   |

<sup>A</sup> The designated number for ceramic is the minimum bead diameter (in mm)  $\times$  1000 (conversion of mm into in.; divide mm/25.4 = U.S. in.).

**TABLE 7 Shot Maintenance Size and Form Maximum Allowable Nonconforming (in accordance with Fig. 6)**

| Size | Maximum 2 % On Screen (mm) | Minimum 80 % On Screen (mm) | Maximum Allowable Nonconforming Shapes, per area 1 cm $\times$ 1 cm |
|------|----------------------------|-----------------------------|---|
| 930  | °6 (3.353)                 | °8 (2.380)                  | 5   |
| 780  | °7 (2.819)                 | 10 (1.999)                  | 5   |
| 660  | 8 (2.380)                  | 12 (1.679)                  | 12  |
| 550  | 10 (1.999)                 | 14 (1.410)                  | 12  |
| 460  | 12 (1.679)                 | 16 (1.191)                  | 15  |
| 390  | 14 (1.410)                 | 18 (1.000)                  | 80  |
| 330  | 16 (1.191)                 | 20 (0.841)                  | 80  |
| 280  | 18 (1.000)                 | 25 (0.711)                  | 80  |
| 230  | 20 (0.841)                 | 30 (0.589)                  | 80  |
| 190  | 25 (0.711)                 | 35 (0.500)                  | 80  |
| 170  | 30 (0.589)                 | 40 (0.419)                  | 80  |
| 130  | 35 (0.500)                 | 45 (0.351)                  | 480   |
| 110  | 40 (0.419)                 | 50 (0.297)                  | 640   |
| 70   | 45 (0.351)                 | 80 (0.178)                  | 640   |

**TABLE 8 Intensity Versus Thickness and Ultimate Tensile Strength**

| Material <sup>A</sup>    | Steel under 1380 MPa         | Steel over 1380 MPa and Titanium | Aluminum Alloys (Stainless Steel Shot) |
|--------------------------|------------------------------|----------------------------------|--|
| Under 2.5-mm thickness   | ...                          | ...                              | ...                                    |
| 2.5 to 10.0-mm thickness | 0.2 to 0.3 mm A <sup>B</sup> | 0.15 to 0.25 mm A                | 0.15 to 0.25 mm A                      |
| Over 10.0-mm thickness   | 0.3 to 0.4 mm A <sup>C</sup> | 0.15 to 0.25 mm A                | 0.25 to 0.35 mm A                      |

<sup>A</sup> Magnesium alloy's response to shot peening is different from that of other materials. It is essential to avoid broken or deformed peening material. Peening must be conducted with materials and under conditions that do not induce cracks.

<sup>B</sup> The suffix letter A indicates that the values have been determined by the use of Test Strip A.

<sup>C</sup> Test Strip A is used for arc heights up to 0.6 mm A. Test Strip C should be used for greater peening intensity. Test Strip N is used if the intensity is below 0.1 mm A.

**8.3.1 Coverage Determination**—Unless otherwise specified, at least one coverage determination for all areas requiring peening shall be made immediately before and after each production run and at least every 8 h of continuous running.

Coverage shall be determined by either of the following methods, as specified by the purchaser:

8.3.1.1 Visual examination using a ten-power magnifying glass. This procedure is not recommended for large areas.

8.3.1.2 Visual examination using an approved impact-sensitive liquid fluorescent tracer system in accordance with the manufacturer's recommendations.

**8.4 Computer-Monitored Equipment**—When auxiliary computer-monitored equipment is used for shot peening, calibration of the monitored systems shall be in accordance with MIL-STD-45662. Intensity verification in accordance with 8.2 shall be conducted prior to initial operation and after calibration.

## 9. Post-Peening Treatment

**9.1 Residual Shot Removal**—After shot peening and the removal of protecting masks, all shot and shot fragments shall be removed from the surfaces of articles by methods that will not erode, scratch, or degrade the surfaces in any way.

**9.2 Surface Finish Improvement**—It is permissible to improve the surface finish of a component after shot peening by polishing, lapping, or honing, provided that the surface temperature is not raised sufficiently to relax the compressive stresses and the amount of material removed is less than 10 % of the depth of the compressive layer induced by peening.

**9.3 Nonferrous Materials**—Nonferrous metals and their alloys that have been shot peened shall be cleaned by an approved chemical cleaning solution to remove all iron contaminants. Cleaning operations shall not degrade the surface or alter the dimensions of the part. Cleaned surfaces shall be chemically tested for freedom from residual iron by the method given in Appendix X2.

**9.4 Thermal and Mechanical Treatment Limits**—No manufacturing operations that relieve compressive stresses or develop detrimental residual stresses shall be permitted after shot peening. When parts are heated after shot peening, as for baking of paint or protective coatings, embrittlement relief



after electroplating, or other thermal treatment, the temperatures used shall be limited as shown in **Table 9**.

**9.5 Protection From Corrosion**—Shot peened parts shall be protected from corrosion during processing and until final preservation and packaging are complete. All shot peened parts shall be preserved, wrapped, or packaged, as specified by the purchaser, to ensure protection from corrosion and damage during handling, transportation, and storage.

## 10. Certification and Test Records

10.1 When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that samples representing each lot have

**TABLE 9 Thermal Treatment Limits**

| Material                        | Maximum Temperature, °C |
|---------------------------------|-------------------------|
| Steel parts                     | 230                     |
| Aluminum alloy parts            | 93                      |
| Magnesium alloy parts           | 93                      |
| Titanium alloy parts            | 315                     |
| Nickel alloy parts              | 538                     |
| Corrosion resisting steel parts | 315                     |

been manufactured, tested, and inspected in accordance with this specification, and that the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. When specified in the purchase order or contract, test strip specimens and test records shall accompany peened parts and shall be inspected along with the appropriate lot. The following information shall be recorded for each specimen:

10.1.1 Lot number and other production control numbers.

10.1.2 Part number.

10.1.3 Number of parts in lot.

10.1.4 Date peened.

10.1.5 Shot peening machine used and machine setting.

10.1.6 Specified peening intensity and actual peening intensity by test strip identification numbers if the test fixture requires the use of more than one strip.

10.1.7 Shot size, type, hardness, standoff (distance), length of time of exposure to shot stream, and shot flow rate.

10.1.8 Percent coverage.

10.1.9 Shot velocity or air pressure.

## 11. Keywords

11.1 peening; shot; shot peening

## APPENDIXES

### (Nonmandatory Information)

#### X1. General Information

**X1.1 ASTM, Federal, and Military Specifications**—Electrodeposits of nickel or chromium and autocatalytic nickel deposits applied in accordance with Specifications **B607**, **B650**, **B689**, and **B733**, Guide **B656**, and QQ-N-290, QQ-C-320, and MIL-C-26074 to steel products can cause significant reductions in the fatigue strength of the product subjected to cyclical stress loading. Shot peening the steel prior to electroplating helps to control or limit the reduction of fatigue strength that can occur.

**X1.2 Reduction of Crack Propagation**—Shot peening induces compressive stresses in the surface of the product. Compressive stresses offset high tensile stresses that may be present in electrodeposited metal coatings, thereby impeding the propagation of cracks that cause fatigue failures under cyclical loads.

**X1.3 Fatigue Life Improvement**—Reductions in fatigue strength are also affected by the hardness and strength of the steel and by the thickness and internal tensile stress of the electrodeposit. Fatigue life may be enhanced by increasing the hardness and strength of the steel and by maintaining the deposit thickness at the minimum value consistent with design requirements. Eliminating or lowering the internal tensile stress of the electrodeposited coating is beneficial. The use of compressively stressed electrodeposited coatings may prevent a significant reduction in fatigue strength.

**X1.4 Maintenance of Fatigue Strength**—Shot peening, combined with proper selection of the steel and control of thickness and internal tensile stress of the electrodeposit, can be used to minimize or prevent the reduction of fatigue strength in plated steel.

**X1.5 Intensity Reduction Indicator**—The Almen strip will quickly indicate a reduction in intensity (lower arc height) caused by a reduction in wheel speed or drop in air pressure, by excessive breakdown of shot or other operational faults, such as non-removal of undersize shot.

**X1.6 Efficiency and Cost**—The smallest shot size capable of producing the desired effect is the most efficient and least costly. An intensity may be considered excessive if, as with very thin parts, it produces a condition in which the tensile stresses of the core material outweigh the beneficial compressive stresses induced at the surface. **Table 8** provides a recommended peening intensity relative to cross-sectional thickness and strength of the steel.

**X1.7 Test Strip Code**—The suffix letter (A, C, or N) indicates that the intensity values have been determined by the use of a test strip of that value. Test Strip A is used for arc heights between 4 (0.1 mm)A and 24 (0.6 mm)A. If greater peening intensity than 24(0.6 mm)A is desired, Test Strip C should be used. Test Strip N is used if the intensity is below 4(0.1 mm)A.



**X1.8 Masking Alternatives**—When it is impractical to mask or otherwise protect areas designated to be free of shot peening marks, sufficient stock may be provided in these areas for the subsequent removal of affected material for compliance with dimensional requirements of the contract, provided that the temperature of **Table 9** is not exceeded. If the beneficial effects of the compressive layer are required, do not remove more than 10 % of the total depth of the compressive layer.

**X1.9 Saturation Curve**—A saturation curve is produced by exposing individual test strips for increasing time periods and plotting the results (exposure time versus arc height). A minimum of four points other than zero shall be used to define the curve; one of the four points used to indicate saturation shall be at least double the time of the saturation point. Saturation is achieved when, as the exposure time for the test strips is doubled, the arc height (does not increase by more than 10 % (see **Fig. 4**). The arc height at saturation for each location must be within the required arc height range for that location. The reuse of test strips is not permitted. The test strip specimens as shown in **Fig. 1** shall be attached as shown in **Fig. 2**, to holders of the form and dimensions also shown in **Fig. 2**, and mounted on a fixture or article and exposed to the shot stream in a manner that simulates conditions used for the articles. The test strips shall be run for the saturation time established by the saturation curve. After exposure, the test strips shall be removed from the holders and the amount of deflection measured with a micrometer gage, of the form and dimensions shown in **Fig. 3**. The arc height or amount of deflection measured on the test strips shall be within the specified intensity range. If the arc height measured is not within the intensity range specified, the process parameters must be adjusted, and new saturation curves must be run. In using the micrometer gage, the central portion of the unpeened side of the test strip shall be placed against the indicator stem of the gage. A peened test strip shall not be repeened after being removed from the test strip holder.

**X1.10 Automatic Equipment**—Automatic shot peening may be accomplished with equipment that propels shot by air pressure or centrifugal force against the product and moves the work through the shot stream in translation, rotation, or both. The equipment shall be capable of consistent reproduction of the shot peening intensities required. The equipment shall

include a separator that removes broken or defective shot continuously during peening. The equipment shall be capable of controlling the peening cycle automatically.

**X1.11 Computer-Monitored Equipment**—Machines equipped with a mechanical means with programmable speed selection for turning the part on its geometric center-line as closely as possible. The machine shall be equipped with mechanical means with programmable speed selection for translating the nozzle across the surface part (either horizontally or vertically). When run without nozzle translation, the machine shall be capable of programmable shutdown of each nozzle at any time during the peening cycle. The equipment shall have the capability to set and verify the rate of shot flow of each individual nozzle. The equipment shall be computer controlled for processing, monitoring, and documentation of the critical process interrupt parameters, which are air pressure of each nozzle, shot flow of each nozzle, wheel speed of each wheel, shot flow of each wheel, part rotation rate, nozzle reciprocation rate and amount, run time for each part, and total cycle time. This type of equipment is capable of programming maximum and minimum limits for each process interrupt parameter. Every second or less, all process interrupt parameters are scanned and evaluated against the pre-programmed maximum and minimum limits. If any deviation from the pre-programmed limits is found, the machine shall be shut down and the malfunction shall be indicated. The problem shall be corrected before the machine process cycle is resumed. The process is then restarted and completed from the exact point of shutdown. The machine shall be capable of storing in memory the data evaluated for each process interrupt parameter and providing that data in hard copy form, if required. The machine shall be able to document the details of any process interruptions in memory or hard copy form. The machine shall be capable of continuous separation of shot, both by size and shape, so that the shot being used conforms to the requirements of **Table 7**.

**X1.12 Manual or Hand Peening and Rotary Flap Peening**—Manual or hand peening and rotary flap peening shall not be permitted, except with the express written permission of the purchaser, since these processes are not as controllable and the results are less predictable than those obtained by automated shot peening.



## **X2. FREEDOM FROM IRON CONTAMINATION TEST**

X2.1 The purpose of this test is to detect contamination by iron residues on the surfaces of aluminum and its alloys, corrosion and heat resisting alloys, etc.

### **X2.2 Materials:**

X2.2.1 Degreasing agent.

X2.2.2 Five percent by volume aqueous solution of hydrochloric acid.

X2.2.3 Ten percent by weight aqueous solution of potassium ferrocyanide.

X2.2.4 Filter paper.

X2.3 *Procedure*—Degrease the area to be tested by wiping with an appropriate solvent such as isopropyl alcohol. Place a drop of the hydrochloric acid solution on the degreased surface and leave for approximately 2 min. Wet a filter paper with a drop of the potassium ferrocyanide solution and place it on the area of the part wetted with the hydrochloric acid solution. Rinse the area with water.

X2.4 *Result*—A deep blue color on the filter paper indicates the presence of iron. On some alloys, a pale blue color may be observed in the absence of iron residues. For comparison purposes, it is advisable to prepare a sample that is known to be free of iron contamination.

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