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SPECIFICATION FOR ELECTROPLATED COATINGS OF CHROMIUM FOR ENGINEERING APPLICATIONS

SRI LANKA STANDARDS INSTITUTION

DRAFTING COMMITTEE ON ELECTROPLATING

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Draft Sri Lanka Standard

SPECIFICATION FOR ELECTROPLATED COATINGS OF CHROMIUM FOR ENGINEERING APPLICATIONS

FOREWORD

This Sri Lanka Standard was authorised for adoption and publication by the Council of the Sri Lanka Standards Institution on 85-11-14 after the draft finalised by the Drafting Committee on electroplating has been approved by the Mechanical Engineering Divisional Committee.

This standard applies to relatively thick chromium coatings, with or without undercoats, for engineering applications where those properties of chromium such as wear resistance, low coefficient of friction, and load bearing characteristics are important.

All values in this standard have been given in metric units.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or observation, shall be rounded off in accordance with CS 102. Number of figures to be retained in the rounded off values shall be the same as that of the specified value in this standard.

The assistance derived from the publications of the International Organization for Standardization, Standards Association of Australia, British Standards Institution and Indian Standards Institution in the preparation of this standard is greatefully acknowledged.

1. SCOPE

This standard specified requirements for electroplated coatings of hard chromium with or without undercoats on ferrous and non-ferrous metals for engineering applications.

2 REFERENCES

CS 102 Presentation of numerical values

SLS 689 Glossary of terms on electroplating and related processes

ISO 1463 Metallic and oxide coatings - Measurement of coating thickness - Microsoopical method

ISO 2177 Metallic coatings - Measurement of coating thickness - Columetric method by anodic dissolution.

ISO 2178 Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method.

ISO 2819/1 Metallic coatings on metallic substrates - Electrodeposited and chemically deposited coatings - Review of methods available for testing adhesion.

ISO 4516 Metallic and related coatings - Vickers and knoop microhardness tests.

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3 DEFINITIONS

For the purpose of this standard the definitions given in SLS 689, and the following shall apply :

3.1 exfoliation : The process of falling away in flakes, layers or scales.

3.2 finished state : The condition of the item at the completion of all electroplating operations.

3.3 inspection batch : A collection of items from which a sample is to be reandomly drawn and inspected to determine compliance with the acceptance criteria.

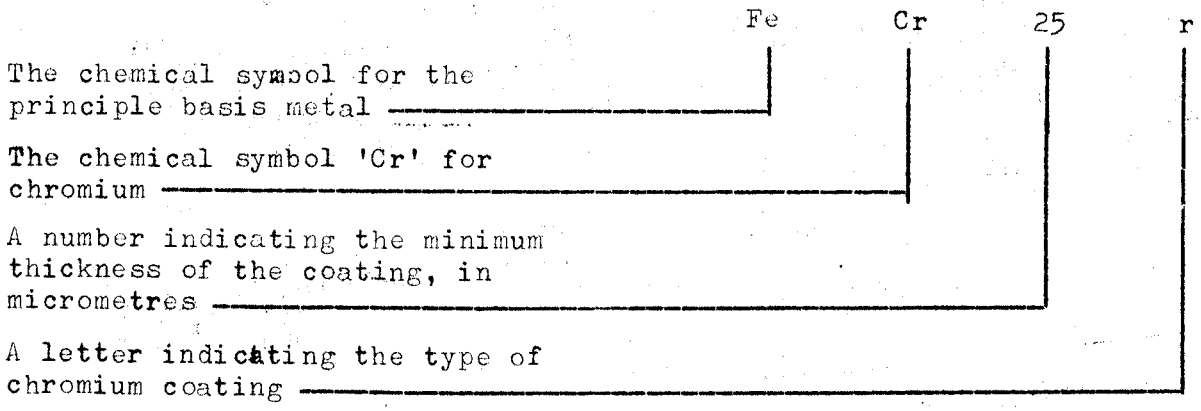
3.4 surface : The surface of the item on which the electroplater is to work.

3.5 significant surface : The part of the surface which is essential to the appearance or serviceability of the article and which is to be covered, or is covered, by the coating.

4 CLASSIFICATION

Chromium coatings are classified according to thickness and the type of coating.

The full classification code comprises the following :



NOTE - The above example shows the code for 25 µm of regular chromium on iron or steel.

Symbols for types of chromium coatings are as follows :

r - regular chromium coating

cf - crack-free type chromium coating

mp - micro porous chromium coating.

5 CONDITION OF THE ITEM BEFORE ELECTROPLATING

5.1 General

The significant surface shall be examined by the electrplater for visible surface defects, such as porosity, cracks and undersirable coatings or any other defects detrimental to the final finish. Any defects shall be brought to the attention of the customer prior to any processing.

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5.2 Surface finish

The surface finish of the item shall comply with the particular requirement of the customer, where any such requirements are so specified (see Appendix A).

NOTE - The surface finish may be important to the appearance or serviceability of the item and it is the customer's responsibility to provide precise details to the electroplater at the time of order.

5.3 Preplating condition

The item as delivered to the electroplater shall preferably be in a condition suitable for electroplating.

NOTE - If the item is to be supplied in a condition requiring mechanical pretreatment the details should be agreed between the customer and the electroplater (see Appendix A).

5.4 Treatment of basis metal before electroplating

Where the suseptibility to failure after electroplating is high due to residual tensile stresses, stress relieving heat treatment of such items are recommended.

Improvement of fatigue strength by the introduction of compressive stresses on to the surface of item by peening is recommended where necessary.

5.5 Stress relieving

Before being electroplated, parts shall, if specified, be stress relieved. The conditions set out in Table 1 shall normally be used, but different conditions, that is, suitable combinations of a shorter time at appropriate higher temperatures may be used if they have been shown to be effective. The heat treatment shall be carried out before tha commencement of any preparation or cleaning treatment using aqueous solutions.

TABLE 1 - Stress relieving conditions before electroplating

Maxified specified tensile strength of steel, R_m (MPa)	Heat treatment
$R_m \leqslant 1050$	None required
$1050 < R_m \leqslant 1450$	1 h minimum at between 190° and 220 °C
$1450 < R_m \leqslant 1800$	18 h minimum at between 190 and 220 °C
$R_m > 1800$	24 h minimum at between 190 and 220 °C.

If stress relief is performed after peening or other cold working processes, the temperature shall not exceed 220 °C. Parts with surface-hardened areas shall be stress relieved at 130 to 150 °C for not less than 5 h, but shorter times at higher temperatures may be used if the resulting loss of surface hardness of the substrate is acceptable.

Steels which have been chemically or electrically stripped of old coatings shall be heat treated within 6 h of stripping, as follows :

a) Steel parts having tensile strength of 1050 MPa or above .....3h at 190° - 220 °C

b) Caburized steel parts .....5h at 130° - 150 °C

Stress relieving heat treatment is not normally required for non-ferrous metals.

5.4.2 Peening

The peening should be applied to surface(s) to be plated and to all adjacent zones of high stress concentration, provided that the increased surface roughening resulting from peening is acceptable or can be removed by grinding.

NOTES

1. Points of high stress occur where there are notches, fillets and abrupt changes of contour.

   The intensity of peening should be such that when measured in accordanc with the procedure given in Appendix D the minimum are height should be not less than the following and be of uniform appearance :

   a) for items made of steel having a tensile strength of less than 1100 MPa ..... 0.3 mm.

   b) for items made of steel having a tensile strength of 1100 MPa or above ..... 0.4 mm.

2. Lower intensities of peening may be necessary on thin sections ; however, in such cases peening may not be fully effective in avoiding a loss of fatigue strength.

   Where grinding after peening and before plating is required, the minimum thickness of metal necessary to achieve any specified surface finish should be removed. Generally this thickness should not be more than 75 µm.

   Steels having tensile strengths of 1050 MPa or above are liable to hydrogen embrittlement during the plating process and should be heat treated, without loss of fatigue strength, at low temperature (see clause 8) after peening and plating.

   For non-ferrous metals, the peening intensity shall be agreed between the customer and the electroplater.

6 COATING REQUIREMENTS

6.1 General

The chromium coating shall be electroplated and be of the specified type. Any part of the specified chromium thickness shall not be substituted by any underplate.

Items which are not subsequently machined shall be free from excessive nodulation and treeing at the edges and from imperfections detrimental to subsequent fabrication. There shall be no blistering or other signs of poor adhesion of the coating on any surface of an item.

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NOTE - On items where a contact mark is unavoidable, the position of th mark is subject to agreement between the customer and the electroplater (see Appendix A).

Electroplated items shall be clean and free from damage.

6.2 Appearance

6.2.1 Regular chromium

The chromium coating of regular chromium on any significant surface which is not required to be subsequently machined shall be bright and lustrous, continuous, smooth and free from plating defects such as blisters, exfoliation or unplated areas when examined at a magnification of 8X.

All plated items shall be free from cracks which are readily visible to the naked eye.

When tested in accordance with the procedure given in Appendix B thick coatings (over 50 µm) shall be free from cracks extending to the basis metal.

There shall be no pitting likely to affect the performance of the finished item.

6.2.2 Crack-free chromium

The chromium coating of crack-free chromium shall be smooth, even and essentially free from cracks.

When tested in accordance with the procedure given in Appendix B there shall be no cracks extending to the basis metal.

NOTES

1. Crack-free chromium coatings are not recommended in thickness exceedin 25 µm and should not be finished by grinding.

2. Heat treatment, as described in clause 8, may adversely affect the corrosion protection characteristics of this type of coating.

6.2.3 Porous chromium

The chromium coating of micro porous chromium which is produced either by mechanical, chemical or electro chemical treatment is to obtain an oil retaining surface. Micro porous coatings can be further classified into 4 types namely pin point, channel point, intermediate and mechanically produced honed type which are identifiable at a magnification of 50X. The method for the determination of the degree of porosity and criteria of acceptance shall be agreed between the customer and the electroplater.

These coatings shall be smooth, dense, uniform and free from plating defec which may affect their proper functioning or protective value.

Pits or unplated areas up to 1.5 mm in diameter, surrounded by an acceptab deposit of chromium may be present in any number, provided that in any 10 mm square, porosity, including pits, is not greater than 40 percent.

Pits or unplated areas greater than 1.5 mm in diameter, measured at the finished surface, surrounded by an acceptable deposit of chromium are subject to agreement between the customer and the electroplater (see Appendix A).

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Porous chromium coatings may be finished to final size by grinding, lapping, honing, or other such method, provided that the degree of smoothness produced complies with the acceptance criteria (see Appendix A). Colour variation shall not be a cause for rejection.

6.3 Partially coated surfaces

Where chromium is specified to be deposited on part of a surface only, the area not to be plated shall be free of coating (see Appendix A). Boundaries of such surfaces shall be free from beads, nodules, jagged edges and other inrregularities.

6.4 Coating thickness

The thickness requirement of the plating shall apply after all metal finishing and post plating grinding operations have been completed.

6.4.1 Regular chromium and crack-free chromium

Thickness of regular and crack-free chromium coatings shall comply with the appropriate thickness classification specified in Table 1 (see also Appendix A, Paragraph A.5)

Coating thickness may be called up by specifing the minimum thickness required, expressed in whole numbers, in micrometres (see clause 4).

TABLE 2 - Thickness of regular and crack-free hard chromium coatings*

Cr	3
Cr	5
Cr	10
Cr	15
Cr	20
Cr	25
Cr	30
Cr	40
Cr	50

thereafter in steps of 25 µm.

* For crack free chromium coatings thickness over Cr 25 are not recommended.

6.4.2 Porous chromium

Thickness of porous chromium coatings shall be not less than 125 µm.

NOTE - The customer should specify the required thickness if a coating thickness less than 125 µm is satisfactory (see Appendix A).

6.4.3 Allowance for build-up of coating

Where items are to be assembled after coating, such items shall be machined undersized before plating to allow for metal build-up during plating.

6.4.4 Thickness measurements

When determined in accordance with ISO, 1463, ISO 2177 or ISO 2178 as appropriate, the local thickness of chromium coating, assessed by taking the average of four determinations made on the significant surface at points selected at random, shall be not less than the specified thickness classification or other specified thickness.

NOTES

1. The method of ISO 1463 is not suitable for chromium thickness below 2 µm.

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2. The method of ISO 2177 should not be used for chromium thickness above 50 µm, unless provision is made to replenish the electrolyte.

3. The method of ISO 2178 is suitable only for the testing of relatively flat items with a magnetic substrate. Under optimum conditions the accuracy of the method is normally within ±10 percent of the true chromium thickness.

4. Alternative methods to those specified above are available, and may be used for routine testing by agreement between the customer and the electroplater (see Appendix A).

5. In some circumstances, items with insufficient coating or worn coatings may be reclaimed and recoated. Appendix C provides information on a suitable procedure.

6.5 Adhesion

The chromium coating shall be adherent on all plated areas. Aby evidence of separation of the chromium from any area of the substrate during any grinding or under moderate impact testing by say, light hammer blows, shall be grounds for rejection. The test method to be used is subject to agreement between the customer and the electroplater.

NOTE = The following methods are given in ISO 2819, for testing hard chromium deposits :

Bending test
Thermal shock test
Grinding or sawing test
Chisel test.

6.6 Hardness

When tested in accordance with ISO 4516, the hardness of the chromium deposit shall be not less than 600 HV.

NOTE - Other hardnesses are subject to agreement between the customer and the electroplater (see Appendix A).

6.7 Porosity of porous chromium

Unless otherwise specified, the extent of surface porosity shall be within the range of 20 percent to 40 percent of the area coated, assesment of porosity being carried out at a magnification of 50X after all metal finishing have been completed.

7 SEPERATE SPECIMENS

Where a direct determination of any particular property of the coating cannot be carried out, separate specimens shall be used. Unless otherwise agreed, the basis metal shall be the same as that of the items being plated.

The separate specimens shall be introduced at regular intervals into the production batches of the items they are to represent. Separate specimens shall be introduced prior to the initial cleaning process, preliminary to plating and shall not be separated from a production batch until the entire process is complete.

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8 HEAT TREATMENT AFTER ELECTROPLATING

8.1 General

If required by the customer, heat treatment after electroplating shall be performed as described in 8.2 or 8.3 . The heat treatment shall be performed as soon as possible and not later than 4 h after electroplating and before any grinding or other mechanical finishing operation.

8.2 Heat treatment of steels for reduction of hydrogen embrittlement

The heat treatment of electroplated steel articles for the reduction of hydrogen embrittlement shall be in accordance with the requirements given in Table 3, but heat treatment at 400 to 480 °C is applicable only to parts that are liable to fatigue failure in service.

Articles shall not be heat treated above their tempering temperature.

Unpeened parts may be heated for shorter periods at a higher temperature, if the conditions have been shown to be effective (see clause 5.4 and the Note to Table 3).

Parts having surface-hardened areas shall be heated at 130 to 150 °C for not less than 5 h or at a higher temperature if the resultant loss of hardness of the substrate is acceptable.

TABLE 3 - Treatment of steels after electroplating

Maximum specified tensile strength of steel, R_m (MPa)	Heat treatment for reduction of hydrogen embrittlement a) of unpeened parts not subject to fatigue ; b) for all peened parts	Heat treatment for reduction of hydrogen embrittlement and restoration of fatigue strength of unpeened parts only*
$R_m \leqslant 1050$	None required	1h minimum at between 400 and 480 °C
$1050 < R_m \leqslant 1450$	2h minimum at between 190 and 220 °C	1h minimum at between 400 and 480 °C
$1450 < R_m \leqslant 1800$	6h minimum at between 190 and 220 °C	1h minimum at between 400 and 480 °C
$R_m > 1800$	18h minimum at between 190 and 220 °C	1h minimum at between 400 and 480 °C

* Treatment at 400 to 480 °C will reduce the hardness of the chromium coating and may also reduce the hardness of the steel.

8.3 Heat treatment of aluminium and aluminium alloys to improve adhesion

It should be noted that the mechanical properties of some aluminium alloys may be adversely affected by heating. If heat treatment can be carried out and is required to give the desired adhesion on aluminium or aluminium alloys, the electroplated articles shall be heated in air to give a temperature rise of 2 to 3 K/min until a temperature of 130 to 140 °C is attained. This temperature shall then be maintained for a period of not less than 2 h and not more than 3 h.

9 SAMPLING

The number of articles to be tested to determine compliance with the specification shall be determined by agreement between the plater and the customer. .....

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APPENDIX A

SUPPLEMENTARY INFORMATION TO BE SUPPLIED WITH THE ENQUIRY OR ORDER

A.1 General

The Sri Lanka Standard Specification for electroplated coatings of chromium for engineering applications does not include all the necessary provisions of a contract. The customer shall state his requirements explicitly.

Information contained in this Appendix is aimed at preventing misunderstandings and at promiting greater accuracy in the electroplating and purchasing of electroplated components covered by this standard.

It should result in the customer's receiving satisfactory electroplated products and service.

A.2 Supplementary information

To enable the electroplater to comply with the requirements of this standard, the customer should supply the following information at the time of enquiry or order or should agree with the electroplater on details, as appropriate:

a) Specification or nominal composition of basis metal, and information on-

   i) Metallurgical condition of the item at the time of delivery ;

   ii) Any mechanical pre treatments required such as the type of any build up by hot metal spraying or welding.

b) Type of chromium to be applied, the coating classification and the reference number of this Sri Lanka Standard, i.e. SLS .....

c) Details of any strike or under coat treatment required.

d) Details of significant surfaces and of any surface that are not to be plated and of any areas on which the chromium deposit may be allowed to extend.

e) Details of any limiting dimension, if applicable.

f) Type, size, extent and location of surface defects that can be tolerated.

g) For porous chromium, any limiting range of porosity if applicable and the coating thickness if less than 125 µm.

h) Whether heat treatment is to be applied before and/or after plating and, if so, by what process (see clause 5 and 8) and whether shot-peening before plating is required.

j) The final finish of the chromium coating, i.e. as-plated or ground or other specified surface finish, such as one treated for oil retention. For ground finishes surface roughness value shall be given, if a specified final surface finish is required.

k) Whether separate specimens are required for testing, together with information concerning size, shape and thickness of separate specimens (see clause 7).

l) Details of special test methods, sampling plan for acceptance testing and arrangements for referee inspection in the event of dispute (see clause A.6)

m) Additional information, as applicable.

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A.3 Stress relieving

Steel items which have been severely cold worked or steels having a tensile strength of 1050 MPa or above which have been ground or subjected to severe machining after tempering shall be heat treated for stress relieving, before plating. As a guide they may be maintained for 1 h preferably at the highest temperature that can be applied without adversely affecting their strengths, for example, for heat treated steels at a temperature of about 25 °C below that used for tempering.

Some steels which have been carburized flame hardened or induction hardened and subsequently ground would be impaired by higher temperature stress relief treatment, and shall instead be stress relieved at a lower temperature. For example, at 130 °C to 150 °C for not less than 1 h.

A.4 Shot-peening

Where fatigue is a consideration, shot-peening prior to plating is recommended for steels which cannot be heat treated in the temperature range 440 °C to 480 °C without a loss of temper, or for items for which heat treatment in this range would lower the hardness of the chromium coating to an unacceptable level (see Table 4).

TABLE 4 - Effect of heat treatment for 2 h to 6 h on the hardness of electroplated chromium

Temperature °C	residual hardness HV
200	800 - 900* small drop
400	650
500	600
600	420
700	300
800	250

*as deposited

A.5 Thickness of coating and use of undercoats

A.5.1 General

The actual thickness of chromium required will depend upon service conditions, and to some extent upon the hardness and surface condition of the basis metal.

Conditions of service may vary from non-corrosive through to mildly corrosive and severely corrosive ; from mildly abrasive to severely abrasive ; and from lightly loaded to heavily loaded.

Items to be coated may be new, or may be worn, but are required to be retained for service by recoating. Most items for coating are steel, but they may be made of aluminium or other metal.

Under these conditions it is important to have close liaison between designers, manufacturers and the electroplater in order to obtain satisfactory electroplating and to avoid adverse effects on the mechanical properties of the item.

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The following paragraphs provide guidance on the thickness of chromium to be used for different conditions of service (see also clause 6) :

a) Where anti-stick properties are required

A coating of 2.5/um to 5/um is beneficial on moulds used in the plastics industry, to provide a surface which permits ease of release of mouldings.

A flash coating of the order of 0.5/um of chromium on some cutting tools, such as taps, dies and drills, improves the working life by preventing swarf from adhering to the tool.

b) Where wear resistance only is required

The thickness will depend upon the degree of wear resistance required. As a guide, a minimum thickness of 12/um will give increased performance under low load sliding conditions because of the low co-efficient of friction of the coating. Under heavy conditions of loading, or in the presence of abrasives, a heavy coating of up to 250/um or more is often required.

Deposits of 50/um thick have been used extensively on rams for use in hydraulic equipment.

c) Where both corrosion resistance and wear resistance are required

The minimum thickness of coating to withstand mildly corrosive conditions of service should be not less than 50/um and not less than 75/um to withstand severe conditions of service.

d) Where worn or overmachined items are to be reclaimed

Where items have been used in service and are required to be reclaimed, consideration should be given to the detection of cracks prior to coating.

Complete removal of chromium from worn chromium plated items and from items with insufficient chromium is recommended before recoating. However, subject to approval by the customer, worn or undersized chromium coatings may be built up without stripping. Where the basis metal has been exposed or the undercoat is likely to be exposed during the recoating process, complete removal of the chromium is necessary to achieve satisfactory adhesion (see also clause 5.3).

A.5.2 Undercoats

Where a build-up greater than 375/um is required, financial considerations may necessitate the use of a nickel undercoat. In such cases an undercoat of 250/um of nickel or more after grinding is recommended. In any event the final thickness of chromium coating thickness should be not less than 100/um and preferably not greater than 250/umm

A.5.3 Finishing to size

Where size limitations are specified, it is important to allow for additional chromium coating to permit grinding to size. The actual finished size dimensions should be specified on the purchase order or in a dimensioned drawing of the item.

A.6 Sampling and inspection

Before processing is commenced, the customer and the electroplater should agree upon a sampling plan for the inspection and testing. The sampling plan may be on the basis of either continuous flow or the separation of coated items into inspection batches.

Any agreement should include the following :

a) The size of the batch

b) The number of samples to be selected for testing and retesting

c) Acceptance criteria

d) Procedures to be followed for referee inspection.

APPENDIX B

FERRICYANIDE POROSITY TEST-PAPER METHOD

B.1 Scope

This appendix sets out a method for the determination of gross porosity in metallic coatings on ferrous substrates by recording pore sites on treated paper.

B.2 Application

The method is suitable for quality control testing of metallic coatings which are cathodic to steel.

B.3 Principle

The test relies on the passage of basis metal ions originating from corrosion cells in pores in the metallic coating being retained on a filter paper which has been treated with sodium chloride. These ions from a coloured reaction product on the filter paper when immersed in a ferricyanide indicator solution.

B.4 Reagents

The following test reagents are required :

a) Gelatine solution - 50g sodium chloride
50g white gelatine
Water to make 1 l
Temperature - approx. 35 °C

b) Chloride solution - 50g sodium chloride
1g non-ionic wetting agent
Water to make 1 l
Temperature - ambient

NOTE - A wetting agent such as nonyl phenol ethylene oxide condensate (ICI Teric N9) is known to perform satisfactorily.

c) Indicator solution - 10g potassium ferricyanide
Water to make 1 l

B.5 Preparation of test areas

Test areas shall be free of foreign matter and, if necessary, shall be degreased in a suitable solvent.

B.6 Procedure

The coating shall be assessed for porosity as follows:

a) Immerse strips of filter paper in the gelatine solution. Remove and allow to dry.

b) When required for use, immerse treated filter papers in the chloride solution, remove and apply to the test area. Press down firmly so that the filter paper makes good contact with the test area.

c) Allow to stand for 10 min. During this period do not allow the filter paper to dry out ; if necessary apply fresh chloride solution to the filter paer in situ by means of an appropriate eye dropper or from a dropping bottle.

d) Remove the filterpaper from the test area and immediately immerse in the indicator solution for 2 s to 3 s to develop any ferrous ions transferred from the basis metal through pores in the coating, and use the filter paper for assessment.

B.7 Assessment of test

A pore site is indicated by the presence of a blue coloured spot on the filter paper.

B.8 Test report

The test report shall include the following information :

a) Test piece identification

b) Relevant product or coating standard

c) Result of the test, i.e. number of pores

d) Report numer and date.

APPENDIX C

RECLAMATION OF WORN CHROMIUM ELECTROPLATED ITEMS AND OF ITEMS ELECTROPLATED WITH INSUFFICIENT CHROMIUM

Before reclamation, consideration should be given to the need for crack-detection of items. Complete removal of the chromium from worn items and from items with induffieient chromium is recommended before electroplating to this standard.

Nevertheless, with special pretreatment, worn or undersized sound chromium coatings may be built up without stripping. This should be carried out after cleaning and anodic etching in the electroplating bath at normal electroplating current density for 10s to 20s. The direction of the current flow shall then be immediately reversed and normal deposition commenced. However, this method should not be used if it is likely that the basis metal or undercoat will be exposed during anodic treatment in the electroplating bath.

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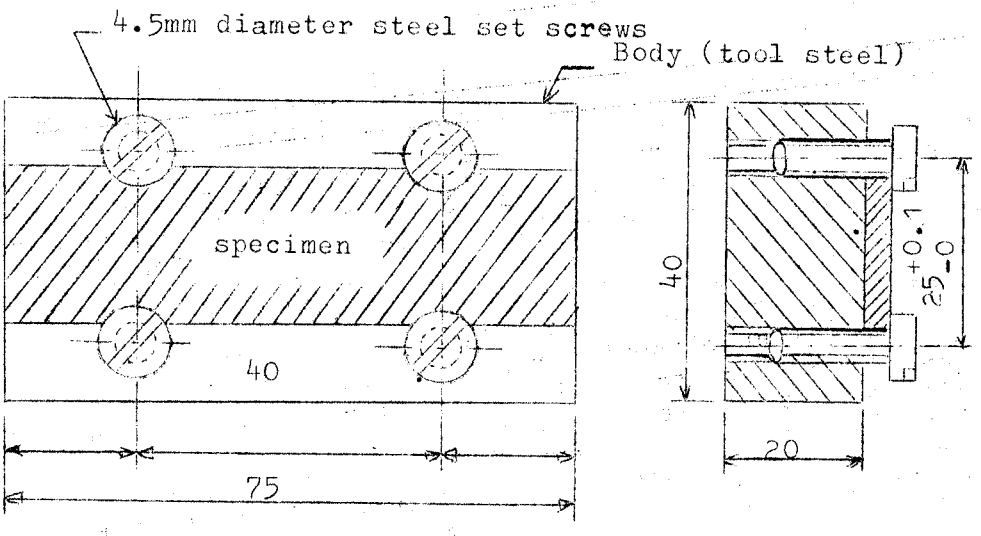
APPENDIX D

METHOD FOR ESTABLISHING SHOT PEENING CONDITIONS

Use a test specimen from carbon steel sheet hardness range 400 HV 30 to 500 HV 30 and thickness of 1.6 mm, which has been cut to a size of 75 mm x 20 $^{+0}_{-0.2}$ mm and ground to a thickness of 1.3 $\pm$ 0.02 mm.

The deviation from flatness shall not exceed an arc height of 38 µm when measured as described below. With the specimen rigidly held in the fixture shown in Fig. 1 peen it on the exposed side.

After peening, remove the specimen from the fixture and measure the curvature of the unpeended surface with a depth gauge, the specimen being su supported on four 5 mm diamter balls forming a rectangle 32 mm x 16 mm. Align the gauge symmetrically on the specimen with its centre stylus at the centre of the specimen. Measure the arc height at the centre of the speciment over the gaguge length of 32 mm, measuring to the nearest 25 µm.. The conditions of peening are then adjusted, if necessary, to give the required arc height.



All dimensions are in mm.

Fig. 1 - Fixture for peening test specimens