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Mechanical Methods for the Inducement of Residual Surface Compressive Stresses

AMENDMENT RECORD

Amd No	Date of Issue	Text Affected	Signature and Date

REVISION NOTE

This Standard has been revised in order to bring the technical methods and procedures into line with current practice and the format into line with the latest MOD requirements.

HISTORICAL RECORD

Def Stan 03-21 / Issue 1 dated 21 July 1983
Def Stan 03-21 / Issue 2 dated 23 January 1998

CONTENT

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PREFACE

MECHANICAL METHODS FOR THE INDUCEMENT OF RESIDUAL SURFACE COMPRESSIVE STRESSES

a. This Defence Standard specifies the requirements for mechanical methods for the inducement of residual surface compressive stresses with emphasis on manual control techniques.

b. This Defence Standard has been produced on behalf of the Standardization Advisory Group (SAG) by the Corrosion Prevention and Metallic Materials Standards Production Group (E3).

c. This Defence Standard has been agreed by the authorities concerned with its use and is intended to be used whenever relevant in all future designs, contracts, orders etc and whenever practicable by amendment to those already in existence. If any difficulty arises which prevents application of the Defence Standard, the Directorate of Standardization (DStan) shall be informed so that a remedy may be sought.

d. Any enquiries regarding this Defence Standard in relation to an invitation to tender or a contract in which it is incorporated are to be addressed to the responsible technical or supervising authority named in the invitation to tender or contract.

e. Compliance with this Defence Standard shall not in itself relieve any person from any legal obligations imposed upon them.

f. This Defence Standard has been devised solely for the use of the Ministry of Defence (MOD) and its contractors in the execution of contracts for the MOD. To the extent permitted by law, the MOD hereby excludes all liability whatsoever and howsoever arising (including, but without limitation, liability resulting from negligence) for any loss or damage however caused when the standard is used for any other purpose.

TEXT

Mechanical Methods for the Inducement of Residual Surface Compressive Stresses

SECTION 1 GENERAL REQUIREMENTS

1 SCOPE

1.1 This Standard details the requirements to be observed when the controlled working of metal surfaces is carried out in order to induce surface compressive stresses. This may be done in order to improve the fatigue properties of items under many types of service loading or to improve resistance to stress corrosion cracking in susceptible alloys, fretting corrosion and corrosion fatigue. For example, they may be applied as a pretreatment to surface finishing operations such as hard chromium plating to offset the loss of fatigue strength which would otherwise occur, or for the reversal of harmful surface tensile stresses persisting from earlier finishing operations such as grinding. These processes may also be used to improve the poor fatigue behaviour of decarburized surfaces.

1.2 This Standard also includes guidance for the control of coverage during manual peening operations.

1.3 The processes covered by this specification are:

Shot peening
Needle peening
Flail or Roto peening
Hammer peening
Roller burnishing

1.4 Processes which are not employed for the prime purpose of inducing a controlled uniform compressive surface stress, e.g. abrasive blasting, are outside the scope of this specification.

1.5 The application of the processes shall be limited to those materials on which test work has shown them to be beneficial within given intensity ranges.

2 WARNING

The Ministry of Defence (MOD), like its contractors, is subject to both United Kingdom and European laws regarding Health & Safety at Work, without exemption. All Defence Standards either directly or indirectly invoke the use of processes and procedures that could be injurious to health if adequate precautions are not taken. Defence Standards or their use in no way absolves users from complying with statutory and legal requirements relating to Health & Safety at Work.

SECTION 1 GENERAL REQUIREMENTS

3 RELATED DOCUMENTS

3.1 The following documents and publications are referred to in the text of this Standard:

Designation	Title
BS 410-1	Test Sieves – Technical Requirements and Testing – Part 1: Test Sieves of Metal Wire Cloth
ISO 565	Test Sieves - Woven Metal Wire Cloth and Perforated Plate - Nominal Sizes of Apertures.
Def Stan 03-2	Cleaning and Preparation of Metal Surfaces

3.2 Reference in this standard to any related document means in any invitation to tender or contract the edition and all amendments current at the date of such tender or contract unless a specific edition is indicated.

3.3 In consideration of **3.2** above, users shall be fully aware of the issue and amendment status of all related documents, particularly when forming part of an invitation to tender or contract. Responsibility for the correct application of standards rests with users.

3.4 DStan can advise from where related documents can be obtained. Requests for such information can be made to the DStan Helpdesk. How to contact the helpdesk is shown on the outside rear cover of Def Stans.

4 DEFINITIONS

4.1 For the purpose of this Standard the following definitions apply:

4.2 Almen test strips

Standardized steel strips used for measuring intensity of shot peening - of increasing thickness and measured intensity in sequence N, A, C (see **Fig 2** and clause **4.5**).

4.3 Coverage

The ratio of the area of all mechanically induced impressions to the total area subjected to treatment expressed as a percentage (see **NOTES 1**, **2** and **3** below).

NOTE 1: The estimation of coverage of the impressions is difficult when this is about 98% of the total surface subjected to treatment, and it is taken that this value has been achieved when the imprints of the impacts appear to cover the surface entirely. The time of peening (or the number of passes of the nozzle or cycles of operation) to reach this stage is known as the 'base time'.

SECTION 1 GENERAL REQUIREMENTS

NOTE 2: '100% coverage' is a theoretical limiting value, and the term 'complete coverage' is preferred. This is obtained by increasing the base time until the impressions begin to cover themselves. Usually, complete coverage requires increasing the base time by 15-20%. Values of 200%, 300%, etc are obtained by multiplying this time by 2, 3, etc.

NOTE 3: Coverage is a visual determination of the peening effect on the part. It will vary in inverse proportion to the substrate hardness. Harder items will show less coverage than the test strip, and softer items will reach complete coverage in less than the base time.

4.4 Deformed Shot

Shot having either a length to diameter ratio greater than 2:1, or broken or chipped surfaces, or with hollow or welded particles (see **Fig 5**).

4.5 Intensity

4.5.1 This is a measure of the energy absorbed by the test strip from the shot stream and, consequently, is related to the level of shot peening in the part being treated.

4.5.2 The intensity is normally expressed by a range which specifies upper and lower limits, together with the type of test strip being used, see **Fig 1**:

0.15A - 0.25 A

Minimum Arc Height (mm)

Maximum Arc Height (mm)

Test Strip Type

Limits of use (see clause **A.1.5**):

Type A: from 0.10A to 0.60A
Type N: up to 0.45N
Type C: from 0.15C to 0.60C

Fig 1 – Peening Intensity

NOTE 1: Examples of typical peening intensities is given in **Tables 6** and **7**.
NOTE 2: See **Annex A** for the determination of peening intensity.

SECTION 1 GENERAL REQUIREMENTS

4.6 Masked areas

Surfaces designated on the drawing to be free of the peening treatment shall be masked or otherwise protected from direct or indirect impingement.

4.7 Material factor

A factor applied to the exposure time in order to take account of the difference in hardness between the component material and the standard Almen test strip (see **B.3.2.4**).

4.8 Optional areas

Those parts of the component where peening may be permitted and masking is not necessary. In these areas the intensity is not specified but is less than in significant areas and coverage need not be complete (see **8.6**).

4.9 Peening angle

The angle of inclination between the axis of the peening nozzle or shot stream and the workplace surface.

4.10 Peening constant

The ratio between the test piece area and the time taken to reach saturation for a given set of peening parameters.

4.11 Process Control Schedule

The document which specifies / defines:

(a) The sequence of manufacturing operations and processes.

(b) The control parameters and their tolerances for each individual process within the total sequence.

4.12 Saturation

Saturation is reached when doubling the peening time causes a rise in the intensity value of not more than 10% on the Almen test strip (see **Fig 6** and **Annex B**).

4.13 Shot

Material used for peening, e.g. cast steel, conditioned steel and stainless steel cut wire, ceramic or glass beads.

SECTION 1 GENERAL REQUIREMENTS

4.14 Significant areas

Those parts of the component surface which require treating to a specified intensity or stress level.

5 INFORMATION TO BE SUPPLIED TO THE PROCESSOR

The following information shall be given on the drawing, contract or order:

(a) The specification and metallurgical condition of the item(s) to be treated.
(b) Details of masked, optional and significant areas.
(c) Shot size, type and hardness.
(d) Details of coverage and saturation required.
(e) Peening intensity and areas where this is to be checked.

6 PROCESS CONTROL SCHEDULE

6.1 A Process Control Schedule suitable for achieving the requirements of this Standard shall be prepared by the processing contractor(s) prior to the commencement of production.

6.2 Details of all preparatory treatments, after-treatments, processing, masked, optional and significant surfaces, tests and all other processes and treatments shall be included in the Process Control Schedule.

6.3 All stages of the complete Schedule shall follow each other without delay.

SECTION 2 PROCESS REQUIREMENTS

7 LIMITATIONS ON USE

7.1 The treatment causes plastic flow of the surface layers, thereby inducing surface compressive stresses in the plane of the surface. The balance of stresses shall not produce unacceptable levels of deformation of the items, and the tensile stresses (which balance the desired compressive stresses) must be located in the thickness of the metal or at surfaces where they will not be detrimental to:

(a) Easily deformed items.
(b) Items where thin walls must be treated on one side only, as there is a risk of deformation with the induction of harmful tensile stresses on the untreated side.
(c) Items made of clad aluminium alloy sheets.
(d) Items where the edges of the treated region are not able to be located entirely in clearly defined significant areas, as there is a risk of tensile stresses bordering treated regions.

7.2 The stresses induced by treatment must be considered relative to subsequent manufacturing operations and in-service conditions, and due care must be taken to minimize relaxation by those operations, by service conditions and by repair, especially where items may be:

(a) Ground, honed or lapped.
(b) Exposed to excessive temperatures (see **11.4**).
(c) Subjected to plastic deformation.
(d) Subjected to high reversed load conditions, as the compressive stresses may be reduced by plastic flow during the compressive part of the load cycle.
(e) Damaged by scoring or deformation in service, or where treated metal may be removed.

7.3 Items bearing traces of corrosion and/or other surface defects such as cracks, porosity, laps, etc shall not be treated.

7.4 By increasing the intensity of peening, the depth of the compressively stressed layer may be increased, though it will not increase the magnitude of the stress significantly.

7.4.1 Treatment to high intensities aimed at producing deep compressive stress layers is not permissible unless tests have shown that they would not damage the surface by cracking it, thereby possibly losing or reversing the desired beneficial effects. This is of particular importance when treating materials susceptible to cracking.

7.5 Treatment is limited to surfaces which permit its application and inspection within the requirements of this Standard.

7.6 For maximum residual compressive stress to be achieved it is necessary to use shot of equal or greater hardness than the substrate material (see **13.6**).

SECTION 2 PROCESS REQUIREMENTS

7.7 Particular care needs to be exercised with easily deformed parts. Peening intensities shall be carefully controlled to avoid deformation and cracking. The use of jigs or special processing techniques should be considered.

8 PREPARATION PRIOR TO TREATMENT

8.1 Areas to be treated shall be finish machined and deburred except for permitted light finishing operations.

8.2 All operations involving plastic strain of significant areas such as bending, drawing, stretching or straightening shall have been completed prior to treatment. However, prestressing of springs may be required after peening.

8.3 All heat treatment shall have been completed prior to treatment. However, any minor stress relieving given after peening shall be at temperatures not exceeding those given in **11.4**.

8.4 Areas to be treated shall be free from dirt and, unless otherwise required, coatings such as paint, plating, anodizing, etc shall be removed. Cleaning shall be in accordance with the requirements of Def Stan 03-2.

8.5 All examinations to ensure freedom from cracks and other surface imperfections shall be carried out prior to treatment.

8.6 The drawing, contract or order shall indicate significant, optional and masked areas on the items. It is desirable to reduce progressively the intensity, over approximately 15 mm, when only part of a surface is to be peened, unless the shape of the item provides a natural boundary.

NOTE: Masking materials shall be chloride free.

8.7 Unless otherwise specified in the drawing, contract or order, items shall not be treated whilst held under any external loading. In certain instances it may be necessary or advantageous to treat under applied constraint, for reasons of accessibility of the shot, or for increasing the level of final residual stress, i.e. strain peening.

8.8 Helical coil compression springs must not be loaded by the application of a tensile force in order to increase coil gap and thereby improve accessibility of the shot during peening. Such loading would have the reverse effect of strain peening and would actually reduce the fatigue life of the spring, since it would generate a residual tensile stress at the surface once the applied load was released after peening.

SECTION 2 PROCESS REQUIREMENTS

9 TREATMENT TECHNIQUES

9.1 Shot peening, mechanised and manual (see clauses **13** and **14**).

9.2 Needle peening (see clause **15**).

9.3 Flail or roto peening (see clause **16**).

9.4 Hammer peening (see clause **17**).

9.5 Roller burnishing (see clause **18**).

10 QUALITY CONTROL

10.1 The maintenance of Quality is performed by control of the process and its reproducibility, since no method of non-destructive testing exists to demonstrate that the required compressive stress has been put into the item.

10.2 All process personnel engaged in peening operations shall be suitably trained and shall have demonstrated their competence in achieving the required standard.

10.3 The peened surfaces of all items and all accompanying test strips shall be examined overall at X10 magnification and shall show complete coverage, over-lapping of shot impressions, and freedom from cracks, laps and sharp indentations. Surface roughness and dimensions on components shall also be examined. Items with areas of incomplete coverage shall be re-peened to the original peening parameters and re-examined.

10.4 A means of providing visual evidence of peening coverage on surfaces can be obtained by the use of witness coatings. Such coatings may be applied either by brush or spray techniques and are not critically dependent on coating thickness. The peening of the coated surface must be in accordance with the established conditions, and the coating used must be capable of removal under these conditions and at the coverage rate specified. However, the Process Control Schedule should in all such cases require that the treatment be applied for the specified time and until the complete removal of the witness coating. The use of such a coating should give increased assurance that complete coverage has been attained. Where 200% coverage is specified, a second application of the coating may be required.

10.5 Roller burnished surfaces shall be examined overall at X10 magnification and shall show complete obliteration of the original surface markings.

10.6 The surfaces required not to be peened shall be examined after the removal of the masking and shall be free from any evidence of peening.

10.7 Items shall be examined visually after any post-peening operations (see clause **11**).

SECTION 2 PROCESS REQUIREMENTS

11 POST TREATMENT OPERATIONS

11.1 Aluminium, titanium and their alloys and corrosion resisting steels which have been peened shall be cleaned to remove any contaminant, e.g. by pickling to remove embedded shot without attacking the parent metal or by non-metallic grit blasting. It is to be noted that chemical or abrasive residue on treated items may interfere seriously with subsequent treatment and should therefore be removed. Cleaning operations shall not degrade the surface or dimensions of the item. Items which have been pickled or blasted with non-metallic grit for removal of ferrous residues shall be demonstrated to be free from ferrous residue, e.g. in accordance with **Annex C.**

11.2 Where polishing, honing, lapping or grinding is required to reduce surface roughness, the treatment shall not raise the surface temperature sufficient to relax the compressive stresses introduced by peening. The depth of metal removal shall be such that:

(a) A witness of the peening indentations remains visible under a magnification of X10. On high hardness steels this procedure may be prevented by the difficulty of viewing the indentations.

(b) The amount of metal removed from the asperities of the peened surface does not exceed 10% of the specified or equivalent Almen A arc height, i.e. 3% of the N scale arc height or 35% of the C Scale arc height. For steels of Rm ≥1450 MPa, the amount of metal removed shall not exceed 5% of the Almen A arc height.

11.3 Freshly treated surfaces can present conditions particularly favourable to corrosion. In these circumstances, the first stage of any final corrosion protective treatment shall be applied within 2 hours or, if this is not possible, a temporary protective coating shall be applied.

11.4 If subsequent processing requires the treated items to be heated, the temperature employed shall not be high enough to significantly reduce the beneficial surface stresses. The maximum temperatures to be used are shown in **Table 1**.

11.5 After any post-treatment operation, items shall be re-examined visually or dimensionally as required and shall meet the requirements of **11.2**.

SECTION 2 PROCESS REQUIREMENTS

Table 1: Maximum Heat Treatment Temperatures	
Material	**Temperature °C**
Aluminium Alloys	100
Magnesium Alloys	95
Corrosion Resisting Steel	400
Steel	230
Titanium Alloy 6/4	480

12 RECORDS

Records shall be kept for each item or batch of items to show:

(a) Date of treatment.
(b) Method of treatment.
(c) Item number and name.
(d) Batch quantity and batch identity.
(e) Operation schedule number and issue.
(f) Specified and measured intensities.
(g) Any divergencies from the Process Control Schedule together with the reason for change and the authorizing signature.

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

13 MECHANISED SHOT PEENING

13.1 Process

The process consists of the controlled bombardment of the metal surface by spherical shot including steel shot, steel and stainless steel cut wire, ceramic or glass beads. The shot may be propelled by a high velocity stream of air or liquid or by a mechanical device in which the shot is fed into a rotating wheel and projected by centrifugal force at the desired velocity.

13.2 Equipment

The equipment shall be such that the velocity and direction of shot in relation to the workpiece can be consistently and closely controlled.

13.3 Provision shall be made for the mechanical manipulation of the workpiece in the stream of shot in order that complete and uniform coverage of the significant surfaces at the desired intensity may be consistently achieved.

13.4 Type of Shot

Peening equipment using dry media shall include a separator for the continuous removal of broken or damaged shot. With wet media peening machines, where separation is difficult, the use of a weir wash separator or calibrated hydrocyclone is advised.

13.5 Shot shall be spherical in shape, free from sharp edges, and shall be of a material capable of producing the required peening intensity without either excessive deformation or fracturing of the particles (see also **B.2.2.1**).

13.6 Ferrous shot (cast steel and both carbon steel and stainless steel conditioned cut wire) shall be within the hardness range HV 440-590 (HRC 45-55) for normal use and HV 580-830 (HRC 55-65) for special applications, e.g. hard steels. Both the shot type and hardness range shall be included in the Process Control Schedule.

13.7 Metal shot shall be supplied and maintained dry and free from rust, dirt, grit, oil, grease or other contaminants.

13.8 Ceramic or glass beads shall be supplied and maintained dry and free from any surface contamination or dressings, and free from lead or free silica.

13.9 All new shot shall be within the screening analyses defined in **Tables 2** and **3** for ferrous and non-ferrous shot respectively.

Table 2 : Ferrous Shot – Sizes of New Shot and Screening Analyses

Nominal Diameter	**100% By Weight Retained On Mesh Size (see NOTE 2)**	**Max 2% By Weight Retained On Mesh Size mm**	**Max 50% By Weight Retained On Mesh Size mm**	**Cumulative Min. 90% By Weight Retained On Mesh Size (see NOTE 2) mm**	**Max 8% By Weight Retained On Mesh Size (see NOTE 2) mm**	**Max. No. Of Deformed Shot Acceptable (1) (see Figure 4 and NOTE 1)**
2.36	4.00	3.35	2.80	2.36	2.00	5 per 645 mm^2
2.00	3.35	2.80	2.36	2.00	1.70	5 per 645 mm^2
1.70	2.80	2.36	2.00	1.70	1.40	12 per 645 mm^2
1.40	2.36	2.00	1.70	1.40	1.18	12 per 645 mm^2
1.18	2.00	1.70	1.40	1.18	1.00	15 per 645 mm^2
1.00	1.70	1.40	1.18	1.00	0.850	20 per 645 mm^2
0.85	1.40	1.18	1.00	0.850	0.710	20 per 161 mm^2
*0.71	1.18	1.00	0.850	0.710	0.600	20 per 161 mm^2
*0.60	1.00	0.850	0.710	0.600	0.500	20 per 161 mm^2
0.50	0.850	0.710	0.600	0.500	0.425	20 per 161 mm^2
*0.43	0.710	0.600	0.500	0.425	0.355	20 per 161 mm^2
0.35	0.600	0.500	0.425	0.355	0.300	30 per 40 mm^2
*0.30	0.500	0.425	0.355	0.300	0.180	40 per 40 mm^2
0.18	0.425	0.355	0.300	0.180	0.125	40 per 40 mm^2

* Standard Sizes

NOTE 1 : Samples shall consist of the number of shot in one layer which completely fills a square of the area specified

NOTE 2: Mesh size is in accordance with ISO 565

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

Table 3: Non-Ferrous Shot - Sizes of New Beads and Screening Analysis

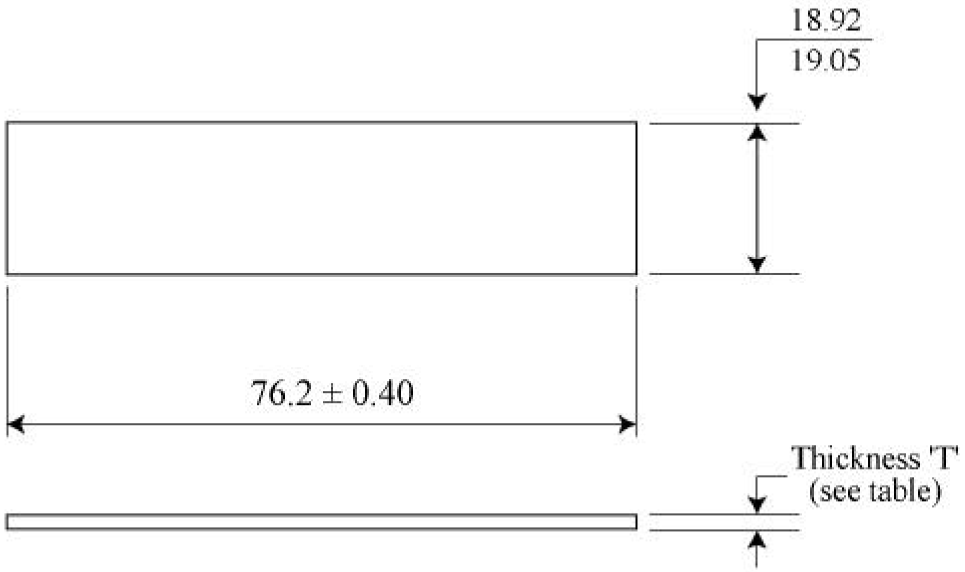
Nominal Diameter mm	100% By Weight Passing Mesh Size mm	Max 2% By Weight Retained On Mesh Size mm	Max 8% By Weight Passing Mesh Size mm	0% Passing Mesh Size mm
* 0.850 +	1.00	0.850	0.600	0.500
0.710	0.850	0.710	0.500	0.425
0.600 +	0.710	0.600	0.425	0.355
* 0.500	0.600	0.500	0.355	0.300
0.425 +	0.500	0.425	0.300	0.250
0.355	0.425	0.355	0.250	0.212
* 0.300 +	0.355	0.300	0.212	0.180
* 0.250	0.300	0.250	0.180	0.150
* 0.212	0.250	0.212	0.150	0.125
0.180	0.212	0.180	0.125	0.106
0.150 +	0.180	0.150	0.106	0.090
* 0.125	0.150	0.125	0.090	0.075
0.106	0.125	0.106	0.075	0.063
0.090	0.106	0.090	0.063	0.053
0.075	0.090	0.075	0.053	0.045
0.063	0.075	0.063	0.045	0.036
0.053	-	-	-	-
* Standard sizes, glass beads				
+ Standard sizes, ceramic beads				

13.10 Size of Shot

Unless otherwise specified, the nominal diameter of peening media shall be no greater than half the minimum fillet radius in the area being peened. For slots or other apertures, through which the media must pass to peen shielded critical areas, the nominal diameter of the media shall be no greater than a quarter of the width of the aperture.

13.11 Ancillary equipment including Almen test strips, test strip holder, Almen gauge (see **Figs 2**, **3** and **4**), sieves for size analysis (see BS 410), masking jigs or materials, (X10) magnifying glass and timer, will also be required.

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING



TEST STRIP	THICKNESS 'T'	FLATNESS *
A	1.30 ± 0.025	± .04
C	2.38 ± 0.025	± .04
N	0.79 ± 0.025	± .04

*when measured on Almen Guage

MATERIAL :-

0.70% Carbon Steel, hardened and tempered
to 425-505 HV30.
Surface to be free from decarburisation

Dimensions are in millimetres

Fig 2 – Almen Test Strip

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

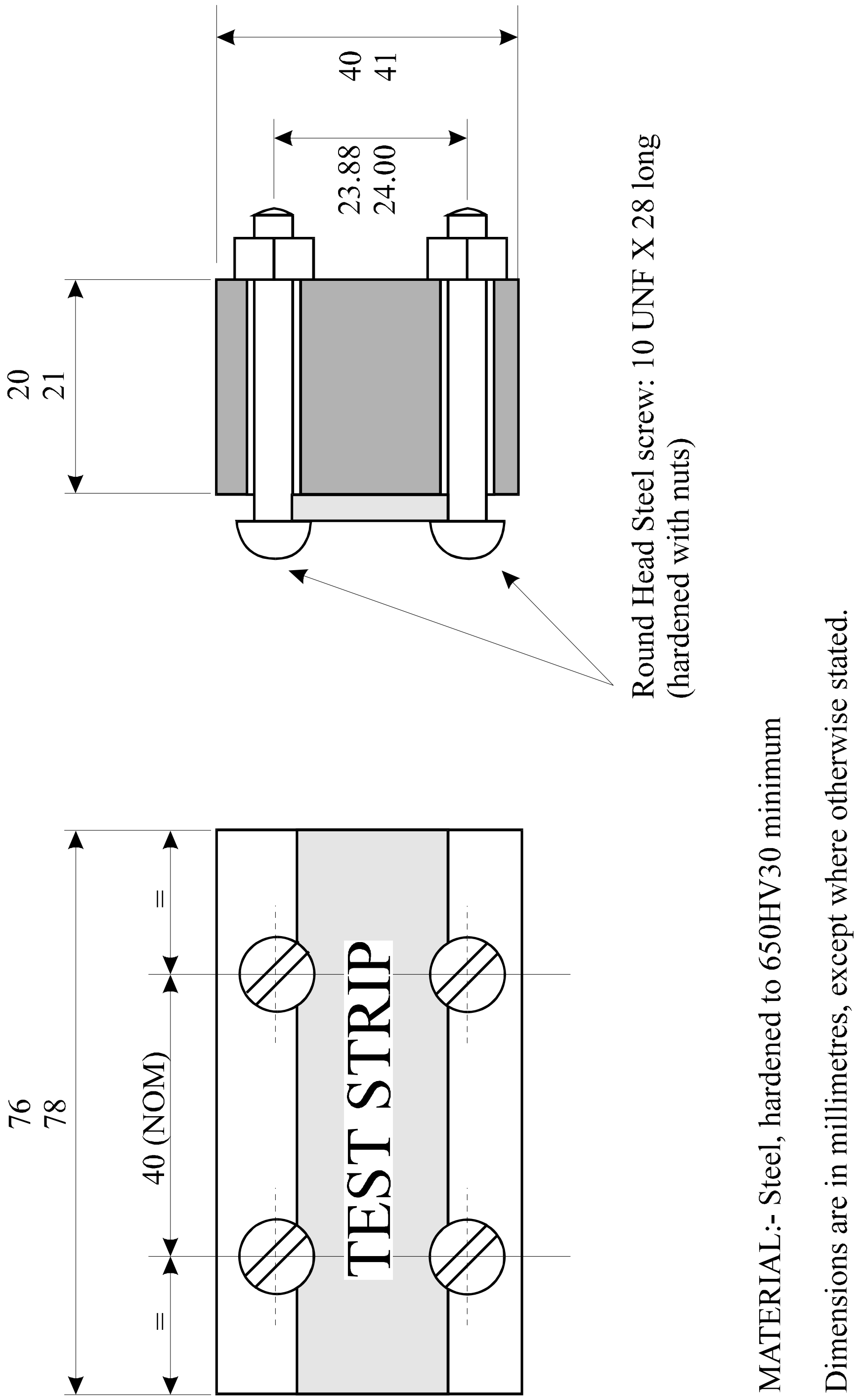


Fig. 3 - Test Strip Fixture

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

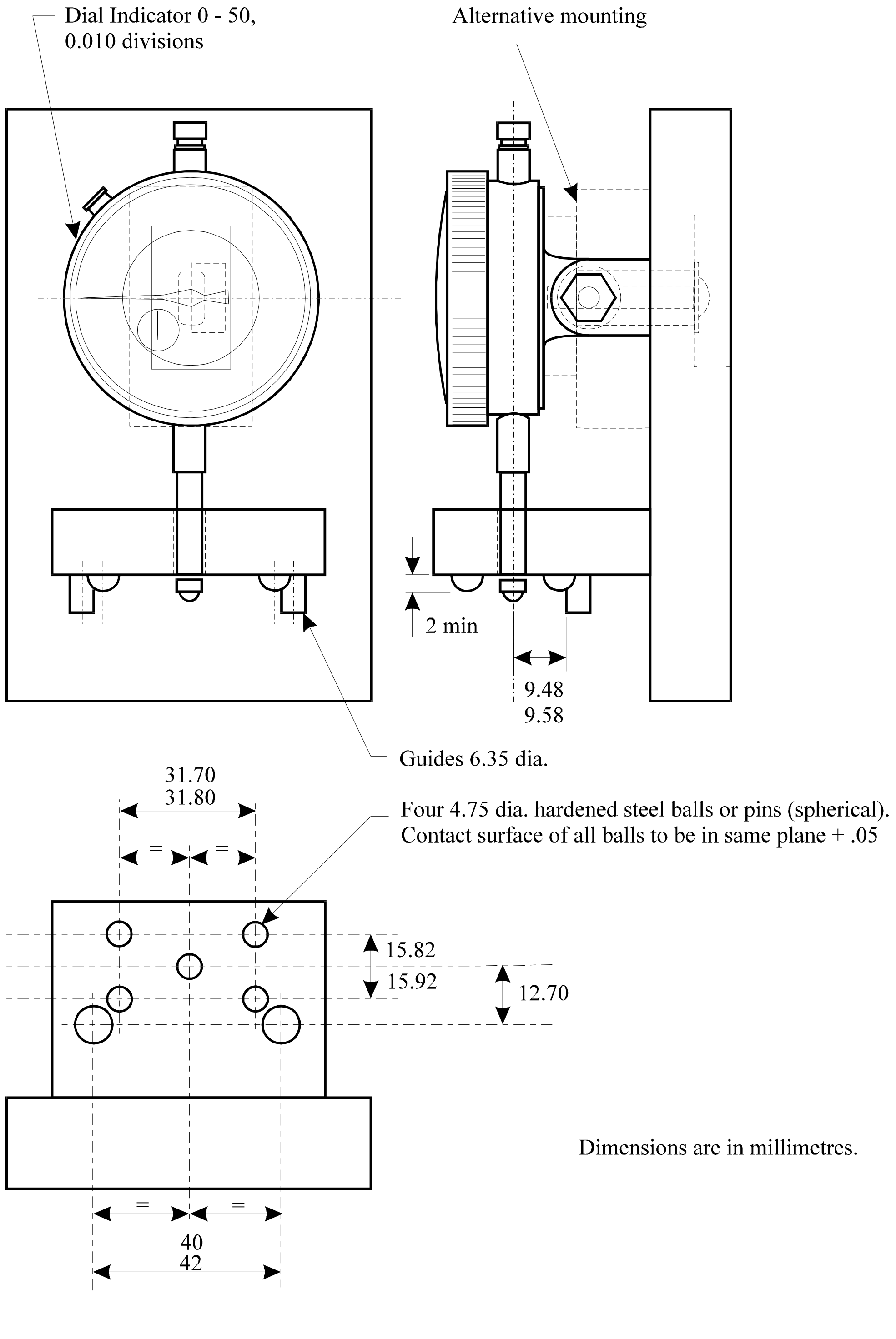


Fig. 4 - Almen Gauge

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

13.12 Process Control Schedule

The process shall be operated in accordance with a Process Control Schedule which has been established and recorded for each design of item to be peened. The Process Control Schedule shall include the following details:

(a) The item number and metallurgical condition.
(b) Any pretreatment, stress relief, heat treatments or surface finish requirements applicable to the item.
(c) The peening intensity range and required coverage.
(d) A description or sketch showing significant, optional and masked areas.
(e) Any jigging, tooling or masking requirements.
(f) The size, material specification and hardness of peening media.
(g) The specific machine identity and setting.
(h) The number, type and size of nozzle(s)/wheel(s).
(i) The nozzle(s)/wheel(s) to workpiece stand-off distance(s).
(j) The peening angle.
(k) The air or water pressure or rotor speeds controlling the impact velocity of the peening media.
(l) The mass flow rate of the peening media.
(m) The duration of peening.
(n) The details of any movement of the item relative to the peening media stream, e.g. speed and direction of rotation and traversing of the workpiece.
(o) The position of any special fixtures for retaining Almen test strips and the frequency of performing intensity checks during production work.
(p) The method of application of saturation data, as detailed in **Annex B**.
(q) Details of any post-treatment, e.g. temporary corrosion protection or pickling, necessary before the next manufacturing operation.

13.13 Peening Intensity

Any required peening intensity verification test strips shall be peened under conditions specified in the Process Control Schedule. Unless otherwise specified, the frequency of intensity determinations shall be:

(a) At the beginning and end of each batch of five or more items.
(b) At the beginning only of each batch of less than five items.
(c) Every 2 hours of continuous operation for ceramic or glass bead peening and every 8 hours of continuous operation for cast steel, conditioned steel and stainless steel cut wire peening.
(d) Whenever there is any change or control settings, replacement of shot, or any event that may affect the peening intensity.

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

13.13.1 All test strips peened with a production batch shall accompany the items they represent through inspection, and they shall all be within the intensity range specified in the Process Control Schedule.

13.13.2 Additionally, stress measurements may be carried out on either components or test coupons, processed under the conditions established by the agreed procedure, in order to verify the stress levels and distribution. Test coupons shall be manufactured in the same manner, or identical design, i.e. section thickness/fillet size, etc and material condition.

13.14 Shot shall be monitored for degradation of size (see **Tables 4** and **5**) and shape (see **Fig 5**) by the removal and examination of a representative sample of not less than 200g. Sampling and examination shall be as detailed below:

(a) Ceramic or glass beads - once every 2 hours.
(b) Conditioned steel or stainless steel cut wire and cast steel shot - once every 8 hours.

13.14.1 The sample shall be halved, and one portion submitted to a sizing test, the other shall be visually examined for the presence of deformed shot (see **4.4**).

Table 4: Ferrous Shot - Uniformity of Shot in Machine

Nominal diameter mm	Max 20% By Weight Passing Through Mesh Size. mm
2.36	1.18
2.00	1.00
1.70	0.850
1.40	0.710
1.18	0.600
1.00	0.500
0.85	0.425
0.71	0.355
0.60	0.300
0.50	0.250
0.43	0.212
0.35	0.180
0.30	0.125
0.18	0.090

NOTE: Maximum broken or unacceptable shot (**Fig. 5**): 15 per 100 shot

SECTION 3 TREATMENT TECHNIQUES – MECHANISED SHOT PEENING

Table 5: Non-Ferrous Shot - Uniformity of Shot in Machine

Nominal Diameter **mm**	**Max 20% By Weight Passing Through Mesh Size** **mm**
0.850	0.500
0.710	0.425
0.600	0.355
0.500	0.300
0.425	0.250
0.355	0.212
0.300	0.180
0.250	0.150
0.212	0.125
0.180	0.106
0.150	0.090
0.125	0.075
0.106	0.063
0.090	0.053
0.075	0.045
0.068	0.036
0.053	-

NOTE: Maximum broken beads: 15 per 100 beads

SECTION 3 TREATMENT TECHNIQUES – MECHANISED PEENING

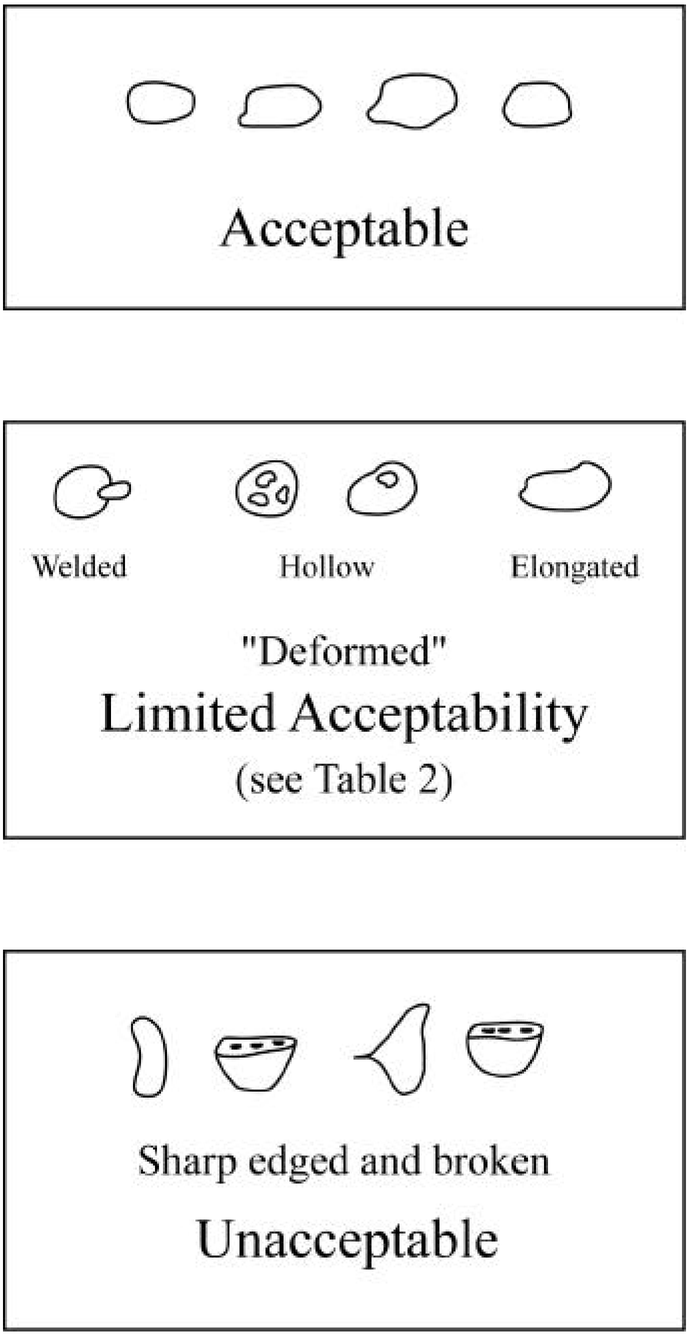


Fig.5 Shape Requirements for Cast Shot

SECTION 4 TREATMENT TECHNIQUES – MANUAL SHOT PEENING

14 MANUAL SHOT PEENING

14.1 Process

The inherent variability of manual shot peening normally renders the process unsuitable for treatment of critical components or assemblies.

14.2 A Process Control Schedule is required as in **13.12**, but shall only include details (a) to (l), (p), (q), and **13.3**.

14.2.1 Coverage requirements shall always be specified in addition to methods (i) and (ii) of **Annex B**.

14.2.2 The peening time per unit area shall be stated.

14.2.3 Operator Control

In order to demonstrate operator control, the Almen test strips for the verification of peening intensity, as required by **13.13**, should ideally be mounted on a square fixture, of at least 150 mm x 150 mm, made from the same material and metallurgical condition as the part(s) being treated. This will also enable satisfactory coverage to be demonstrated simultaneously.

14.2.4 All test strips peened with a production batch shall accompany the items they represent through inspection, and they shall all be within the intensity range specified in the Process Control Schedule.

14.2.5 Additionally, stress measurements may be carried out on either components or test coupons, processed under the conditions established by the agreed procedure, in order to verify the stress levels and distribution. Test coupons shall be manufactured in the same manner, of identical design, i.e. section thickness/fillet size, etc and material condition.

14.2.6 Shot shall be monitored for degradation of size (see **Tables 4** and **5**) and shape (see **Fig 5**) by the removal and examination of a representative sample of not less than 200g. Sampling and examination shall be as detailed below:

(a) Ceramic or glass beads - once every 2 hours.
(b) Conditioned steel or stainless steel cut wire and cast steel shot - once every 8 hours.

14.2.7 The sample shall be halved, and one portion submitted to a sizing test, the other shall be visually examined for the presence of deformed shot (see **4.4**).

SECTION 5 TREATMENT TECHNIQUES – NEEDLE PEENING

15 NEEDLE PEENING

15.1 Process

The process entails the use of a cluster of metal needles usually of hardened tool steel, but other metals may be used dependent upon the material being treated, encased in an air pressure gun which subject the material to repeated impacts. The velocity is such that each impact produces plastic deformation of the surface. The surfaces requiring treatment are traversed at a rate such as to give the required coverage. The process is usually applied manually to local areas of components or assemblies and is therefore subject to limitations of control.

15.2 Needles shall be rounded and of such a diameter and profile as to permit suitable access to all the areas to be peened.

15.3 Ancillary equipment including Almen test strips, test strip holder, Almen gauge (see **Figs 2**, **3** and **4**), masking jigs or materials, (X10) magnifying glass and timer, shall also be required.

15.4 Process Control Schedule

The process shall be operated in accordance with a Process Control Schedule which has been established and recorded for each design of item to be peened. The Process Control Schedule shall include the following details:

(a) The part number and metallurgical condition.
(b) Any pre-treatment, stress relief, heat treatments or surface finish requirements applicable to the item.
(c) The peening intensity range and required coverage.
(d) A description or sketch showing significant, optional and masked areas.
(e) Any jigging, tooling or masking requirements.
(f) The needle material, metallurgical condition, diameter, shape of tip and number of needles in the cluster.
(g) The type and model of gun.
(h) The peening angle.
(i) The air pressure to the gun.
(j) The duration of peening.
(k) The method of application of saturation data, as detailed in **Annex B**. It should be noted that coverage requirements should always be specified in addition to methods (i) and (ii) of **Annex B**.
(l) Details of any post-treatment, e.g. temporary corrosion protection or pickling, necessary before the next manufacturing operation.

SECTION 5 TREATMENT TECHNIQUES – NEEDLE PEENING

15.5 Peening Intensity

Any required peening intensity verification test strips shall be peened. Unless otherwise specified on the Process Control Schedule, the frequency of intensity determinations shall be:

(a) At the beginning and end of each batch of five or more items.
(b) At the beginning only of each batch of less than five items.

15.5.1 In order to demonstrate operator control, the Almen test strips for the verification of peening intensity, as required by **13.13**, should ideally be mounted on a square fixture, of a least 150 mm x 150 mm, made from the same material and metallurgical condition as the part(s) being treated. This will also enable satisfactory coverage to be demonstrated simultaneously.

15.5.2 All test strips peened with a production batch shall accompany the items they represent through inspection, and they shall all be within the intensity range specified in the Process Control Schedule.

15.5.3 Additionally, stress measurements may be carried out on either components or test coupons, processed under the conditions established by the agreed procedure, in order to verify the stress levels and distribution. Test coupons shall be manufactured in the same manner, of identical design, i.e. section thickness/fillet size, etc and material condition.

15.6 The needle profiles shall be checked visually at the beginning and end of each 8 hour period of operation and any worn or damaged needles replaced.

SECTION 6 TREATMENT TECHNIQUES – FLAIL PEENING

16 FLAIL PEENING

16.1 Process

The process entails the use of a thread woven multi-flap rotary brush on which are mounted hard shot, e.g. cast steel or tungsten carbide, (the type depending upon the individual operation), powered by a rotary power tool. The shot impacts the surface of the workpiece causing plastic deformation, thereby inducing a compressive stress. The surfaces requiring treatment are traversed at a rate such as to give the required coverage. The process is usually applied manually to local areas of components or assemblies and is particularly useful for the peening of holes.

16.2 Process Control Schedule

The process shall be operated in accordance with a Process Control Schedule which has been established and recorded for each design of item to be peened. The Process Control Schedule shall include the following details:

(a) The item number and metallurgical condition.
(b) Any pre-treatment, stress relief, heat treatments or surface finish requirements applicable to the item.
(c) The peening intensity range and required coverage.
(d) A description or sketch showing significant, optional and masked areas.
(e) Any jigging, tooling or masking requirements.
(f) The type of flap, flap diameter and type of shot.
(g) The flap deflection and/or distance from the spindle to the work surface.
(h) The rotary speed controlling the impact velocity of the shot.
(i) The duration of peening.
(j) The method of application of saturation data, as detailed in **Annex B**. It should be noted that coverage requirements should always be specified in addition to methods (i) and (ii) of **Annex B**. The shot energy is determined by the rotational speed.
(k) Details of any post-treatment, e.g. temporary corrosion protection or pickling, necessary before the next manufacturing operation.

16.3 Peening Intensity

Any required peening intensity verification test strips shall be peened. Unless otherwise specified on the Process Control Schedule, the frequency of intensity determination shall be:

(a) At the beginning and end of each batch of five or more items.
(b) At the beginning only of each batch of less than five items.

SECTION 6 TREATMENT TECHNIQUES – FLAIL PEENING

16.3.1 In order to demonstrate operator control, the Almen tests strips for the verification of peening intensity, as required by **13.13**, should ideally be mounted on a square fixture, of at least 150 mm x 150 mm, made from the same material and metallurgical condition as the part(s) being treated. This will also enable satisfactory coverage to be demonstrated simultaneously. It may be found necessary to use the equipment manufacturer's own Almen strip holder in order to obtain valid test readings.

16.3.2 All test strips peened with a production batch shall accompany the items they represent through inspection, and they shall all be within the intensity range specified in the Process Control Schedule.

16.3.3 Additionally, stress measurements may be carried out on either components or test coupons, processed under the conditions established by the agreed procedure, in order to verify the stress levels and distribution. Test coupons shall be manufactured in the same manner, of identical design, i.e. section thickness/fillet size, etc and material condition.

16.4 The rotary flap brushes shall be checked visually at the beginning and regularly during each period of operation and the presence of existing flap wear or shot removal shall necessitate flap replacement.

SECTION 7 TREATMENT TECHNIQUES – HAMMER PEENING

17 HAMMER PEENING

17.1 Process

The process consists of a single metal rod usually of hardened tool steel, but other metals may be used dependent upon the material being treated, encased in an air pressure gun which is used to subject the material to repeated impacts. The velocity is such that each impact produces plastic deformation of the surface, thereby inducing a compressive stress. The surfaces requiring treatment are traversed at a rate such as to give the required coverage. The process is usually applied manually to local areas of components or assemblies and is therefore subject to limitations of control.

17.2 Process Control Schedule

The process shall be operated in accordance with a Process Control Schedule which has been established and recorded for each design of item to be peened. The Process Control Schedule shall include the following details:

(a) The item number and metallurgical condition.
(b) Any pre-treatment, stress relief, heat treatments or surface finish requirements applicable to the item.
(c) The required coverage.
(d) The description or sketch showing significant, optional and masked areas.
(e) Any jigging, tooling or masking requirements.
(f) The hammer material, metallurgical condition, diameter and shape of the tip.
(g) The type and model of gun.
(h) The peening angle.
(i) The air pressure to gun.
(j) The duration of peening.
(k) Details of any post-treatment, e.g. temporary corrosion protection or pickling, necessary before the next manufacturing operation.

17.3 The procedures described in **Annex B** are not appropriate since it is not possible to determine the peening intensity by the use of Almen test strips. Therefore, even less control is possible than for the other manual processes covered by the Standard and hence the information included in this section is for guidance purposes only.

17.4 The hammer profile shall be checked visually at the beginning, end and regularly during each period of operation and if undue wear or damage has occurred, the hammer shall be replaced.

SECTION 8 TREATMENT TECHNIQUES – ROLLER BURNISHING

18 ROLLER BURNISHING

18.1 Process

The process consists of the application of a roller force to a surface either by rollers or spherical bearings such that plastic deformation occurs, thereby inducing a compressive stress. The stress level and depth is dependent upon the specific working conditions applied; in particular, rolling speed, contact stress, number of passes and total amount of deformation, e.g. the increase in diameter of the hole. It is especially suitable for application to fillets, grooves or holes, and is capable of very close dimensional control together with the production of a good surface finish.

18.2 Process Control Schedule

The process shall be operated in accordance with a Process Control Schedule which has been established and recorded for each design of item to be peened. The Process Control Schedule shall include the following details:

(a) The item number and metallurgical condition.
(b) Any pre-treatment, stress relief, heat treatments or surface finish requirements applicable to the item.
(c) The dimensions of the treated surfaces before and after treatment including tolerances and surface finish.
(d) A description or sketch showing areas to be treated.
(e) The diameter of the burnishing tool.
(f) The speed of rotation of the burnishing tool.
(g) The number of passes.
(h) Details of any post-treatment, e.g. temporary corrosion protection or pickling, necessary before the next manufacturing operation.

18.3 Verification of the process shall be by measurement of the change in size of the component. Additionally, stress measurements may be carried out.

ANNEX A

DETERMINATION OF THE INTENSITY OF SHOT PEENING

A.1 METHODOLOGY

A.1.1 The test strips shall conform to **Fig 2**. Before use, the test strips shall be degreased and checked for flatness using an Almen gauge as shown in **Fig 4**, the specimen being supported on the four steel balls, the gauge to be aligned on the specimen with its central stylus at the centre of the specimen. The reading of the rotating scale shall be set to zero at this stage and locked in position.

A.1.2 The test strips shall be held rigidly flat for peening in the fixture illustrated in **Fig 3** or on a flat face machined onto a dummy part. They shall be peened on the exposed side under the same conditions as the production items.

A.1.3 After peening, the test strips shall be removed from the fixture and the arc height of the unpeened surface shall be measured using the Almen gauge. A peened test strip shall not be re-peened after being removed from the test strip fixture.

A.1.4 The arc height at the centre of the specimen over the gauge length of shall be measured.

A.1.5 The 'C' strip is usually used if the arc height on the 'A' strip would exceed 0.60 mm and the 'N' strip is usually used if the arc height on the 'A' strip would be less than 0.10 mm.

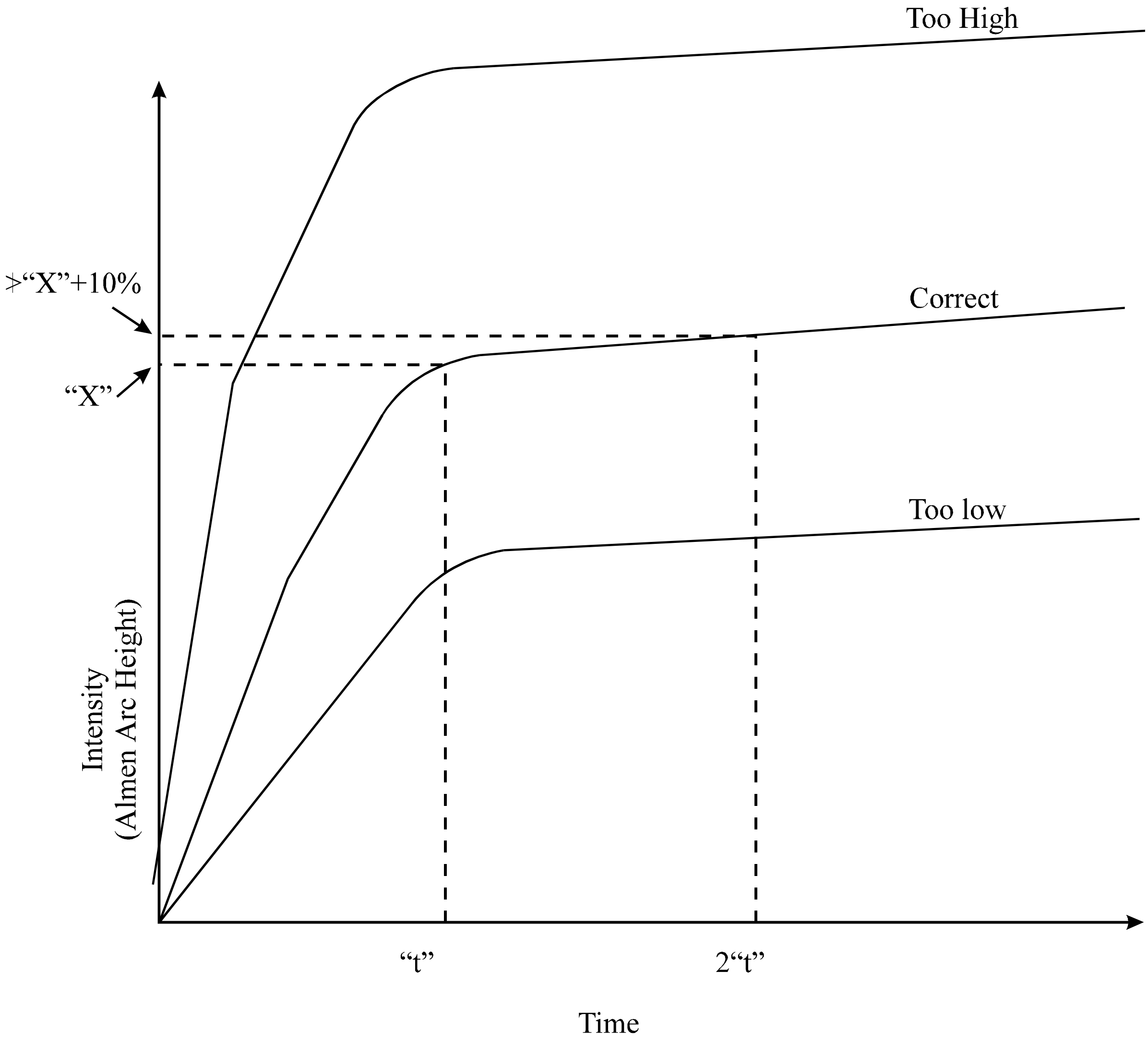
A.1.6 During initial process development, when the intensity at saturation is being established, there shall be at least four Almen strips peened for different lengths of time to determine the curve (see **Fig 6**) at each location. The times chosen will clearly establish the "knee" of the curve.

A.1.7 Prior to peening a production component, the intensity at saturation using two Almen strips shall be verified at each location, which will confirm the "t" (and 2 "t") values.

A.1.8 Periodic examination shall be performed on the Almen gauge (see **Fig 4**) to check its accuracy of calibration.

A.2 PEENING INTENSITIES

Examples of Peening Intensities for various materials are given in **Tables 6** and **7**.



“t” = Saturation Time
“X” = Minimum Intensity Required

Fig. 6 Determination of 'Saturation'

ANNEX A

Table 6: Guide to Peening Intensities

Material	Thickness mm	Intensity mm	Test Strip
Steel Rm≥1500 MPa + Carburized	> 6	0.40 - 0.50	A
Steel Rm≥1500 MPa + Carburized	3 - 6	0.30 - 0.40	A
Steel Rm≥ 1500 MPa + Carburized	< 3	Special advice to be sought	
Steel Rm≥ 1080 - 1500 MPa	> 6	0.40 - 0.50	A
Steel Rm≥ 1080 - 1500 MPa	3 - 6	0.30 - 0.40	A
Steel Rm≥1080 - 1500 MPa	< 3	0.20 - 0.30	A
Steel Rm< 1080 MPa	> 6	0.30 - 0.40	A
Steel Rm< 1080 MPa	3 - 6	0.20 - 0.30	A
Steel Rm< 1080 MPa	< 3	Special advice to be sought	
Titanium Alloys	> 3	0.20 - 0.30	A
Titanium Alloys	1.5 - 3	0.15 - 0.20	A
Titanium Alloys	< 1.5	Special advice to be sought	
Titanium Alloys Splines		0.25 - 0.35	A
Aluminium Alloys	> 2.3	0.10 - 0.20	N
Aluminium Alloys	< 9.5	0.20 - 0.30	N
Aluminium Alloys	> 9.5	0.30 - 0.40	N

NOTE 1: This table applies only where more specific requirements are not stated on the drawing, contract, order or the Process Control Schedule.

Note 2: See **Fig 1** for explanation of Peening Intensities.

Table 7: Guide to Peening Intensity for Spring Steel

Wire Diameter or Strip Thickness mm		Intensity mm	Test Strip	Nominal Shot Size mm
From	Up to & including			
3	4	0.25 - 0.35	A	0.40 - 0.60
2	3	0.15 - 0.25	A	0.25 - 0/45
1	2	0.30 - 0.40	N	0.15 - 0.30
0.2	1	0.20 - 0.30	N	0.09 - 0.20

ANNEX B

SATURATION

B.1 INTRODUCTION

B.1.1 As defined in **4.12**, 'saturation' is that condition which exists in an Almen test strip when doubling of the peening time causes a rise in the intensity value of not more than 10%. In terms of compressive residual stress in the surface of the test piece, saturation corresponds to the point where further peening induces only a small increase in stress level. This results from very nearly all of the surface having been impacted by the shot, i.e. 'coverage' is approaching 100%. Further peening serves only to ensure that these small areas which have not been struck receive impacts and, thereby, ensures that the residual stress distribution becomes more uniform.

B.1.2 At saturation, the Almen test strip curvature, i.e. the intensity, is an indication of the depth of the compressive residual stress in the test piece. Under saturation condition, higher impact energies will result in deeper penetration.

B.1.3 Thus, for any given intensity, saturation corresponds to the condition where the Almen test strip has a uniform distribution and consistent magnitude of the compressive residual stresses, and saturation corresponds to coverage which is very close to 100%.

B.1.4 The Almen test strip is an artificial notion when the peening of metals of different hardnesses is being considered. Softer materials will show larger indentations, and harder materials will show smaller indentations for a given shot energy. Saturation and nearly 100% coverage will thus occur earlier on soft materials than on the Almen test strip, and the reverse for harder materials. The primary purpose of the Almen strip is to measure the energy of the shot stream for process and Quality Control. For this measurement to be valid it is necessary to ensure that saturation occurs within a reasonable peening time.

B.1.5 Since the purpose of peening components is to ensure that a uniform distribution and reproducible level of compressive residual stress is induced in the surface, it is clear that saturation must be reached also in the component. Where the component material is of similar hardness to the Almen test strip, peening data obtained on test strips is applicable directly to the component. However, where marked differences in hardness between the component material and the test strip exist, some other method of determining the peening conditions for obtaining saturation in the component is required. Several methods are available, such as:

ANNEX B

(a) applying a suitable multiplication factor on the 'peening constant';
(b) use of test strips manufactured from the component material in place of standard Almen test strips;
(c) determination of saturation in the component by visual estimation of the time to produce complete coverage.

Each of these methods are in use and are described in clause **B.3**.

B.2 DETERMINATION OF SATURATION

B.2.1 General

The general principle of the procedure is shown in **Fig 6**. A series of test strips are peened for increasing durations using shot stream energies similar to those expected to be used on the component, and a plot of intensity against time is made. The point of saturation falls within the desired intensity when the shot stream energy is correct. Higher and lower shot energies produce plots with saturation points too high and too low respectively. Shot stream energy is adjusted until a satisfactory plot is obtained.

B.2.2 Procedure

B.2.2.1 The peening machine shall be set up with the nozzle or impellers arranged in the most suitable positions to give the requisite shot stream direction (peening angles) for the components. The nozzle or impellers shall be adjusted to give free and uninterrupted flow of shot. The machine shall be charged with shot of a suitable grade (see **13.5**) and set air pressure or impeller speed to a nominal initial level. Mechanical traversing speeds, where used, shall also be set to a nominal initial level.

B.2.2.2 Almen test strips of suitable type (A, C or N) shall then be positioned, preferably mounted on specially machined regions of a dummy component, to represent the most critical areas to be peened. Where manual peening has been agreed, a test strip mounted on a test strip fixture (**Fig 3**) shall be held in the shot stream in the same position as the component will be held.

B.2.2.3 The test strip(s) is (are) peened uniformly overall for a time which it is anticipated will be insufficient for saturation to occur. (In the case of mechanically traversed components the time may conveniently be one complete traverse.) The test strip is then removed from the test strip fixture or dummy component and the intensity is measured as described in **Annex A**.

B.2.2.4 The procedure in **B.2.2.3** is repeated for various multiples or sub-multiples of the peening time used, until the measured intensity ceases to increase.

ANNEX B

B.2.2.5 A plot is then prepared of intensity measured against time of peening (number of traverses) of the type shown in **Fig 6**. The test strip is also examined for uniformity and degree of coverage.

B.2.2.6 From the plot produced, the time to give saturation and the intensity at saturation can be determined. If the latter is not within the range specified for the item, the shot stream energy shall be raised or lowered, e.g. by higher or lower air pressure or impeller speed, larger or smaller nozzles, repositioning of shot stream, in whichever sense is appropriate. The procedure in **B.2.2.2** to **B.2.2.5** is repeated until the desired intensity at saturation is reached.

B.2.2.7 The uniformity of coverage of the test strips shall be satisfactory. Uneven coverage indicates that the shot stream traverses have been spaced too widely or that restrictions in the shot flow exist. Following any adjustments, re-determination of the saturation plot shall be made as required by **B.2.2.6**.

B.2.2.8 The peening conditions finally established can be used to provide data for the preparation of the Process Control Schedule using the peening constant method.

B.3 APPLICATION OF SATURATION DATA TO PEENING OF COMPONENTS

B.3.1 Where the component material is of similar hardness to the Almen test strip, peening data obtained is applicable directly to the component. Where marked differences in hardness exist between the hardness of the component and that of the test strip, one of the following methods shall be used.

B.3.2 Method (i) - Peening constant method - Standard test strip

B.3.2.1 In this method data obtained during the establishment of the saturation plot is used directly for determining the Process Control Schedule but a factor dependent upon the hardness of the components is used.

B.3.2.2 The shot stream energy conditions, i.e. shot size, velocity, nozzle size, air pressure, impeller speed, peening angles, etc are utilized by incorporating them directly into the Process Control Schedule. The only factor not established is the time of peening. Where the Almen test strips were mounted on a dummy component, and the whole component traversed through the shot stream(s), the basic time to be used can be measured in numbers of traverses required to reach saturation, i.e. "t" in **Fig 6**. Where the Almen test strips were mounted on a test fixture, the area peened in a given time, i.e. the peening constant, can be calculated as:

$$\text{peening constant} = \frac{\text{area of test strip } (1450\ \text{mm}^2)}{\text{time to reach saturation (t minutes)}}$$

knowing the area to be peened on the component the 'basic' time needed to peen the component can be calculated.

ANNEX B

NOTE: Care will be needed when items containing 'gaps' (e.g. U-shaped pieces) are mechanically traversed to take account of the portion of the traverse when the shot stream is not striking the component.

B.3.2.3 The basic time determined in **B.3.2.2**. is the minimum time to peen a component of hardness similar to the test strip to saturation at a specified intensity. Where the component is of this hardness, this basic time shall be recorded in the Process Control Schedule as the minimum time of peening or minimum numbers of traverses. For metals of appreciable different hardness, a material factor shall be used for multiplying the 'basic' time, and this factored time shall be used in the Process Control Schedule.

B.3.2.4 The material factor shall be derived from test data which have been produced by peening non-standard test strips in the material of the components to saturation under conditions similar to standard test strips. The material factor then becomes:

$$\frac{\text{time to peen non-standard material strips to saturation}}{\text{time to peen standard Almen strips to saturation}}$$

It should be noted that whilst this factor will be generally dependent on hardness it will vary from metal to metal due to different rates of work hardening. It may also vary with shot size and hardness.

B.3.2.5 In order to eliminate any effects of variations in the machine operation from component to component it is desirable to increase the shot exposure time by at least 20%. This additional exposure time may be incorporated in the material factor.

B.3.3 Method (ii) - Peening constant method - Comparable material test strips

B.3.3.1 In this method the uncertainties of material factors and material property differences compared with test strips are eliminated by replacing the Almen test strips with test strips of comparable material as the components to be peened.

B.3.3.2 The method of determining saturation points in **B.2.2** and the method of determining the 'basic' peening time of Method (i) in **B.3.2** is followed exactly except that the standard test strips are replaced by ones of comparable material to the item. The 'basic' peening time so determined is not factored but is used directly as calculated and recorded in the Process Control Schedule.

B.3.3.3 Non-standard material test strips may be of non-standard thicknesses if necessary but it will probably me more convenient to use thicknesses similar to standard test strip shown in **Fig 2**.

B.3.3.4 When non-standard material test strips are to be used the type of test strip required shall be stated on the component drawing and on the Process Control Schedule.

ANNEX B

B.3.4 Method (iii) - Visual coverage - Standard test strip

B.3.4.1 The principle of this method is that the shot stream energy is specified, established, controlled and monitored by means of standard test strips, but the point of saturation for the material is determined by visual estimation of the coverage obtained on the component after various peening times. It is dependent on the premise that saturation corresponds to 98% coverage.

B.3.4.2 The peening machine shall be set up as required for peening the component. Using standard Almen test strips, positioned on a dummy component or at a position representative of the component, the shot stream energy shall be adjusted in accordance with the procedure of **B.2.2** to produce a saturation intensity within the desired range.

B.3.4.3 A production component shall then be peened uniformly over the areas required to be peened using this shot stream energy, for a period of time less than that anticipated to be necessary, e.g. one traverse or one-quarter of the estimated time.

B.3.4.4 The surface of the component shall be examined visually and an estimate of the 'coverage' obtained. The component shall be replaced in the machine and peened for a further similar period and a further estimate of coverage made. These operations shall be repeated until it is clear that complete coverage has been reached and exceeded.

B.3.4.5 From a plot of the shot exposure time (or number of traverses) against coverage (which will be of similar form to **Fig 6**), the exposure time (base time) to achieve 98% coverage can be determined. This time corresponds to the minimum exposure time required to induce complete coverage in the component surface and may be used directly in the Process Control Schedule. However, in order to eliminate any effects of variations in the machine operation from component to component, it is desirable to increase the shot exposure time by a factor of at least 20%, i.e. to 120% of base time. Greater coverage may be defined in the drawing, contract or order, in which case the appropriate shot exposure time shall be given.

B.3.4.6 On the first production component the base time (98% coverage) is determined, the dummy component having served to adjust the intensity previously. The base time (or number of traverses or cycles) is increased to obtain complete coverage (see **B.3.3**) or coverage specified in the drawing, contract or order.

B.3.4.7 The first component (typical component) is the object of complete inspection which is repeated at the frequency defined in the Process Control Schedule and at the end of the run. The maintenance of intensity is verified periodically in peening the dummy component or test fixture equipped with Almen strips at specified locations.

ANNEX C

TEST FOR FREEDOM FROM IRON RESIDUE

C.1 OUTLINE

The purpose of the test is to detect readily soluble iron shot residues on metal surfaces where corrosion of such residues would be harmful to the operation of the item, e.g. aluminium alloys, titanium and its alloys, corrosion and heat resisting alloys. The test is based upon dissolving any iron contamination in dilute acid and detecting it as a blue precipitate of ferrocyanide.

C.2 MATERIALS OR APPARATUS

C.2.1 Degreasing agent such as ethyl or iso-propyl alcohol, butanone, etc.

C.2.2 5% by volume aqueous solution of hydrochloric acid.

C.2.3 10% by weight aqueous solution of potassium ferrocyanide.

C.2.4 Filter paper.

C.2.5 Dropper bottles.

C.3 PROCEDURE

C.3.1 Degrease the area to be tested by wiping with solvent.

C.3.2 Place a drop of 5% hydrochloric acid on the surface to be tested and leave for approximately 2 minutes.

C.3.3 Wet a filter paper with a drop of 10% potassium ferrocyanide and place the wetted area over the drop of hydrochloric acid on the surface being tested; note any colour change.

C.3.4 Rinse the area tested with water, dry, and re-apply oil or lanolin as a temporary protective coating.

C.4 VERIFICATION

A blue colour on the filter paper indicates the presence of iron. A deep blue colour indicates heavy contamination. However, on some alloys a very pale blue colour may occur in the absence of iron contamination, and a repeat test or an area or sample that is known to be contamination free may be necessary for comparison.

NOTE: Particular care must be taken when cleaning stainless steel to ensure complete removal of any chloride contamination.

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