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1 Scope

This specification applies to the processing of stainless steel components, intended for downhole service. The treatment creates a layer of compressive stress which prevents stress corrosion cracking, (SCC) as long as service stresses do not overcome the applied compression, and as long as wear and corrosion do not remove the compressed material. This specification should not be used when surface peening is used for surface conditioning (e.g. anti-galling) where there is no requirement for a compressive layer.
This specification cannot be used as the sole definition of shot peening requirements: it is always necessary to define the areas and intensity of application by a control drawing.

2 Responsibilities

2.1 Designer Responsibilities

When this document is referenced on a drawing, it is the Designer's responsibility to identify the areas to be shot peened, and to designate the required intensity with zone letters. It is also the designer's responsibility to designate any masking requirements for shot peening. A guideline for the control drawing is provided in the Appendix

2.2 Contract Manufacturer responsibilities

The contract manufacturer, typically a machine shop, is responsible for the following:

- Selecting a shot-peening supplier capable of meeting the requirements of this specification. Suppliers listed on document 100832944 shall be used unless they are more than a one day travel distance.
- Submitting all drawings and specifications needed for correct execution
- Verifying compliance, including intensity, coverage and decontamination, using the Almen specimens, the Certificate of Compliance, and spot testing for residual contamination.
- Final inspection, including surface finish and dimensions which may have been affected by peening
- Retaining Almen specimens and Certificates for at least 4 years.

2.3 Shot-Peening Supplier Responsibilities

The supplier is responsible for the following:

- Creating and documenting a process procedure for the part
- Selecting peening media compliant to the specification
- Adjusting the peening equipment to the required Almen intensity.
- Masking any areas to be protected
- Peening the specified area with 200% coverage unless otherwise specified
- Decontaminating any areas peened with steel shot
- Cleaning residual shot from the workpiece
- Retaining a process record for each lot of parts to include, for each peeening operation:
    - Station or machine identification
    - Operator identification
    - Air pressure, nozzle and shot type and size
    - Rate of shot feed and speed of nozzle travel (if these are adjustable)
    - Rate of part rotation
- Providing Almen Specimens and a Certificate of Conformity to the customer, either the Contract Manufacturer or Schlumberger

3 Applications

3.1 Materials of Application

The materials which benefit most from compressive treatment are stainless steels, which are extremely vulnerable to SCC in chloride solutions. This treatment is only moderately effective against sulphide stress cracking (SSC). Compressive treatment also increases fatigue endurance.

The most common applications are:

- Austenitic stainless steels such as 304, 316, 310, Nitronic 50
- Precipitation Hardened Stainless steels such as 17-4PH, 15-5PH, 13-8 Mo
- Non-magnetic Drill collar steels such as P530, P550, NMS100, DNM140.

This list is not intended to be exhaustive.

3.2 Areas to be Treated

Compressive treatment is required on surfaces which are:

- Exposed to well fluids

AND

- Subject to the possibility of tensile stresses from forming , machining or service stresses.

Some examples include:

- The inside surface of a drill collar: the forging process of large diameter bars creates tensile residual stresses on the inside.
- A flow passage through an MWD chassis: the mud pressure creates large tensile service stresses.
- A cavity created by Electrical Discharge Machining (EDM). This process generates large tensile stresses at the base of each discharge crater.
- A welded area exposed to mud. Welding creates large residual stresses, especially in the heat-affected zone.
- An application that does not normally require compressive treatment is a pressure housing. The large compressive service stresses overcome any residual stresses from the tube drawing operations.

Note that inside areas less than 1 inch diameter (or minimum dimension) are impractical to shot peen. If such features cannot be protected from well fluids, roller burnishing or a material change may be required.

Commonly used shot peening requirements are listed below. See the Appendix for their applications. The surface roughness is listed for information, except for codes A1 and A2 where the roughness supersedes the roughness in the title block, For code A2 hammer peening can be used as the surface finish operation. For codes B, C, and D the requirements are those of the drawing

Code	Intensity Required	Typical shot type	Decontamination required?	Best Roughness after shot peen (µin Ra)
A1 (external)	10-16 Almen C	Steel S-330 to S-780 Stainless cut wire	Yes No	250
A2 (internal)	10-14 Almen C	Steel S-330 to S-780 Stainless cut wire	Yes No	250
B	14-20 Almen A	Steel S-110 to S-330 Stainless cut wire 62	Yes No	125
C	10-14 Almen A	Ceramic .033 in Steel S-70 to S-130 Glass .033 in	No Yes No	63-90
D	3-7 Almen A	Ceramic or glass .005 to .033in.	No	45

4 Methods

4.1 Shot Peening

Shot peening is the most flexible process available for compressive treatment. It is done by projecting small pellets (shot) , usually spheres, in an air stream at the surface to be treated. The pellets may be steel, ceramic or glass. The degree of compressive treatment is controlled by the air speed, the size and density of the shot, and the strength of the shot. Steel is used for high intensity, ceramic or glass for lower intensity.

4.1.1 Shot

The use of carbon steel shot will leave a residue on the surface of stainless steel parts which is magnetic and may lead to accelerated corrosion. This must be removed by "decontamination peening" with glass shot. If stainless steel shot is used, this step is not required. The choice of shot type is optional to the service provider, as long as Almen intensity and degradation of surface finish are respected.

4.1.2 Zones of Application

The area of shot peening application should be defined on a control drawing. Dimensions should be from the end of the part since the usual dimensional control is tape measure. Masks must be designed for areas to be protected from heavy shot peening, such as seal surfaces and threads. On outside surfaces it is recommended to "fade out" the shot peening over several inches to avoid inducing tensile stresses at the edge of the peened area. This is less practical on inside surfaces because of rebounding shot. A similar effect can be achieved by overlapping areas of decreasing intensity. Fade out over at least one inch is required unless prohibited by the drawing.

4.1.3 Process Control

Since measurements of the results of shot peening are limited, it is important that the process be well controlled. The key variables are:

- Shot size and shape
  - This is controlled by inspection of incoming shot, and by screening of any recycled shot, to standards equivalent to MIL-S-13165 or AMS 2430
- Shot velocity
  - This is controlled by air pressure, nozzle design and the shot itself, none of which must be changed after the Almen specimen is peened
- Coverage
  - This is controlled by the rate at which shot is fed into the air stream, and by the scan rate of the peening operation, which must be fully controlled.
- The peening nozzle

Control of coverage on long inside surfaces can only be assured by process controls, of the key process variables:

- The rate of shot feed into the air stream;
  - This would be measured in pounds per minute and is usually a fixed setting for a given shot size
- The speed of movement of the nozzle through the part
  - This would be expressed in inches per minute, and set by a drive wheel
- The speed of rotation of the workpiece. This shall be sufficient to assure overlap of the spray pattern on successive rotations
  - This is typically expressed in RPM, and controlled by a powered roller

If any of these variables is adjustable, the value shall be defined in the peening procedure.

4.2 Burnishing: Roller or Ball

Burnishing is the deformation of the material surface by rolling a hard roller or ball across the surface, indenting it. This can be very well controlled, but it is normally applicable only to cylindrical surfaces and threads. Burnishing may be substituted fror shot peening unless otherwise specified on the drawing.

Requirements for burnishing are detailed in specification 100832943

5 Inspection and Verification

5.1 Shot Peening

5.1.1 Intensity

The intensity of shot peening is measured using Almen test specimens, as described in Mil-S-13165 or AMS2430 . This specimen is a steel strip (AISI 1070, hardened to 44-50 HRC). As it is peened, it bends to a saturation value. The depth of arc over a span of 1.25 inches is measured, and this depth, in thousandths of an inch is the Almen Intensity. The most commonly used scale, Almen A uses a strip .051" thick. For commonly used materials with yield strength around 100ksi, the depth of the compressive layer (in thousandths of an inch) is approximately the same as the Almen A intensity. The Almen C intensity gives a compressive layer roughly three times thicker. An Almen specimen is required for each shot peen area definition.

For inside surfaces, the almen specimen should be mounted on a tubular fixture of approximately the same inside diameter, facing inwards.

Almen specimens shall be delivered to Schlumberger or the contract manufacturer, for verification of their curvature, and to serve as a reference for visual inspection of the peeened part. The peening customer, either Schlumberger or the contract manufacturer should verify the the curvature and visual appearance of the Almen specimens.

Almen specimens are available in two stainless steels: 17-4PH, and non-magnetic drill collar material

Part 100832945, Part 100832946 for 17-4PH

Part 100832947, Part 100832948 for Non-Mag material

They may be used in place of the standard strips with the same arc-height numbers for similar materials being peened

5.1.2 Coverage

Optimum protection requires that the peening craters overlap, and this is considered 200% coverage. It may be verified on external surfaces, and shallow bores, by coating the surface to be peened with a fluorescent or colored dye, and verifying that the dye is completely removed by the peening operation. This is known by the proprietary name of the "Peenscan" process. This is of limited value on surfaces that require decontamination, and is not practical on deep bores.

Coverage is therefore assessed primarily by visual inspection, comparing the appearance of the peened surface with a reference, either the Almen specimen or a test piece of the same material being peened, witnessed by the customer. A test piece may be required if the subject material is unusually hard or has different reflective properties from alloy steel. In order to minimize doubt about the intensity, the test piece should follow the design of paragraph 5.2

On long bores, 100% visual inspection with a borescope is required.

5.2 Decontamination

When carbon steel shot has been used, it leaves a residue implanted in the surface, which must be removed by a decontamination process. The inside ands outside surfaces of at least one piece from every peening lot shall be tested for residual contamination by the following procedure.

5.2.1 Contamination Test Procedure

- Mix the test solution: water plus 2% by weight (0.25 oz per pint) of common salt and 0.5% by volume acetic acid (or 10% by volume white vinegar).
- Apply the test solution to each area, inside or outside, that may have been peened with steel shot
- Leave to react for 10 to 30 minutes
- Verify that there is no rust discoloration
- Clean thoroughly with fresh water

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5.3 Qualification

Shot Peening Suppliers who have been qualified by audit and/or extensive satisfactory experience are listed in Record 100832944

6 Documents Cited

Military Specification MIL-S-13165C "Shot Peening of Metal Parts"
SAE Specification AMS 2430 Shot Peening, Automatic
Record 100832944 " Qualified Vendor List, Shot Peening"
Specification 100832943 " Specification, Burnishing of Stainless Steel Parts

7 Authority

Activity	Responsible	Authority	Consulted	Informed
Process Execution	Manufacturing Engineer	Production Manager	Quality Manager Manager	Suppliers
Update of this document	Materials Engineering Manager	Engineering Manager	Quality Manager Sustaining Manager	Users

Appendix Shot Peening Requirements

These requirements are intended to be used in conjunction with a drawing defining the areas to be shot peened, and a table of peening intensity. Note that the letter designations may not be the same on the drawing as in this document.

Notes:

1) Coverage required is 200% minimum
2) Mask areas B , C, and D while peening areas A1 and A2. When peening areas B and C, overlap areas A1 and A2 or fade out over 2 inch minimum.
3) Almen specimens are required for each zone, on each shot-peening lot, as defined in MIL-S-13165C
4) Where steel shot is used, the surface must be decontaminated with glass beads

Table A1 Drill Collar

Area Designation	Intensity	Typical application area
A1	10-16 Almen C	Outside of Collar
A2	10-14 Almen C	Inside of collar, exposed to mud. No seals
C	10-14 Almen A	API threads (see specification 100010437)
D	3-7 Almen A	Static O ring seal surfaces, ACME and UN threads

Table A2 Stainless steel chassis

Area Designation	Intensity	Typical application area
A	10-14 Almen C	Inside of chassis exposed to mud. No seals
C	10-14 Almen A	Outside of chassis (optional)
D	3-7 Almen A	O ring seal surfaces, ACME and UN threads