SAE INTERNATIONAL

AEROSPACE MATERIAL SPECIFICATION

AMS2438	REV. E
Issued 1987-01 Revised 2015-03 Superseding AMS2438D	

(R) Plating, Chromium Thin, Hard, Dense Deposit

RATIONALE

AMS2438E results from a Five Year Review and update of this specification.

NOTICE

ORDERING INFORMATION: The following information shall be provided to the plating processor by the purchaser.

1) Purchase order shall specify not less than the following:

- AMS2438E
- Plating thickness desired (See 3.4.1)
- Basis metal to be plated
- Tensile strength or hardness of the basis metal
- Pre-plate stress relief to be performed by plating processor (time and temperature) if different from 3.1.2
- Special features, geometry or processing present on parts that requires special attention by the plating processor. Shot peening requirements and parameters if specified.
- Hydrogen embrittlement relief to be performed by plating processor (parameters or reference document) if different from 3.3.1
- Minimum thickness on internal surfaces, if required (See 3.4.1.2)
- Optional: Periodic testing frequency (4.2.2) and sample quantity (4.3.2)
- Quantity of pieces to be plated
- Part number

2) Parts manufacturing operations such as heat treating, forming, joining and media finishing can affect the condition of the substrate for plating, or if performed after plating, could adversely affect the plated part. The sequencing of these types of operations should be specified by the purchaser or cognizant engineering organization and is not controlled by this specification.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS2438E

1. SCOPE

1.1 Purpose

This specification covers the requirements for thin, hard, dense electrodeposited chromium plating on surfaces of ferrous and nonferrous alloys.

1.2 Application

This plating has been used typically to provide improved lubricity, wear and/or corrosion resistance to selected materials but usage is not limited to such applications. This process does not provide sacrificial corrosion protection as with cadmium, zinc or zinc nickel plating. (See 8.6)

1.3 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS6330	Steel Bars, Forgings, and Tubing, 0.65Cr - 1.25Ni (0.33 - 0.38C)
AS2390	Chemical Process Test Specimen Material

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B117	Operating Salt Spray (Fog) Apparatus
ASTM B253	Preparation of Aluminum Alloys for Electroplating
ASTM B487	Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section
ASTM B499	Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals
ASTM B504	Measurement of Thickness of Metallic Coatings by the Coulometric Method
ASTM B567	Measurement of Coating Thickness by the Beta Backscatter Method
ASTM B568	Measurement of Coating Thickness by X-Ray Spectrometry

ASTM B571 Qualitative Adhesion Testing of Metallic Coatings

ASTM B748 Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope

ASTM D2625 Endurance (Wear) Life and Load-Carrying Capacity of Solid Film Lubricants (Falex Pin and Vee Method)

ASTM D4060 Abrasion Resistance of Organic Coatings by the Taber Abraser

ASTM E376 Measuring of Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

ASTM E384 Knopp and Vickers Hardness of Materials

ASTM F519 Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

2.3 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ANSI B46.1 Surface Texture

2.4 U.S. Government Publications

Copies of these documents are available online at http://quicksearch.dla.mil.

FED-STD-141 Paint, Varnish, Lacquer, and Related Materials; Methods for Testing of

3. TECHNICAL REQUIREMENTS

3.1 Preparation

3.1.1 Surface texture of functional surfaces shall be 16 microinches (0.40 µm) Ra or smoother determined in accordance with ANSI B46.1.

3.1.2 Stress Relief Treatment

3.1.2.1 All steel parts having a hardness of 36 HRC and above and that are machined, ground, cold formed or cold straightened after heat treatment shall be cleaned to remove surface contamination and thermally stress relieved before plating. (Residual tensile stresses have been found to be damaging during electroplating.) Furnaces used for stress relief shall be controlled per AMS2750; the minimum requirements shall be Class 5, with Type D Instrumentation. Temperatures to which parts are heated shall be such that stress relief is obtained while still maintaining hardness of parts within drawing limits. Unless otherwise specified, the following treatment temperatures and times shall be used:

3.1.2.1.1 For parts, excluding nitrided parts, having a hardness of 55 HRC and above, and for carburized and induction hardened parts, stress relieve at 275 °F ± 25 (135 °C ± 14) for 5 to 10 hours.

3.1.2.1.2 For parts having a hardness less than 55 HRC, and for nitrided parts, stress relieve at 375 °F ± 25 (191 °C ± 14) for a minimum of 4 hours. Higher temperatures shall be used only when specified or approved by the cognizant engineering organization.

3.1.2.1.3 For peened parts: If stress relief temperatures above 375 °F (191 °C) are elected, the stress relieve shall be performed prior to peening or the cognizant engineering organization shall be consulted and shall approve the stress relief temperature.

3.1.3 The plating shall be applied over a surface free from water breaks. The cleaning procedure shall not produce pitting or intergranular attack of the basis metal and shall preserve dimensional requirements. See 8.5.

3.1.4 Aluminum alloys shall be zincate treated in accordance with ASTM B253 or other method acceptable to the cognizant engineering organization prior to plating.

3.2 Procedure

3.2.1 Parts shall be plated by electrodeposition of chromium onto a properly prepared surface directly on the basis metal without a coating of other metal underneath, except that a preliminary plating of nickel or copper 0.00005 inch (1 µm), maximum, is permissible on aluminum and titanium alloys.

3.2.2 Spotting-in is not permitted.

3.3 Post Treatment

3.3.1 Hydrogen embrittlement relief (baking) of steel parts shall be performed in accordance with AMS2759/9.

3.4 Properties

The plating shall conform to the following requirements:

3.4.1 Thickness

The finished thickness shall be as specified, determined on representative parts or test panels in accordance with ASTM B487, ASTM B499, ASTM B504, ASTM B567, ASTM B568, ASTM B748, ASTM E376, or other method acceptable to the cognizant engineering organization. When a single thickness value is specified, the applicable tolerance shall be in accordance with Table 1 (See 8.13).

Table 1A - Thickness tolerances, inch/pound units

Thickness Range Inch	Tolerance, Inch plus and minus
Up to 0.0001	0.00001
Over 0.0001 to 0.00025	0.000025
Over 0.00025 to 0.0006	0.00005

Table 1B - Thickness tolerances, SI units

Thickness Range Micrometers	Tolerance, Micrometers plus and minus
Up to 2.5	0.25
2.5 to 6.3	0.63
6.3 to 15.0	1.3

3.4.1.1 The plating shall be substantially uniform in thickness on significant surfaces except that slight build-up at exterior corners or edges will be permitted provided drawing dimensions are met.

3.4.1.2 All surfaces of the part, except those that cannot be touched by a sphere 0.75 inch (19 mm) in diameter, shall be plated to the specified thickness. Unless otherwise specified, surfaces such as holes, recesses, threads and other areas where a controlled deposit cannot be obtained under normal plating conditions, may be under the specified limit provided they show visual plating coverage.

3.4.2 Hardness shall be 900HV100 or higher (or equivalent), determined on a metallographic cross section in accordance with ASTM E384. Plating thickness for determination of microhardness shall be 0.001 inch (0.025 mm) thick minimum in order to produce valid test impressions.

3.4.3 Adhesion

Adhesion shall meet the requirements of ASTM B571 by the Bend Test method with no mandrel. When examined at 3 to 5X magnification, there shall be no evidence of internal delamination or loss of adhesion from basis metal. The formation of cracks in the plating or the basis metal which do not result in flaking, peeling or blistering of the plating shall not be cause for rejection.

3.4.4 Abrasion and wear resistance shall be such that the plating passes either one of the following tests:

3.4.4.1 Three standard Taber specimens, cleaned, plated, and post-treated in the same manner as the parts represented shall, after 5000 cycles, show a wear index based on the weight-loss method of less than 1.2 average, or 6 milligrams, for three tests, determined in accordance with FED-STD-141, Method 6192, or ASTM D4060 using CS-10 wheels or equivalent approved by the cognizant engineering organization, each subjected to a 1000 gram load. Conditioning of the panels under temperature-humidity controls per ASTM D4060 prior to Taber abrasion is not required. Taber panels may be prepared to remove microscopic surface glaze by subjecting the test panel to an initial abbreviated Taber abrasion test of up to 2500 cycles. If performed, the panels shall subsequently be re-weighed, Taber abrasion tested for the full 5000 cycles and shall show a wear index based on the weight loss method of less than 1.2 average, or 6 milligrams, for three tests (See 3.5.2 and 8.12).

3.4.4.2 An AMS6330 steel pin, cleaned, plated, and post-treated with the parts represented shall show an average endurance life of 60 minutes minimum and an average weight loss of 2 milligrams/hour maximum for three tests, determined in accordance with ASTM D2625, using a Falex lubricant tester, or equivalent approved by cognizant engineering organization and a 750 pound (340 kg) gage load in additive-free, white mineral oil, U.S.P. 18. The 96 degree V-blocks shall be 50 HRC minimum and shall not be coated or treated.

3.4.5 Corrosion Resistance and Porosity on Steel

Thin dense chrome plating shall be as free from surface imperfections as possible, such that a uniform, tightly adherent barrier coating is produced. See 3.5.1 and 8.6. Although not capable of providing sacrificial corrosion protection as with some other metallic plating systems, the thin dense chrome shall provide a capability to protect the basis metal from corrosion when tested by either one of the following methods:

a) Plated carbon and alloy steel parts or test panels (4.3.3) having a plating thickness of 0.0005 inch (13 µm) maximum, shall show no visible evidence of corrosion of the basis metal after being subjected for not less than 50 hours to a continuous salt fog corrosion test conducted in accordance with ASTM B117.

or

b) Plated carbon and alloy steel parts or test panels, having a plating thickness of 0.0005 inch (13 um) maximum shall show no visible indications (blue) when subjected to the potassium ferricyanide (ferroxyl) porosity test below.

Plated low alloy steel parts or low steel specimens shall be evaluated. Note: Panels subjected to distortion or flexing during processing can exhibit cracking or crazing type indications, so care should be exercised to prevent such false indications. All specimen surfaces shall be cleaned to remove any oil or grease. Contamination removal shall be accomplished with a solvent acceptable to the purchaser. A sheet of filter paper or other suitable adsorbent paper, saturated in the ferroxyl solution shall be applied for 10 minutes to the flat surface of the specimen or the article. Complete contact of the filter paper with the chrome plated test specimen shall be ensured using strokes with a soft bristle brush. Filter paper shall be kept saturated during the duration of the 10 minute test. Pits, pores, or cracking of the chrome are revealed by dark blue spots or lines. For a permanent record, the filter paper may be dried. The approximate solution composition shall be as follows:

Potassium ferricyanide ($K_3Fe(CN)_6$) 1 gm

Sodium Chloride (NaCl) 10 gm

Water (distilled or deionized) to make 1 liter

c) Imperfections as noted in 3.5.1 that result in positive test indications from a) or b) above shall not be cause for rejection.

3.4.6 Hydrogen Embrittlement

The plating process after baking shall not cause hydrogen embrittlement in steel parts 36 HRC and over determined in accordance with 4.3.3.4.

3.5 Quality

Plating, as received by purchaser, shall be smooth, continuous, free from delamination within the plating, uniform in appearance and, except as noted in 3.5.1 and 3.5.2, shall be free from imperfections detrimental to usage of the plating. Plating shall be visually free from frosty areas, pin holes, porosity, blisters, nodules, and pits. Slight staining or discoloration shall be acceptable.

3.5.1 Pinholes and other imperfections which can be shown to be the result of failure of the plating to bridge or fill imperfections in the surface of the base metal, such as acceptable levels of porosity in a casting are acceptable.

3.5.2 Thin dense chrome deposits can exhibit a surface glaze which is acceptable provided the abrasion-wear resistance requirements of 3.4.4 are met. (See 8.12)

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The processor shall supply all samples for processor's tests and shall be responsible for the performance of all required tests. Parts, if required for tests, shall be supplied by purchaser. The cognizant engineering organization reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that processing conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Thickness (3.4.1), and quality (3.5) are acceptance tests and shall be performed on parts, or samples representing parts when permitted herein (See 4.3.3.2.1), from each lot.

4.2.2 Periodic Tests

Hardness (3.4.2), abrasion resistance (3.4.4), and corrosion resistance, porosity (3.4.5) are periodic tests and shall be performed at least monthly unless frequency of testing is specified by the cognizant engineering organization. Tests of cleaning and processing solutions are periodic tests and shall be performed at a frequency established by the processor unless frequency of testing is specified by the cognizant engineering organization. See 8.7 and 4.4.3. Adhesion (3.4.3) is a periodic test that shall be performed no less than daily for each generic class of alloy as defined by AS2390 processed during that day. Hydrogen embrittlement (3.4.6) is a periodic test and shall be performed in accordance with ASTM F519 at least once in each month that steel parts 36 HRC and over are plated unless frequency of testing is specified by the cognizant engineering organization.

4.2.3 Preproduction Tests

All property verification tests (See 3.4) are preproduction tests and shall be performed prior to production and when the cognizant engineering organization requires confirmatory testing.

4.3 Sampling for testing shall not be less than the following; a lot shall be all parts of the same part number, plated to the same range of plate thickness in the same solutions in each eight hours of continuous production, and presented for processor's inspection at one time.

4.3.1 Acceptance Testing

Test samples shall be selected randomly from all parts in the lot. The minimum number of samples shall be as shown in Table 2 unless the cognizant engineering organization provides a differing quantity or sampling plan.

Table 2 - Sampling for acceptance tests

Number of Parts in Lot	Quality	Thickness
up to 7	All	All or 3*
8 to 15	7	4
16 to 40	10	4
41 to 110	15	5
111 to 300	25	6
301 to 500	35	7
501 to 700	50	8
701 to 1200	75	10
over 1200	125	15

*Whichever is less

4.3.2 Periodic Tests

Sample size shall be four (4) panels for corrosion resistance and porosity, one (1) for hardness, four (4) for hydrogen embrittlement as specified in ASTM F519 unless otherwise specified by the cognizant engineering organization, and three (3) for abrasion and wear resistance. For adhesion tests, four (4) test specimens of each generic class of alloy, as defined by AS2390, that have been be processed through the same cleaning and plating operations as the parts that they represent. These adhesion test specimens shall be processed prior to the first production lot of parts or with the first production lot of parts.

4.3.3 Sample Configuration

4.3.3.1 Nondestructive testing shall be performed wherever practical and where authorized herein. Except as noted below, actual parts shall be selected as samples for tests. Correlation of results on panels to parts for characteristics that differ from parts, such as thickness, must be established.

4.3.3.2 Thickness, Hardness, and Adhesion Tests

4.3.3.2.1 Separate test specimens for thickness made of the alloy established in accordance with AS2390, cleaned, plated, and post treated with the parts represented may be used when plated parts are of such configuration or size as to be not readily adaptable to the specified tests, or when nondestructive testing is not practical on actual parts, or it is not economically acceptable to perform destructive tests on actual parts.

4.3.3.2.2 Separate test specimens may be used for hardness, and should be from an alloy established in accordance with AS2390. A greater plating thickness on microhardness test panels is required to obtain a valid test result. Hydrogen embrittlement relief (baking) is not required of hardness test specimens.

4.3.3.2.3 Separate test specimens for adhesion tests, shall be made of the same generic class of alloy as defined by AS2390 processed. The test specimens shall be 0.025 inch (0.6 mm) minimum thickness and not less than 1 x 4 inches (25 x 102 mm).

4.3.3.3 Corrosion Tests

Corrosion testing shall be performed on separate low carbon or low alloy steel panels approximately 4 x 1 inch (102 x 25 mm) and 0.025 inch (0.64 mm) thick minimum or bars approximately 0.5 inch (13 mm) in diameter and 4 inches (102 mm) long. Surface texture shall be not rougher than 16 microinches (0.40 µm) RHR, determined in accordance with ANSI B46.1.

4.3.3.4 Hydrogen Embrittlement Test

Test shall be in accordance with the requirements of ASTM F519 Type 1a.1 using round notched specimens, unless a different specimen is specified by the cognizant engineering organization, stressed in tension under sustained load. For test purposes, the plating thickness, as measured on the smooth section of the specimen, shall be the same thickness as the parts normally processed or 0.00004 to 0.00025 inches as a default, but with visual plating at the root of the notch. Testing beyond the 200 hour test period is not required. When parts to be plated are fabricated from an alloy for which AMS2759/9 requires a baking temperature lower than 375 °F (191 °C), test specimens shall be baked at the same temperature for 96 hours.

4.4 Approval

4.4.1 The process and control factors or a preproduction part, or both, whichever is specified, shall be approved by the cognizant engineering organization before production parts are supplied.

4.4.2 If the processor makes a significant change to any material, process, or control factor from that which was used for process approval, all preproduction tests shall be performed and the results submitted to the cognizant engineering organization for process reapproval unless the change is approved by the cognizant engineering organization. A significant change is one which in the judgment of the cognizant engineering organization could affect the properties or performance of the parts.

4.4.3 Control factors shall include, but not be limited to the following:

Surface preparation
Plating bath composition and composition control limits
Plating bath temperature limits and controls
Thermal post treatment times and temperatures
Method for determining plating thickness
Method of adhesion test
Pretreatment, plating voltage/current
Method of stripping (if required)
Periodic test plan for cleaning and processing solutions. See 8.7.

4.5 Reports

The processor shall furnish with each shipment a report stating that the parts have been processed and tested in accordance with the specified requirements and that they conform to the acceptance tests requirements. This report shall include the purchase order number, lot number, AMS2438E, part number, and quantity.

4.6 Resampling and Retesting

4.6.1 If any acceptance test fails to meet specified test requirements, the parts in that lot may be stripped, pretreated, plated, and post treated as defined herein and retested. Alternatively, all parts in the lot may be inspected for the nonconforming attribute, and the nonconforming parts may be stripped, pretreated, plated, post treated as defined herein, and retested.

4.6.1.1 When stripping is performed, the method shall be acceptable to the cognizant engineering organization and shall not roughen, pit, or embrittle the basis metal or adversely affect part dimensions. When parts have been stripped and replated, the purchaser shall be informed.

4.6.2 If any periodic test fails to meet specified test requirements, the process is nonconforming. No additional parts shall be plated until the process is corrected and new specimens are plated and tested. Results of all tests shall be recorded and, when requested, reported. Purchasers shall be notified of all parts plated since the last acceptable test. Alternatively, adhesion test failures on plated parts may be dispositioned as specified in 4.6.1.

5. PREPARATION FOR DELIVERY

5.1 Plated parts shall be handled and packaged to ensure that the required physical characteristics and properties of the plating and parts are preserved.

5.2 Packages of plated parts shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the parts to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

The processor shall mention AMS2438E in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Parts on which the plating does not conform to this specification or to modifications authorized by the cognizant engineering organization will be subject to rejection.

8. NOTES

8.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Parts manufacturing operations, such as heat treatment, forming, joining, and media finishing, can affect the condition of the substrate for plating, or, if performed after plating could adversely affect the plate. The sequencing of these types of operations should be specified by the cognizant engineering organization and is not controlled by this specification.

8.3 The parts manufacturer should ensure that surfaces of metal parts supplied to the processor are free from blemishes, pits, tool marks, or other irregularities that will affect the quality of the finished parts. Defects and variations in appearance that arise from surface conditions of the substrate, such as porosity, scratches, or inclusions that persist in the furnished plate despite observance of industry accepted plating practices would not be considered as cause for rejection.

8.4 The purchaser should ensure that exterior corners and edges are broken to prevent excessive edge buildup.

8.5 An acid dip may be used for surface activation or neutralization of residual alkaline cleaners. However, the immersion time should be minimized, as measured in seconds, to preclude pitting and hydrogen embrittlement.

8.6 Although not capable of providing sacrificial corrosion protection as with some other metallic plating systems, the thin dense chrome should provide a minimal capability to protect the basis metal from corrosion. Supplementary treatments such as oil or chromate dip can enhance thin dense chrome plate ability to provide barrier corrosion protection.

8.7 ARP4992, Periodic Test Plan for Process Solutions, is recommended to satisfy the requirements for control of processing solutions.

8.8 Terms used in AMS are clarified in ARP1917. ASTM B374 “Standard Terminology Relating to Electroplating” should be utilized as a reference and referee document when areas of design definition or technical interpretation arise.

8.8.1 Plating is intended to be deposited in an uninterrupted process except as may be required by the operator for making thickness measurements. After the plate has dried, resumption of plating can result in detectable visual discontinuities or weak interlaminar adhesion that may not be readily apparent. Such resumption of plating is known as 'double plating' and localized addition of plate is known as 'spotting-in.'

8.9 This plating process alters the product dimensions. Compliance with dimensional tolerances affected by the plating process requires communication of manufacturing planning information between the part fabricator and the plating processor. The cognizant engineering organization should specify the stage at which the plating thickness and the product dimensions (e.g., threads, features) apply, such as: before plating, as-plated, or after metal removal operations that are to follow plating.

8.10 The purchaser is expected to provide the processor with a properly dimensioned part that allows for the change in dimensions expected from the process. The purchaser should also provide any special instructions that may need to be observed concerning plating thickness or plated part dimensions.

8.11 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.12 Taber Abrasion

Some thin dense chrome (TDC) plating baths, proprietary or generic, can produce a microscopic surface glaze as measured in microns, with diminished wear characteristics. The cognizant engineering organization shall determine the acceptability of this characteristic and the need, if any to additionally prepare the as-plated surface by grinding, honing, liquid honing, lapping, polishing or other suitable means to condition the TDC surface prior to delivery. The existence of this surface glaze is many times detected by the results of a Taber abrasion test (See 3.4.4.1).

8.13 Thin dense chrome plate can be used for widely varying applications, with typical plating thicknesses between 0.00025 and 0.0006 inches. For some applications such as anti-friction rolling element bearings, etc., thicknesses between 0.00004 and 0.00025 inches can produce crack free chrome plating, enhancing rolling contact fatigue and corrosion resistance.

PREPARED BY AMS COMMITTEE "B"