AEROSPACE MATERIAL SPECIFICATION

AMS-C-81769	REV. A

Issued 1998-06
Reaffirmed 2008-05
Stabilized 2015-01

Superseding AMS-C-81769

Chemical Milling of Metals, Specification for

RATIONALE

AMS-C-81769 has been declared “STABILIZED” by AMS Committee B. This document will no longer be updated and may no longer represent standard industry practice.

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NOTICE

This document has been taken directly from U. S. Military Specification MIL-C-81769 and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace MIL-C-81769. Any part numbers established by the original specification remain unchanged.

The original Military Specification was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Under Department of Defense policies and procedures, any qualification requirements and associated qualified products lists are mandatory for DOD contracts. Any material relating to qualified products lists (QPL's) has not been adopted by SAE and is not part of this technical report.

1. SCOPE:

1.1 This specification covers the requirements for surface metal removal of ferrous and non-ferrous metals by milling processes using controlled immersion of parts in chemical etching solutions.

2. APPLICABLE DOCUMENTS:

The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-I-6866	Inspection, Penetrant, Method of
MIL-I-6870	Inspection Requirements, Nondestructive, For Aircraft Materials and Parts
MIL-T-9046	Titanium and Titanium Alloy, Sheet, and Plate
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
FED-STD-151	Metals; Test Methods

2.2 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 5545	Plate, Sheet and Strip, Alloy-Nickel Base, 19 Cr, 11 Co, 10 Mo, 3 Ti, 1.5 Al, Vacuum Melted, Solution Heat Treated

2.3 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 117	Salt Spray (Fog) Testing
ASTM E 8	Tension Testing of Metalic Materials
ASTM E 290	Semi-Guided Bend Test for Ductility of Metallic Materials

2.4 ANSI Publications:

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI B 46.1	Surface Texture

3. REQUIREMENTS:

3.1 Materials:

3.1.1 Etchants: Etchants, their compositions and control temperatures, are usually considered proprietary information. The criteria for an etchant shall be a uniform reaction on the work piece, good surface finish, reasonable temperature range and a feasible analytical control. The etchants may be modified by additives, concentration, and temperature to provide the best results for a particular metal or metallurgical condition. The etchants shall not downgrade the chemical and mechanical properties of the parts.

3.1.2 Maskants: Any suitable masking material may be used provided no detrimental effects are produced on the work and complete protection is provided in the masked areas from etchants. After processing, the maskant material shall be capable of complete removal without leaving any discoloration or residue.

3.2 Chemical milling application:

3.2.1 Metal preparation: Heat treatments and mechanical operations such as shearing and forming should be performed before articles or parts are chemically milled. Normally sufficient trim should be allowed on each part for handling lugs or tooling holes common for chemical milling and for post chemical milling operations. Holes that would add to the complexity of processing should be avoided. All burrs and sharp corners shall be removed from parts to prevent mask failure.

3.2.2 Cleaning: The surfaces and adjacent areas of all parts to be chemically milled shall be thoroughly cleaned to remove all oil, grease, paint, pencil markings, drawing or cutting lubricants, dirt, scale, artificial oxide, rust film, and other foreign substances. Cleaning shall be in accordance with MIL-S-5002. The cleaning materials and processes shall not damage the metal to be cleaned, shall perform their intended function and shall not interfere with subsequent operations.

3.2.3 Masking: After all metal preparation and cleaning operations, the articles or parts shall be masked. Maskants shall be applied to provide a continuous, impermeable chemical resistant coating free from air bubbles, pinholes, cuts and other defects. The masked parts shall be cured and cooled to room temperature prior to scribing or cutting through the masked area with a tool. A templet may serve as a guide. Care should be taken to avoid cutting the mask beyond the area to be etched. The depth of the basis metal cut, caused by scribing, shall be kept to an absolute minimum. Cutting the basis metal to any great depth can result in ridging at the base of the undercut fillet during etching. This condition shall be avoided to prevent rejection. The masking material shall then be stripped or removed from the areas to be chemically milled or etched.

3.2.3.1 Other masking techniques: Screening or photoresist techniques should be used for shallow milling of relatively small parts that require greater dimensional accuracy or finer detail than that of the scribe-and-peel maskant method.

3.2.4 Application: Parts shall be etched or chemically milled by controlled time of immersion in solutions that are controlled for their chemical reaction with the various metals (see 3.1.1). Parts shall be positioned, racked or suspended in such a manner as to avoid entrapment of gases, which can prevent attack on the areas to be etched or which can interfere with dissipation of heat from masked areas, to prevent sludge settlement on the parts, and to allow good solution circulation over the parts.

3.3 Quality:

3.3.1 Workmanship: Parts, contoured, shaped, or formed by chemical milling, shall be processed using metals and alloys in a careful and workmanlike manner. The part shall be uniformly etched and shall be free from roughness, sharp edges, ridging, pitting, distortion and other evidences of poor workmanship that will render the parts unsuitable for the purposes intended. Defects in quality of workmanship as detailed in 3.3.8 and the subparagraphs thereof shall be considered as failure and shall be cause for rejection of the part, unless it can be repaired within acceptable tolerances or reclaimed prior to final inspection.

3.3.2 Appearance: The parts shall be finished clean and free from processing residues that may cause subsequent discoloration and corrosion. The finished surface shall be free from pits, dents, scratches and other evidence of irregular etchant action. Scratches which can be noticeably felt with the finger nail shall be cause for rejection. Light scuff marks and minor abrasive marks are acceptable. Unevenness of edges due to masking imperfections shall not be considered as pits. Pitting on trim areas which will subsequently be removed from the parts shall not be considered objectionable.

3.3.3 Surface roughness or finish: Unless otherwise specified, surface roughness or finish of fatigue critical parts shall not be in excess of 125 microinches (roughness height). Surface roughness or finish of all other parts shall not be greater than 200 microinches (roughness height).

3.3.4 Raised area: Raised areas or small islands, created by residual maskant or insufficient etching action, shall be removed by mechanical methods such as filing, sanding or grinding provided that the method utilized shall be suitable for the intended purpose. Removal shall not adversely affect mechanical properties and the specified dimensional tolerances or increase susceptibility to corrosion.

3.3.5 Line definition: Line definition is the extent to which the actual etched straight line deviates from the ideal etch line. Perfect masking should produce a clean straight edge, however, there will be deviation due to cutting or imperfection in masking. The edge of unmilled area, as shown in Figure 1, may be uneven and is acceptable provided the total variation does not vary from the ideal line by more than ±0.030 inch.

3.3.6 Fillet radii: Fillet radii should not be specified for chemically milled parts as radii are inherent and fixed by the process itself. Radii will vary with material, heat treatment, temper, depth of cut and grain direction of the part material. Reworking of fillet of chemically milled area shall be permissible to obtain conditions for compliance with the requirements of the applicable drawing. Power operated rotary files and grinding devices as well as abrasive papers may be used for any reworking. When fillet radii are required for clad aluminum alloy parts, the clad coatings in areas to be chemically milled may be removed prior to processing, if necessary.

3.3.7 Sharp edges: No sharp edges, corners or projections shall be present. They shall be removed for acceptance. Sharp edges shall be broken to a radius of 0.005 to 0.030 inch or to a curved or flat surface of suitable comparable dimensions by being faired smoothly into the adjacent surfaces. Grinding of edges and fillets of chemically milled areas will be permissible provided susceptibility to corrosion is not increased and mechanical properties of the material are not affected.

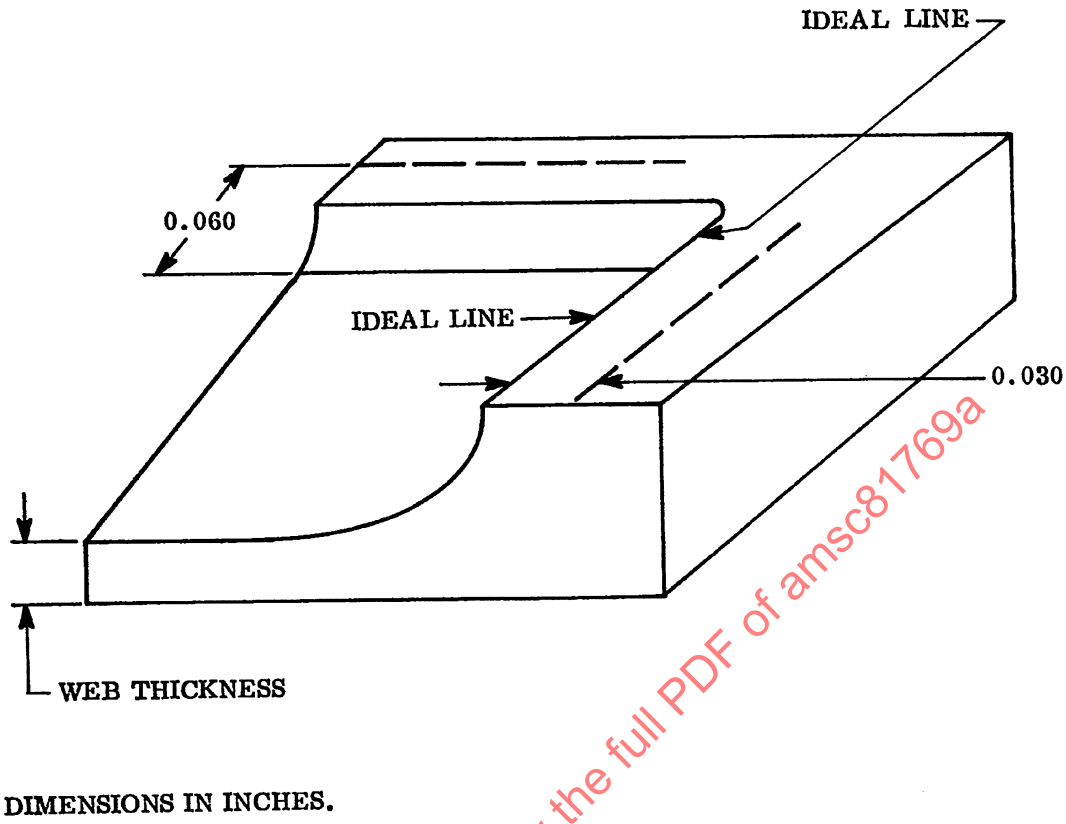


Figure 1. Line definition

3.3.8 Defects:

3.3.8.1 Channeling: This defect, as illustrated in Figure 2-A, is the formation of a channel or groove at the base of the fillet. This condition is undesirable but is acceptable provided that it can be corrected by mechanically blending the undercut as shown in the figure so that all required dimensions shall be within the specified tolerances.

3.3.8.2 Gas channeling: This surface condition, as illustrated in Figure 2-B, is the result of bubbles of hydrogen or other gases ascending to the surface of the etch bath. The resultant formation of vertical grooves or channels in the etched areas shall be cause for rejection unless corrected by approved mechanical means and all dimensions are within the specified tolerances.

3.3.8.3 Dishing: Dishing, as illustrated in Figure 2-C, is acceptable provided all required dimensions shall be within the specified tolerances. Dishing is thinning of the central portion of the metal remaining after milling. This defect is the result of increased etching rate from side to center and may be due to improper agitation, racking, or temperature control of the etchant. The thickness of the metal at the thinned central portion shall be not less than the specified minimum web thickness.

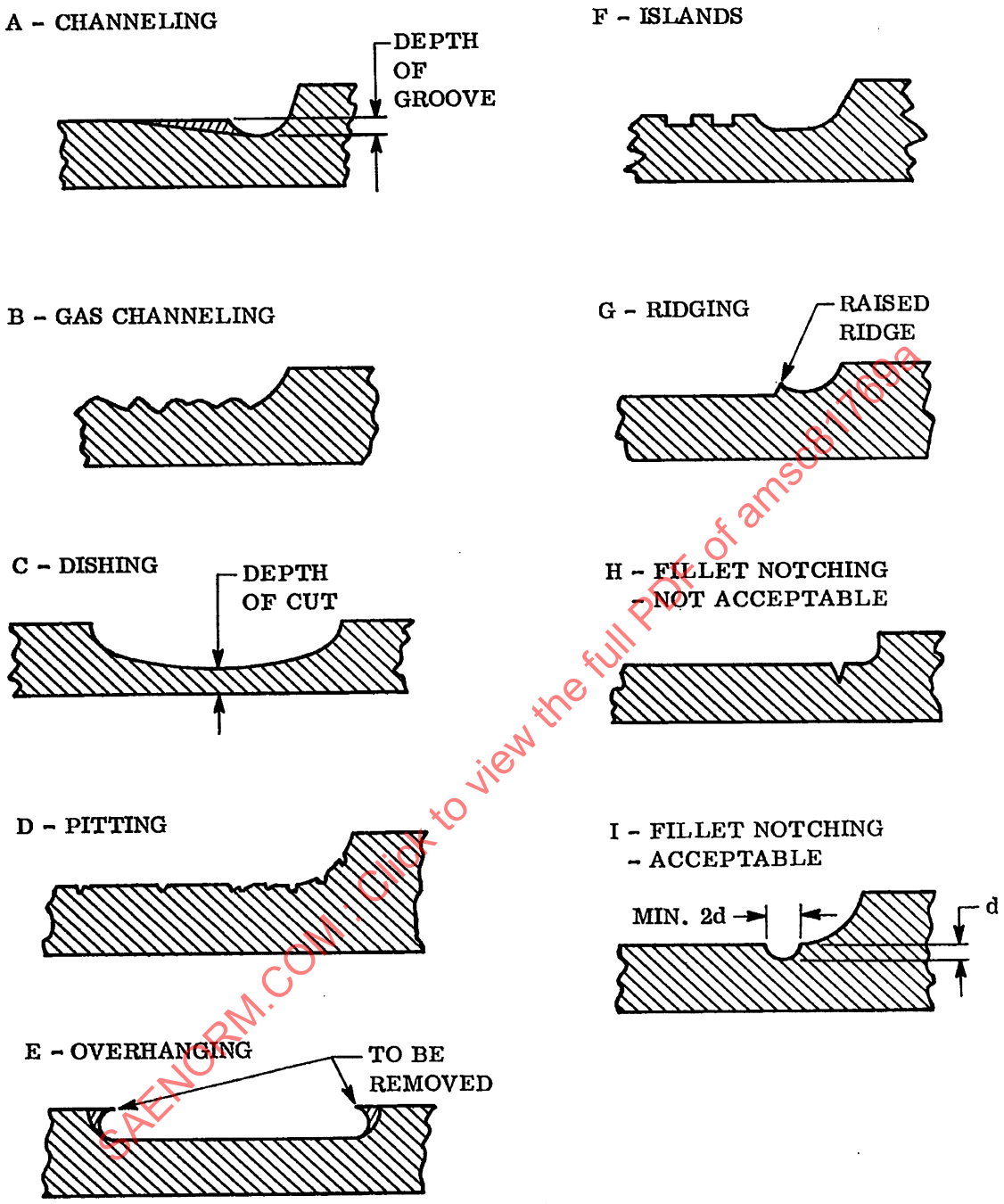


Figure 2. Defects

3.3.8.4 Pitting: Pitting appears as pits or depressions formed in the etched area. This defect, as illustrated in Figure 2-D, shall be cause for rejection unless the condition can be remedied by mechanical means within the tolerance specified for each required dimension.

3.3.8.5 Overhanging: The presence of overhanging metal over the etched area, as illustrated in Figure 2-E, is undesirable and shall be cause for rejection. The overhanging metal shall be not greater than 0.003 inch. However, when the overhang is cleared off by mechanical means, the part shall be acceptable provided that all required dimensions shall be within the specified tolerances.

3.3.8.6 Islands: This defect is the result of unwanted masking action of dirt or particles of maskant which remain on the surface to be etched. It appears as high spots within the etched area, as illustrated in Figure 2-F, due to a non-uniform etching rate. This surface condition shall be cause for rejection unless the islands are removed by approved mechanical means and all dimensions are within specified tolerances.

3.3.8.7 Ridging: This defect, as illustrated in Figure 2-G, is the formation of a raised ridge at the base of the fillet. This condition is undesirable. It can be acceptable provided the ridge is removed by mechanical means and all required dimensions shall be within the specified tolerances.

3.3.8.8 Fillet notching: Fillet notches or scratches, which are the result of scribing too deeply, shall be allowed provided that the chemical milling has reduced the scratch from a sharp notch, as illustrated in Figure 2-H, to a smooth depression at the bottom of the fillet which blends into the surrounding surface, as illustrated in Figure 2-I. The thickness of the metal part at the root of such a depression shall be within the specified tolerances. The diameter of the depression shall be not less than twice the depth of the fillet notch.

3.4 Corrosion resistance properties:

The parts shall be finished clean and free from processing residues that may cause subsequent corrosion and discoloration. The materials used for chemical milling shall not result in any attack of the metal surface showing intergranular attack, preferential attack upon grain boundaries or weldments, pitting or other metal degradation, except as noted below. Unless otherwise specified, daily determination for this behavior shall be made in accordance with MIL-S-5002, using a microscopic method and examination of the part at a magnification which will clearly establish the conditions. However, when intermittent milling conditions exist, the frequency of examination shall be reduced accordingly but shall be not less than weekly intervals. Parts with pitted surfaces or showing intergranular attack shall be rejected.

3.4.1 Aluminum and aluminum alloys: Intergranular attack resulting from the chemical milling of aluminum and aluminum alloys, when examined in accordance with 4.5.1.3, shall be not greater in depth than 0.0008 inch on grain boundaries or weldments. On grain ends (fillet area) the attack shall not exceed a depth of 0.0015 inch, except for alloys 2024 and 6061 where a depth of 0.0025 inch shall be acceptable.

3.4.2 Titanium and titanium alloys: Intergranular attack resulting from the chemical milling of titanium and titanium alloys, when examined in accordance with 4.5.1.3, shall be not greater in depth than 0.0003 inch on the grain boundaries or weldments. On the grain ends (fillet area), the attack shall not exceed a depth of 0.0005 inch.

3.4.3 Ferrous materials: Preferential attack resulting from the chemical milling of ferrous materials, when examined in accordance with 4.5.1.3, shall be not greater in depth than 0.0003 on the grain sides or weldments. On the grain ends (fillet area), the attack shall not exceed a depth of 0.0005 inch.

3.4.4 Nickel and cobalt alloys: Preferential attack resulting from chemical milling of nickel and cobalt alloys, when examined in accordance with 4.5.1.3, shall be not greater in depth than 0.0005 inch at the grain boundaries or in connection with any of the defects detailed in 3.3.9. With material conforming to AMS 5545 the intergranular attack shall not exceed 0.001 inch in depth.

3.5 Mechanical properties:

The mechanical properties of the metal parts, as detailed in the applicable material specifications, shall not be downgraded or decreased by chemical milling except for those precipitation hardening stainless steels and nickel base alloy whose properties are lowered in some conditions. The acceptable ultimate and yield strength, as well as the minimum acceptable percentage elongations for these materials shall be as specified by the procuring activity. When specified, milled parts shall be examined for ultimate tensile strength, yield strength, elongation, bending, etc. (see 6.2).

3.6 Hydrogen contamination:

The hydrogen contents of titanium and titanium alloy parts after chemical milling shall not exceed the limit as stated in the applicable material specification if the thickness of the remaining metal is 0.040 inch or greater. If the remaining metal thickness after chemical milling has been reduced to less than 0.040 inch, the allowable limit shall not exceed 0.025 percent or introduce over 0.004 percent hydrogen into the parts, whichever is less, provided the increased hydrogen content does not adversely affect the material properties. Hydrogen contents above the specified limits shall be cause for rejection of processed parts unless the procuring activity will permit salvaging of such parts by vacuum annealing. Hydrogen absorption for other metals shall be as specified by the procuring activity.

3.7 Stress relief treatment:

Unless otherwise specified, metals and alloys susceptible to hydrogen embrittlement shall be stress relieved prior to chemical milling. Such parts, of steels and nickel base alloys, having an ultimate tensile strength of 150,000 pounds per square inch (psi) and above, which are machined, ground, cold formed or cold straighten, shall be given a stress relief heat treatment at a minimum of 375 ±25°F for 3 hours or more prior to chemical milling. The temperature and time at temperature shall be such that maximum stress relief is obtained without reduction in hardnes to less than the specified minimum.

3.8 Hydrogen embrittlement relief:

Unless otherwise specified, ferrous parts having a hardness of Rockwell C40 and higher shall be baked at a minimum of 375 ±25°F for 3 hours or more, within 4 hours after chemical milling, to provide hydrogen embrittlement relief. The baked parts, when tested in accordance with 4.5.5.2 shall not crack or fail by fracture. When specified in the contract or order, conformance to the requirements for freedom from hydrogen embrittlement shall be determined on those parts which will be subjected to a sustained tensile load in use (see 6.2).

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for inspection:

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplier and services conform to the prescribed requirements.

4.1.1 General: The supplier's cleaning, pretreatment and chemical milling equipment and all details relating to the chemical milling operations shall be subject to inspection by an authorized representative of the procuring activity who shall be given all reasonable facilities to determine conformance to the requirements of this specification. The chemical milling of various alloy products and parts made therefrom shall be subject to such control and regulations by competent personnel as necessary to produce the desired properties.

4.2 Classification of inspection:

The inspection requirements specified herein are classified as follows:

(a) Production control inspection (see 4.3).
(b) Quality conformance inspection (see 4.4).

4.3 Production control inspection:

4.3.1 Control records: When specified in the contract or order (see 6.2), the chemical milling processor shall maintain a record of each processing tank or bath in the chemical system showing all additions of replenishing or regenerating chemicals, of all analyses performed. Upon request of the procuring activity, such records shall be made available. These records shall be maintained for not less than one year after completion of the contract or purchase order.

4.3.2 Production control: The equipment, materials used, procedures and operations employed by a processor shall be capable of performing high quality chemical milling of aluminum and aluminum alloys, titanium and titanium alloys, ferrous alloys, high strength steels, nickel base alloys, cobalt base alloys, magnesium alloys, refractory metals, etc. as specified in this document or in the contract or purchase order. Upon request of the procuring activity, such capability shall be demonstrated by the processor. Sufficient periodical, analytical inspection shall be conducted in accordance with recommended procedures of the suppliers of the etchants, maskants and other chemical materials. If any tank or other equipment is not used for production in accordance with this specification for a period of three months or longer, the production control inspection tests (see 4.3.3), in addition to the above, shall be conducted at the beginning of reuse. Failure to adequately demonstrate capability of production control to produce satisfactory chemical milled parts conforming to the requirements contained herein shall be cause for disapproval of the chemical milling facilities for processing various metal parts.

4.3.3 Frequency of tests: At least once every six months, or more frequently if required by the procuring activity, specimens or parts shall be prepared and tested in accordance with Table I to assure the suitability of the processor's equipment and milling procedures and to observe the lack of any detrimental effects upon the milled materials. The results of quality conformance inspection, made to determine conformance of chemically milled materials to all requirements of this specification (including destructive testing) and to the requirements of the respective parts specification for definite contracts or orders, are acceptable as evidence of the properties being obtained with equipment and procedures employed for the semi-annual testing.

4.3.4 Production control specimens: Test specimens for production control shall be prepared in accordance with 4.5.1.1, 4.5.2.1, 4.5.3.1, 4.5.4, and 4.5.5.1 as applicable for the tests detailed in Table I. Specimens for dimensions, tolerances and surface roughness shall be production items. When the work or parts are of such form, size, shape and value as to prohibit use thereof, or are not readily adaptable to the test specified herein, representative samples of the same material, composition and heat treatment shall be provided. Such samples shall be processed by chemical milling throughout all processing stages with the parts they represent and unless otherwise specified should be of the same cross-sectional dimensions.

4.4 Quality conformance inspections:

4.4.1 Lot: A lot shall consist of all parts of the same design and kind; fabricated from metal of the same composition, type, form, size and thickness; processed during one continuous production period and submitted for inspection at one time.

4.4.2 Sampling for visual examination and nondestructive tests: Sampling for visual examination and nondestructive tests shall be in accordance with MIL-STD-105, Inspection Level II, Acceptable Quality Level (AQL) of 1.5 percent defective by random selection from each lot.

TABLE I
PRODUCTION CONTROL TESTS AND SPECIMENS

Test	Materials	Requirement Paragraph	Specimen Preparation Paragraph 1/	Test Reference Paragraph
Corrosion Tests				
Salt Spray Resistance	All	3.4	4.5.1.1	4.5.1.2
Intergranular Resistance	All	3.4, 3.4.1, 3.4.2, 3.4.3 and 3.4.4	4.5.1.1	4.5.1.3
Tension Tests	All	3.5	4.5.2.1	4.5.2.2
Bend Tests	All	3.5	4.5.3.1	4.5.3.2
Hydrogen Contamination	Ti and Ti alloys	3.6	4.5.4	4.5.4
Embrittlement Relief	Ferrous Parts of Rockwell C40 and higher	3.8	4.5.5.1	4.5.5.2

1/ Specimens or parts shall be visually examined in accordance with 4.4.3.1, dimensionally inspected as stated in 4.4.3.2 and tested for surface roughness as stated in 4.4.3.3.

4.4.3 Inspection and test: Inspection and test procedures shall be in accordance with the requirements of MIL-I 6870 and as specified herein. The lot shall be accepted or rejected according to the procedures of 4.4.3.1 for visual examination, of 4.4.3.2 for dimensional inspection and 4.4.3.3 for surface roughness.

4.4.3.1 Visual examination: Chemically milled parts and articles shall be visually examined to determine the quality and finish of the product as specified in 3.3, 3.3.1, 3.3.2, 3.3.4, 3.3.5, 3.3.7 and 3.3.8. Fluorescent or dye penetrants in accordance with MIL-I-6866 procedures may be used as inspection aids. All indicated flaws shall be checked visually at 5 to 10 power magnification.

4.4.3.2 Dimensional inspection: Samples shall be inspected for compliance with dimensional requirements of 3.3.5, 3.3.6, and 3.3.8, as well as those of applicable drawings and specifications.

4.4.3.3 Surface roughness: The surface roughness or finish of samples shall be evaluated to determine conformance to 3.3.3. Test procedures as detailed in ANSI B 46.1, using suitable test equipment, shall be utilized.

4.4.3.4 Sampling for destructive tests: Unless specified in the contract or order (see 6.2), destructive testing shall not be required for quality conformance inspection. A random sample of parts shall be taken from each lot or separately prepared specimens (see 4.3.4) shall be taken to represent each lot for each specified test as required or stated in the contract or order (see 6.2). Samples for destructive examinations shall be as detailed in 4.5.1.1 for the corrosion test, in 4.5.2.1 for tension tests, in 4.5.3.1 for bend test, in 4.5.4 for hydrogen contamination and in 4.5.5.1 for embrittlement relief.

4.5 Test Methods:

4.5.1 Corrosion tests:

4.5.1.1 Specimen preparation: Four specimens for corrosion resistance tests shall be prepared from the same material used for the part (see 4.3.4). Specimens should be approximately 6 inches long, 3 inches wide and the thickness of the part. Specimens shall be processed with the lot including masking. Prior to etching, the maskant shall be stripped from one half the specimen area. Specimens shall be chemically milled to the same depth as the deepest cut required for the part. At the option of the supplier, specimens may be prepared from tabs on the edges of the part or from trim areas.

4.5.1.2 Salt spray corrosion resistance: Two of the specimens, prepared in accordance with 4.5.1.1, shall be stripped of all maskant and shall be subjected to a 5 percent salt spray test in accordance with ASTM B 117. Specimens shall be exposed for 20 hours, unless another exposure period is specified by the procuring activity. After exposure test pieces shall be cleaned in warm running water, blown dry with clean dry air and the exposed area compared with unexposed area for any evidence of differential attack, pitting or other metal degradation to determine conformance to 3.3.2 and 3.4.

4.5.1.3 Intergranular corrosion resistance: The remaining two specimens, prepared in accordance with 4.5.1.1, shall be stripped of the maskant. These as well as the two specimens tested in accordance with 4.5.1.2 shall be used for determination of intergranular corrosion resistance for compliance with 3.4. At least two small cross-sectional specimens shall be prepared from each test piece, from each of the different treated areas, for microscopic examination at 100X magnification. For aluminum alloys, the intergranular corrosion test shall be in accordance with Fed. Test Method Std. No. 151, Method 822.

4.5.2 Tension tests:

4.5.2.1 Specimen preparation: Twelve test specimens shall be prepared in accordance with ASTM E 8 from the same metal as the part (see 4.3.4). Six of the specimens shall be prepared with the axis of the specimen (load direction) parallel to the longitudinal directions and the remainder shall be prepared with the axis of the specimen parallel to the long transverse direction. Three longitudinal and three transverse specimens shall be processed through all operations so that they will be chemically milled to the same depth as the deepest cut of the part. The unetched specimens shall be machine surface finished to the same roughness height as those of the chemically milled specimens.

4.5.2.2 Tests: All specimens prepared in accordance with 4.5.2.1 shall be subjected to the procedures detailed in ASTM E 8 to determine ultimate tensile strength, yield strength, percentage elongation and percentage reduction of area for conformance to 3.5.

4.5.3 Bend test:

4.5.3.1 Specimen preparation: Twelve test specimens shall be prepared from the same basis material as the part (see 4.3.4). Six of the specimens shall be prepared with the axis of the specimen parallel to the longitudinal direction and the remainder shall be prepared with the axis of the specimen parallel to the long transverse direction. The specimens shall be not less than 3 inches long and 1 inch in width. Sharp corners of the specimens shall be broken with emery cloth used in the axial direction. Three longitudinal and three transverse specimens shall be processed through all operations so that they will be chemically milled to the same depth as the deepest cut of the part. The thickness of the processed specimen shall be the web thickness of the part (see Figure 2). The unetched specimens shall be machined or ground to the same thickness and surface finish (roughness height) as the chemically milled specimens.

4.5.3.2 All specimens, except those of titanium and titanium alloys, shall be bent in accordance with ASTM E 290, around a pin, mandrel or roller with a diameter equal to four times the thickness of the specimen through 180°. For titanium and titanium alloys, the bend test to be used shall be that detailed in MIL-T-9046. The specimens shall be examined for fracture as well as the number and size of cracks found on the test pieces for compliance with 3.5.

4.5.4 Hydrogen contamination: A random sample of the milled titanium or titanium alloy shall be selected from each lot in accordance with MIL-STD-105, Inspection Level S-3, acceptance number of zero. Samples shall be prepared as described in Method 111 or Method 112 of Fed. Test Method Std. No. 151 from approximately the top 1/32 inch of the metal surface. The material should be handled only by using clean white gloves and should be stored in hermetically sealed containers during the period between sampling and actual analysis. The sample must not be contaminated by foreign matter, or moisture or both. The hydrogen contents shall be determined by using the hot-vacuum-extraction method in which the sample is outgassed by heating in the range of 950° to 1000°C at a pressure of 10^{-4} torr or lower. The extracted gases shall be analyzed for hydrogen by one of the following four techniques:

(a) Gas chromatography.
(b) Pressure measurement before and after catalytic oxidation of hydrogen to water and removal of water.
(c) Pressure measurement before and after diffusion of hydrogen through a palladium membrane.
(d) Mass spectrometry.

In case of dispute, hydrogen analysis by mass spectrometry shall be the basis for acceptance. An unmilled sample of the test metal shall be used for a control to determine compliance with 3.6.

4.5.5 Embrittlement relief:

4.5.5.1 Specimen preparation: Separate specimens for the embrittlement relief test shall be four rounded notched specimens prepared from the material used for the part (see 4.3.4). The axis of the specimen (load direction) shall be parallel to the longitudinal direction. The gage length and test areas of the specimens shall be finished by chemical milling so that the configuration shall be in accordance with Figure 8 of ASTM E 8 for rounded specimens. Grip section areas may be masked to prevent chemical milling of that area. Specimens shall be machined to have a 60 degree V-notch located approximately at the center of the gage length. The cross section area at the root of the vee shall be approximately equal to half the area of the full cross section area of the specimens reduced section. The vee shall have a 0.010 ±0.0005 inch radius of curvature at the base of the notch.

4.5.5.2 Test: Compliance with 3.8 shall be determined with milled specimens. The specimens shall be subjected to a sustained tensile load equal to 75 percent of the ultimate notch tensile strength of the material. The specimens shall be held under load for at least 200 hours and then examined for cracks or fracture.

4.6 Rejection:

Chemically milled parts not conforming to the requirements of this specification shall be rejected.

4.6.1 Resubmitted inspection lots: Lots found unacceptable may be resubmitted in accordance with MIL-STD-105.

4.7 Report of products tests:

The supplier shall retain all reports showing results, when applicable, for all tests on materials for production parts required by this specification as performed by the supplier or an authorized representative of the laboratory in which the test was conducted. Records shall be maintained on file for at least one year, after which they may be destroyed.

5. PREPARATION FOR DELIVERY:

5.1 Packaging and packing:

Preservation, packaging and packing methods for chemically milled parts or articles employed by a supplier shall be such as to preclude damaging during shipment and handling.

6. NOTES:

6.1 Intended use:

This specification is intended for use in the control of chemical milling processes as applied to aluminum and aluminum alloys, ferrous alloys, magnesium alloys, titanium and titanium alloys, nickel alloys, cobalt alloys, etc. Chemical milling procedures are used to shape and remove surface metal by selective chemical etching rather than by conventional mechanically milling and machining operations.

6.1.1 Advantages: More than one part with the same alloy composition may be etched at one time in a single tank of adequate size. Production rates and sizes of parts are governed only by the capacity of the etchant tank. Sheets, plates, extrusions and formed sections can be formed, heat treated and then milled on one or on both sides simultaneously. Thus warpage, due to residual stress in the material, is minimized. Integrally stiffened parts can be produced, thus eliminating the need for riveted or welded stiffeners in some designs. The original mechanical properties of the metals are not affected by chemical milling. Most important is that close tolerances in the design of parts can be held.

6.1.2 Limitations: The dents, scratches, pits, cracks, roll and die marks and other surface irregularities are reproduced and enlarged in a chemically milled surface. Chemical milling over a welded area will often result in pits and uneven etching. Fillet radii cannot be controlled to a great extent, being approximately equal to the depth of the cut. Inside corners take a spherical shape, whereas outside corners remain sharp. Cuts deeper than 0.500 inch are generally not recommended. This precludes milling holes and deep, narrow grooves.

6.2 Ordering data:

Procurement documents should specify the following:

(a) Title, number and date of this document.
(b) Surface roughness, other than specified (see 3.3.3).
(c) Other than daily examination for corrosion resistance (see 3.4).
(d) Examination for mechanical properties (see 3.5).
(e) Hydrogen absorption values for metals other than titanium and its alloys (see 3.6).
(f) Stress relief treatment, if not required (see 3.7).
(g) Hydrogen embrittlement relief treatment, if not required (see 3.8).
(h) Control record requirement (see 4.3.1).
(i) Sampling for destructive tests and specified tests required (see 4.4.4).

6.3 Design information:

6.3.1 Metals: Nearly all metals can be chemically milled. With most metals, parts to be chemically milled can be in any form of the wrought or cast alloys. The metal should be free as possible from nicks, gouges, seams, scabs, cracks, inclusions, blowholes, pits, roll marks and other surface imperfections. Generally, with aluminum alloys, surface defects are reproduced in the milled surfaces. With most other metals and alloys such surface defects may be washed out or disappear as a result of processing.

6.3.2 Grain direction: Whenever possible, the longest cut made for any part should be made parallel to the grain orientation direction, that is the longitudinal or rolling direction of the sheet or plate. Grid pattern cuts should be laid out at 45° to the grain direction. Applicable drawings of parts to be chemically milled should have the grain direction noted. These production practices for quality are illustrated in Figure 3.

6.3.3 Dimensional tolerances: Thickness of milled parts can be controlled to extremely close tolerances. The following tolerances may be applied to dimensions of various milled parts.

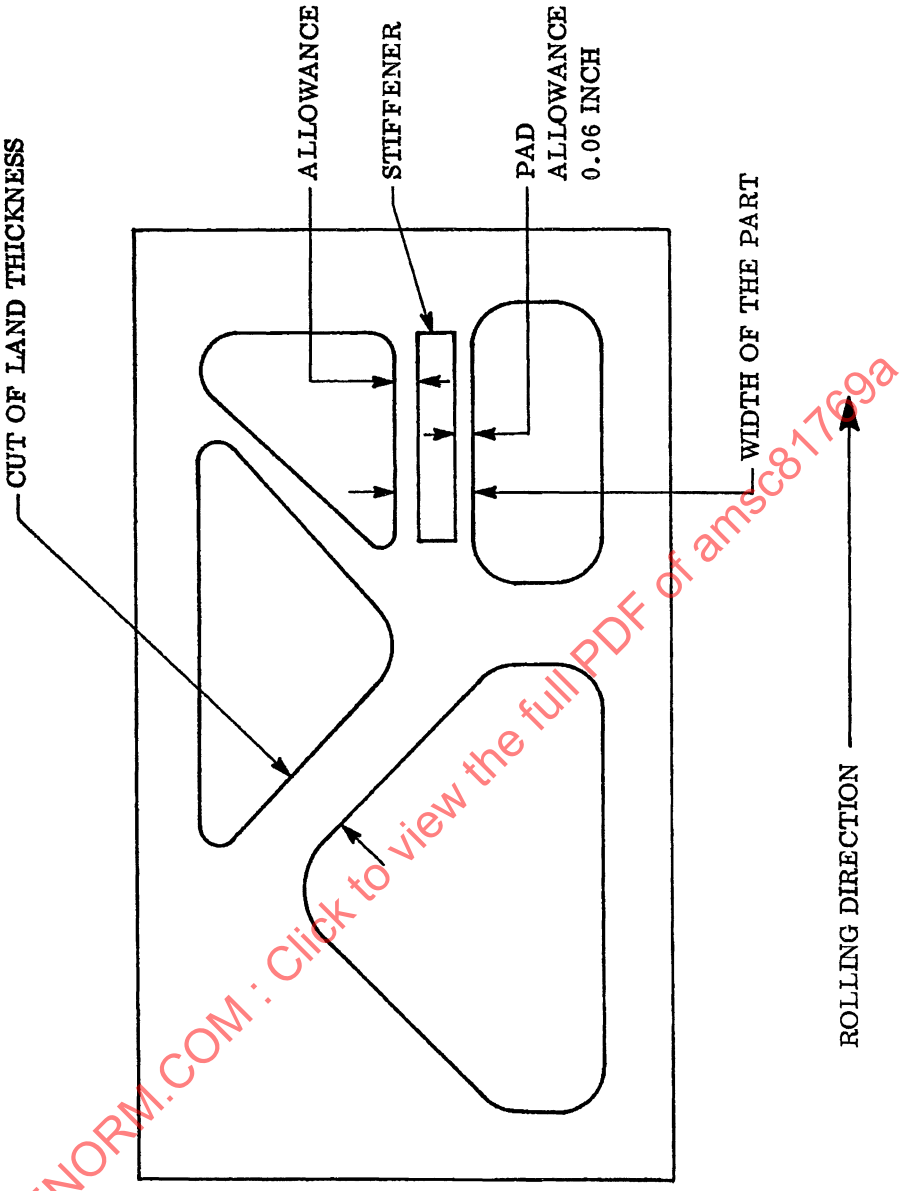


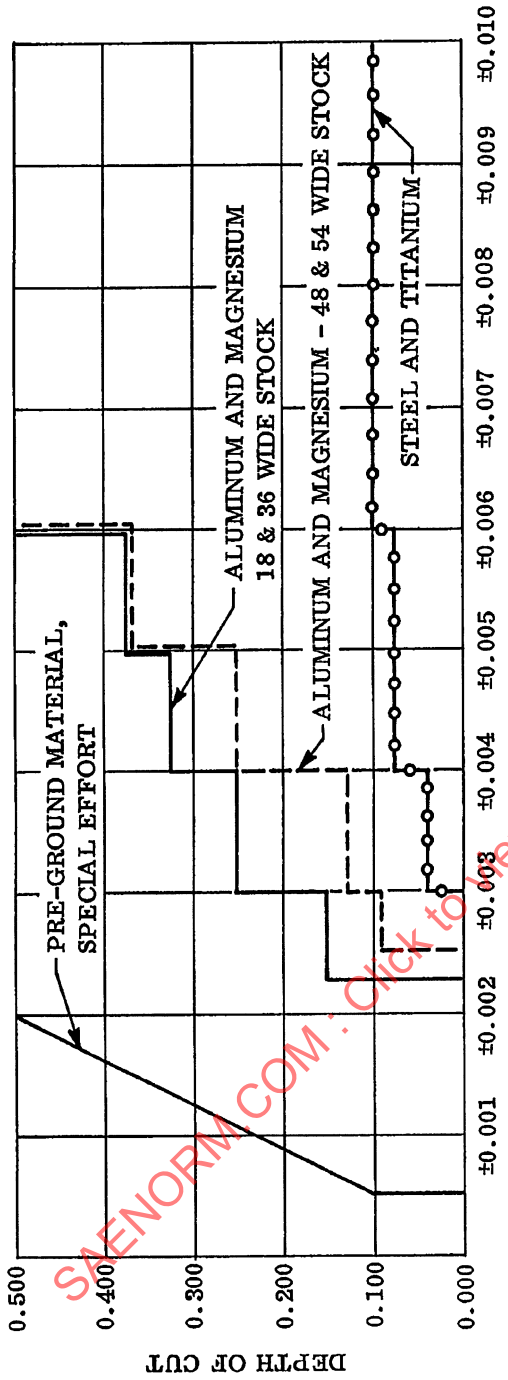
Figure 3. Grain direction

6.3.3.1 Aluminum and its alloys: The tolerances shown in Figure 4 may be used with the desired values for web thickness, the thinnest metal remaining after milling (see Figure 1). The maximum depth of cut should be 0.500 inch for sheets and plates, 0.250 inch for forgings and 0.150 inch for extrusions. The depth of cut should not vary from the specified value by more than ±0.003 inch. The length and width of milled areas should not vary from dimensions by more than the values shown in Figure 5. The minimum width of cut should be twice the depth of cut plus 0.060 inch for cuts up to 0.125 inch deep. For cuts over 0.125 inch deep, the minimum width of cut should be twice the depth of cut plus 0.125 inch. These tolerances, shown in Figure 6 are for normal production values. Lands remaining on unetched portions of parts (see Figure 3), should not vary in width from the values shown in Figure 5. The minimum land width should be twice the depth of cut, but not less than 0.125 inch. It should be not greater than 1.0 inch. These values are also shown in Figure 6. However, for closer tolerances, it is recommended that values in Figures 4, 5, 6 marked special effort be used for dimensional tolerances. The minimum distance between cuts on opposite sides of parts should be 0.125 inch, but a minimum distance of 0.250 inch should normally be used. When a stiffener member is attached to a chemically milled part (see Figure 3), the width of the part should include an allowance of 0.06 inch on either side of the attaching member. Parts, etched in accordance with photographic techniques and by light sensitive resistance should use the special effort values for dimensional tolerances.

6.3.3.2 Titanium and titanium alloys: The linear tolerances for milled titanium and titanium alloy parts should be as detailed in 6.3.3.1. The web thickness should not differ from the values by more than the tolerances shown in Figure 4. However, for closer tolerances, it is recommended that the values in Table II be used for web thickness tolerances. When titanium and titanium alloys are step etched, the thickness tolerances for the intermediate steps of parts should be 50 percent greater than the tolerances permitted in Table II. The linear tolerances for the intermediate steps should be ±0.05 inch.

TABLE II
TOLERANCES FOR WEB THICKNESS

Original thickness inch	Chemically milled area - per side		
	Less than 15 square feet	15 to 25 square feet	Greater than 25 square feet
Up thru 0.050	±0.002	±0.003	±0.004
0.051 - 0.100	±0.003	±0.004	±0.005
0.101 - 0.200	±0.004	±0.006	±0.007
0.201 - 0.400	±0.005	±0.007	±0.008
0.401 and over	±0.006	±0.008	±0.010



DIMENSIONS IN INCHES.

1/ If stretch forming operation precedes the chemical milling, add ±0.001 inch tolerance to the above. If machining precedes chemical milling, add ±0.005 inch. If the parts are forged, add ±0.015 inch to the tolerance values.

Figure 4. Tolerances for web thickness 1/