

INCH-POUND

MIL-M-46196A

7 April 1993

SUPERSEDING

MIL-M-46196

24 May 1988

MILITARY SPECIFICATION

METAL MATRIX COMPOSITES (MMC):
ALUMINUM REINFORCED WITH SILICON CARBIDE PARTICLES OR WHISKERS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification establishes the requirements and tests for aluminum reinforced with silicon carbide particles or whiskers metal matrix composite (MMC) products.

1.2 Form. The form will be forgings, sheet, and extrusions.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

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Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, U.S. Army Research Laboratory, Materials Directorate, ATTN: AMSRL-MA-S, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC No. A6902

AREA CMPS

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MIL-M-46196A

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-I-25135 - Inspection Materials, Penetrants

STANDARDS

MILITARY

MIL-STD-130 - Identification Marking of U.S. Military Property
 MIL-STD-410 - Nondestructive Testing Personnel Qualification and Certification
 MIL-STD-1190 - Minimum Guidelines For Level C Preservation, Packing and Marking
 MIL-STD-2154 - Inspection, Ultrasonic, Wrought Metals, Process for
 MIL-STD-6866 - Inspection, Liquid Penetrant

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D3552 - Standard Test Method for Tensile Properties of Fiber-Reinforced Metal Matrix Composites
 ASTM D3553 - Standard Test Method for Fiber Content by Digestion of Reinforced Metal Matrix Composites
 ASTM E3 - Standard Methods of Preparation of Metallographic Specimens
 ASTM E8 - Standard Test Methods of Tension Testing of Metallic Materials
 ASTM E34 - Standard Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys
 ASTM E55 - Standard Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition
 ASTM E111 - Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
 ASTM E127 - Standard Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks
 ASTM E494 - Standard Practice for Measuring Ultrasonic Velocity in Materials
 ASTM E883 - Standard Guide for Metallographic Photomicrography

(Application for copies of American Society For Testing and Materials publications should be addressed to ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified in the contract or purchase order, a sample shall be subjected to first article inspection (see 4.2.1, 6.2, and 6.4). No change shall be made in materials or processes after first article inspection without prior written approval from the procuring activity.

3.2 General requirements. The deliverable products shall conform to the contract, purchase order, or other controlling document provided by the procuring activity, this specification and all referenced documents. Any conflicts are to be resolved by means of the order of precedence (see 2.3).

3.3 Materials. Material shall consist of a uniform blend of aluminum alloy and silicon carbide particles or whiskers.

3.3.1 Manufacturer changes. All products supplied to this specification shall be identical with respect to design and materials unless prior written approval of the change has been obtained from the procuring activity. Failure of a manufacturer to comply with this requirement shall be sufficient cause for withdrawal of approval of the manufacturer of the product and for rejection of all products affected by such changes.

3.3.2 Traceability. Material shall be serialized in a suitable manner so that traceability of the material through all subsequent fabrication is maintained.

3.3.3 Recordkeeping. When specified in the contract or purchase order, a manufacturer's certification that the material was manufactured in accordance with this specification together with a report shall be furnished at the time of shipment. The following information shall be provided.

- a) Date of Processing
- b) Form
- c) Chemical composition of matrix
- d) Reinforcement type and the volume percent
- e) Lot or batch number

3.4 Properties.

3.4.1 MMC composition. Metal matrix composite composition shall consist of aluminum alloy matrix and silicon carbide reinforcement as specified in table I. The aluminum alloy matrix chemical composition shall be determined in accordance with ASTM E34 and the practice that covers the sampling for the determination of chemical composition shall be ASTM E55.

The content of silicon carbide reinforcement shall be determined in accordance with ASTM D3553.

MIL-M-46196A

3.4.2 Material properties. Material properties shall be in accordance with table II when tested by the methods given in table IV. Properties shall be uniform throughout the material.

3.5 Marking. Product marking shall be permanent and legible. All marking shall be placed on the shape in accordance with MIL-STD-130. The specification number and serial number shall be placed on each product.

3.6 Workmanship. Material procured under this specification shall be manufactured and processed in a careful and workmanlike manner in accordance with good design and sound practice and shall be free from defects that will affect life, serviceability, or appearance. The material should be of uniform quality and condition, free of blisters, splits, wrinkles, folds, fins, seams, laps, cracks, segregations, or other injurious defects that would negatively affect the properties of the material. The material should also be free from porosity, stray fibers, fiber crossovers in any ply, fiber misalignment ($\pm 2^\circ$ allowed), foreign matter, banding, dye penetrant, microcracks, or any other internal defect that would negatively affect the properties of the material. The material shall be free of delamination.

3.7 Storage. When packaged as specified in 5.1, products shall be capable of being stored at $77 \pm 18^\circ\text{F}$ ($25 \pm 10^\circ\text{C}$) and 75 percent maximum relative humidity for 10 years. After such storage products shall be capable of meeting all requirements of this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor 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 this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective materials, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Certificate of compliance (COC). When specified in the contract or purchase order, the supplier shall furnish with each shipment, a certificate of compliance (in triplicate) signed by a duly authorized representative of the supplier, stating compliance with the requirements specified herein and

listing the specific results of all acceptance tests (See 6.4). The certificate of compliance shall also include this specification number, the purchase order number, and the lot number.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

- a. First article (i.e., preproduction) inspection (see 4.2.1)
- b. Quality conformance (i.e., lot acceptance) inspection (see 4.2.2)

4.2.1 First article inspection. First article inspection shall consist of all the tests contained in this specification.

4.2.2 Quality conformance inspection. Unless otherwise specified, quality conformance inspection shall consist of the tests specified herein and in tables III and IV as specified by the procuring activity.

4.2.2.1 Macrostructural examination. A longitudinal macrostructural specimen shall be prepared from the material. The length and width of the specimen shall be as large as practical. The macrostructure shall be observed at 10X magnification. Observations of the macrostructure shall reveal uniform distribution of the silicon carbide reinforcement and display no features known to be detrimental to the material properties or performance.

4.2.2.2 Microstructural examination. A metallographic specimen shall be sectioned from the material. The specimens shall be examined in the longitudinal orientation at 100X. Observations of the microstructure shall reveal uniform distribution of the silicon carbide reinforcements and display no features known to be detrimental to the material properties or performance. Photomicrographs shall be made to verify materials uniformity using the guidelines of ASTM E3 and E883.

4.2.3 Noncompliance. If a sample fails to pass first article or quality conformance inspection, the manufacturer shall notify the procuring activity and the cognizant inspection activity of such failure and take corrective action on the materials or processes, or both, as warranted, and on all units of product which can be corrected and which were manufactured with essentially the same materials and processes, and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action, acceptable to the procuring activity has been taken. After the corrective action has been taken, inspection shall be repeated on additional sample units (all tests and examinations, or the tests which the original sample failed, at the option of the procuring activity). Final acceptance and shipment shall be withheld until the inspection has shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure shall be furnished to the cognizant inspection activity and the procuring activity.

4.3 Nondestructive testing and inspection (NDTI) When specified in the contract or purchase order, nondestructive testing and inspection (NDTI) shall be performed. The standards specified herein may be used for guidance, although specific modification to these procedures may be necessary to accommodate testing and evaluation of aluminum metal matrix composites reinforced with silicon carbide particles or whiskers.

MIL-M-46196A

4.3.1 Visual surface inspection. Visual inspection shall be performed over 100 percent of the surface of the product and shall meet the requirements specified in 3.6.

4.3.2 Penetrant surface inspection. Determination of surface conditions shall be performed in accordance with MIL-STD-6866, Type 1, Method B by personnel certified according to MIL-STD-410 using penetrants and dry developers conforming to MIL-I-25135, Type I, Method B, Sensitivity Level 2. Penetrant shall be removed after inspection.

4.3.2.1 Acceptance criteria. The following acceptance criteria apply to penetrant surface inspection:

- a. Linear indications shall be equal to or less than 0.060 in (1.52 mm).
- b. Maximum dimension of pores and other defects shall be equal to or less than 0.030 in (0.762 mm).
- c. The amount of fluorescent bands shall not exceed that specified by the procuring activity.
- d. Defects whose maximum dimensions are between 0.020 and 0.030 in (0.508 and 0.762 mm) shall not be closer than 0.100 in (2.54 mm) to any other such defect.

Note: Questionable indications shall be refereed using 5X to 10X magnification.

4.3.3 Ultrasonic inspection. Ultrasonic inspection shall be in accordance with MIL-STD-2154, Type I, Class AA and the following:

- a. The transducer shall be selected such that resolution of all the 2/64 in (0.8 mm) diameter flat bottom holes (FBH) in the standard is possible. Standards shall be in accordance with figure 1.
- b. Ultrasonic inspection of each preform shall be accomplished using appropriate fixturing to locate the transducer perpendicular to the flat surface.
- c. The preform shall be inspected so that the entire part volume is scanned. A recording device shall be included in the test apparatus to provide a permanent C-scan record of the preform and the standard.
- d. The transducer shall be coupled to the test piece by means of immersion or a water column using water to which a corrosion inhibitor and a wetting agent may be added.
- e. A written test procedure and a test plan for each preform geometry shall be provided to the supplier's inspector by the supplier.
- f. Each preform shall be tested and evaluated relative to test standards (figure 1) of similar thickness to the preform

MIL-M-46196A

containing flat bottom holes of 2/64, 3/64, and 5/64 in (0.8, 1.2, and 2.0 mm) diameter.

4.3.3.1 Acceptance criteria. Acceptance criteria shall be in accordance with MIL-STD-2154, Type I, Class AA for single discontinuities, and Class A for multiple discontinuities. The receiver gain setting shall be made by maximizing the signal from a 2/64 in (0.8 mm) flat bottom hole and adjusting the gain such that the signal is 50 ± 2 percent of the full scale of the analyzer display. The flaw gate is then set to 20 ± 2 percent of the full scale.

4.4 Sampling size and sampling for inspection. Each lot of material shall be inspected and tested to demonstrate conformance with the requirements of the governing specification. Samples for inspection shall be selected based on a sampling plan provided or approved by the procuring activity. The sampling plan shall specify the frequency of sampling as well as thickness, size, number of specimens to be cut from the sample, and tests to be conducted.

4.4.1 Lot size. Lot size shall consist of all metal matrix composite components produced in a single production run.

4.5 Rejection. Unless otherwise specified (see 6.2), where one or more test specimens fail to meet the requirements of the specification the lot represented by the specimen or specimens shall be subject to rejection.

4.6 Retest. When no sampling plan is provided or approved by the procuring activity and when there is evidence that indicates that the specimen was not representative of the lot of material, at least two specimens shall be selected to replace each test specimen which failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

5. PACKAGING

5.1 Preservation and packaging. Preservation, packing and marking shall be in accordance with MIL-STD-1190, unless otherwise specified in the contract or order. Preservation and packaging shall be level C (see 6.2).

5.1.1 Level C. Cleaning, drying, preservation, and packaging shall be in accordance with manufacturer's commercial practices. If the materials are cleaned by immersion, then the edges must be masked prior to cleaning, or the material must be trimmed a minimum 0.25 in (6.35 mm) after cleaning.

5.2 Packing. Unless otherwise specified in the contract or order, packing shall be level C (see 6.2).

5.2.1 Level C. All material shall be packed for shipment in such a manner as to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

5.3 Marking. In addition to any special marking specified in the contract or order, shipments shall be marked in accordance with the requirements of the cognizant activity.

MIL-M-46196A

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This specification covers aluminum reinforced with silicon carbide particles or whiskers metal matrix composite materials (MMC). Aluminum alloys reinforced with silicon carbide have unique properties which provide specific design advantages. These materials have a high ratio of elastic modulus to density. One of them may be used in place of beryllium because of their lower cost, nontoxicity in machining and handling and producibility due to near-net shape forging. A useful feature of aluminum metal matrix composite materials reinforced with silicon carbide is the ability to tailor the coefficient of thermal expansion (CTE) and elastic modulus by varying the silicon carbide content. These composites are intended for missile guidance system instrument covers and for structural use, e.g., in spacecraft. This specification is a procurement document and for guidance in selecting structural composite materials, see SDS Spacecraft Structural Composite Materials Selection Guide, Ketema, Inc., Composite Materials Div, 3611 South Harbor Blvd., Suite 225, Santa Ana, CA 92704.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification
- b. Whether first article inspection is required (see 3.1)
- c. Packing required (see 5.2)

6.3 First article. When a first article inspection is required, the first article should consist of three units. The contracting officer should include specific instructions in acquisition documents regarding arrangements for examinations, approval of first article test results and disposition of first articles. Invitations for bids should provide that the procuring activity reserves the right to waive the requirements for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the procuring activity, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior approval is presently appropriate for the pending contract.

6.4 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

MIL-M-46196A

<u>Reference Paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
4.1.2	DI-MISC-80678	Certification/Data Sheet	---

(Copies of data item descriptions related to this specification, and identified in section 6 will be approved and listed as such in DOD 5010.12L, Vol. 11, AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094 or as directed by the contracting officer.)

6.5 Definitions.

Linear indication. A linear indication is an indication whose length is at least three times its width.

Particle. A very small piece or part, not necessarily a single crystal, having a ratio of maximum length to minimum diameter (L/D ratio) less than five (5).

Preform. A preform is material from which the final shape is fabricated.

Whisker. A very small single crystal with a rod-like shape having a ratio of maximum length to minimum diameter (L/D ratio) greater than 5.

6.6 Subject term (key word) listing.

Aluminum alloy matrix
 Mechanical properties
 Metal matrix composite composition
 Missile guidance system instrument covers
 Silicon carbide reinforcement
 Structural composite materials

Custodians:

Army - MR
 Navy - AS
 Air Force - 11

Preparing activity:

Army - MR

Project CMPS-0077

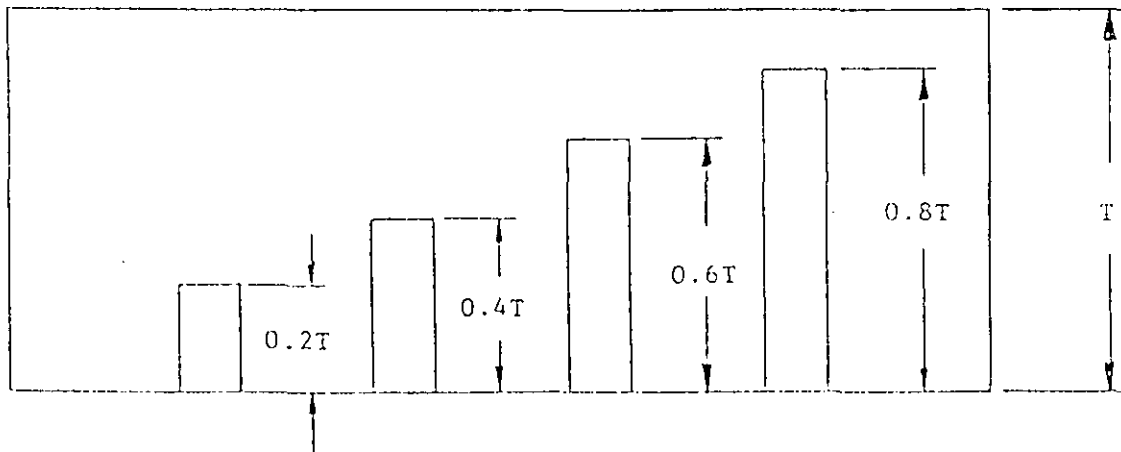
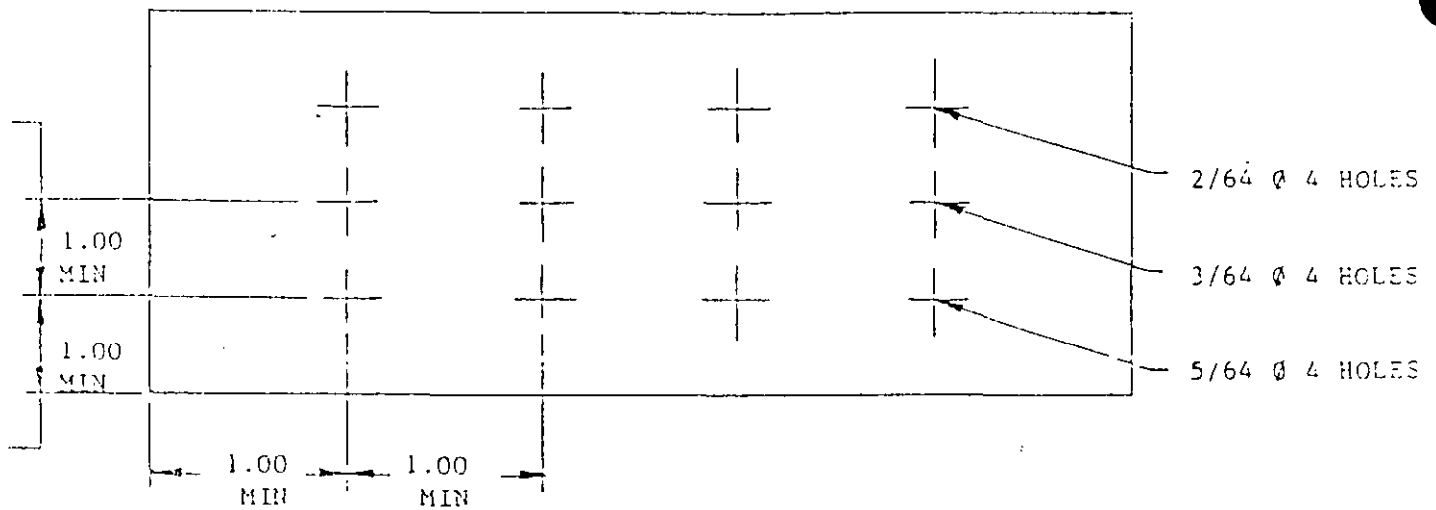
Review activities:

Army - MI
 Navy - OS

User activity:

Army - AV

MIL-M-46196A



T = Nominal thickness of preforms $\pm 10\%$

Notes:

1. All tolerances shall be in accordance with ASTM E127.
2. Layout of hole positions may be modified to suit supplier. Holes may be distributed among several different standards.
3. Plug holes shall be in accordance with ASTM E127.

FIGURE 1. Ultrasonic standard.

TABLE I. Metal matrix composite composition ^a
reinforcement: silicon carbide

Aluminum Alloy Matrix.....	6061 ^b	2009 ^c	2124 ^d	6090 ^e
Reinforcement Type.....	Particles	Whiskers	Particles or Whiskers	Particles
Reinforcement Volume, %	40 ± 2	15 ± 2	25 ± 2 or 35 ± 2	25 ± 2
Matrix Alloy Composition: Weight, % :				
Silicon.....	0.40-0.80	0.25	0.20	0.40-0.80
Iron.....	0.70	0.05	0.30	0.70
Copper.....	0.15-0.40	3.2-4.4	3.8-4.9	0.30-0.90
Manganese.....	0.15	0.05	0.30-0.90	0.15
Magnesium.....	0.80-1.20	1.0-1.6	1.2-1.8	0.80-1.20
Zinc.....	0.25	0.10	0.25	0.25
Other Elements, each...	0.05	0.05	0.05	0.05
Other Elements, total..	0.15	0.15	0.15	0.15
Aluminum.....	Remainder	Remainder	Remainder	Remainder

NOTE:

- ^a Compositions are maximum unless shown as range.
- ^b Chromium 0.35; Titanium 0.15.
- ^c Oxygen 0.60.
- ^d Chromium 0.10; Titanium 0.15.
- ^e Oxygen 0.05-0.07; Chromium and Titanium, 0.15 percent each.

TABLE II. Metal matrix composite property requirements ^a
reinforcement: silicon carbide

Aluminum Alloy Matrix	6061 ^b	2009	2124		6090	
Form	Forgings	Sheet	Sheet			Extrusions
Reinforcement Type	Particles	Whiskers	Whiskers		Particles	Particles
Reinforcement Volume, %	40 ± 2	15 ± 2	25 ± 2	35 ± 2	25 ± 2	25 ± 2
Thickness, in.	≈ 2.0	0.060-0.130	0.060	0.060	0.060	C
Temper ^d	T6P	T8P	T6P	T6P	T6P	T6P
Test Temperature	Room	Room	Room	Room	Room	Room
Mechanical Properties: ^e						
Tensile Strength, S_u , ksi (MPa) ^f						
L	65.0(448)	88.0(607)	72.4(499)	76.1(525)	60.2(415)	64.1(442)
LT	...	71.0(490)	87.5(603)	21.8(150)	46.2(319)	62.7(432)
Yield Strength, S_y , ksi (MPa)						
L	55.0(379)	64.0(441)	70.5(486)	62.3(430)	...	70.6(487)
LT	...	52.0(359)	65.4(451)	79.8(550)
Elongation, e, percent						
L	1.0	3.3	0.66	0.55	1.23	0
LT	...	5.1	1.52	0.005	0	0
Modulus of Elasticity, E, Msi (GPa)						
L	18.5(128)	14.3(98.6)	14.9(103)	15.3(106)	14.0(96.6)	16.9(117)
LT	...	12.9(89)	14.5(100)	14.6(101)	14.9(103)	17.6(121)
						15.2(105)

For all lettered footnotes, see page 13.

MIL-M-46196A

NOTE:

- a Some properties may not be needed for procurement purposes so they should not be considered. Physical properties such as coefficient of thermal expansion and thermal conductivity are affected by processing and temperature. They vary considerably therefore these requirements should be negotiated with the supplier.
- b Longitudinal and transverse directions are not defined in this case.
- c The size of the extrusions was 0.5 inches thick by 5.0 inches wide by 14.0 feet long.
- d The "P" following the temper designation means the properties resulting from this treatment have not been registered with the American Aluminum Association. Consult the supplier to see what properties can be expected.
- e For these properties, a value which 99% of the population of values is expected to exceed was calculated. This calculation was made as recommended in MIL-HDBK-5, Metallic Materials and Elements For Aerospace Vehicle Structures. It was assumed that the distribution of the data was normal. The number of data values used in the calculations was five, except it was 150 to 200 in the case of 2009 Al, SiC/15w, 48 in the case of 6090 Al/SiC/25p, and unknown in the case of 6061 Al/SiC/40p. The data calculated are minimum values for procurement acceptance purposes. They are not design allowables. For design guidance, the technical literature should be consulted; e.g., Ketema Inc., SDS Spacecraft Structural Composite Materials Selection Guide, prepared for WPD L502, AFWAL, Materials Laboratory, Wright Patterson AFB, OH.
- f Multiply ksi by 6.895 to convert to MPa.

TABLE III. Nondestructive testing and inspection.

<u>Examination</u>	<u>Test Conditions</u>	<u>Acceptance Criteria</u>
Visual surface inspection	4.3.1	3.6
Penetrant surface inspection	4.3.2	4.3.2.1
Ultrasonic inspection	4.3.3 and ASTM E127	4.3.3.1

TABLE IV. Properties and test methods.

<u>Property</u>	<u>Test Method</u>
Tensile strength	ASTM E8
Yield strength	ASTM E8
Elongation	ASTM E8 or ASTM D3552.
Modulus of elasticity	ASTM E111 or ASTM E494

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:		1. DOCUMENT NUMBER MIL-M-46196A	2. DOCUMENT DATE (YYMMDD)
3. DOCUMENT TITLE METAL MATRIX COMPOSITES (MMC): ALUMINUM REINFORCED WITH SILICON CARBIDE PARTICLES OR WHISKERS			
4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed)			
5. REASON FOR RECOMMENDATION			
6. SUBMITTER			
a. NAME (Last, First, Middle Initial)		b. ORGANIZATION	
c. ADDRESS (Include Zip Code)		d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (if applicable)	7. DATE SUBMITTED (YYMMDD)
8. PREPARING ACTIVITY			
Department of the Army US Army Research Laboratory Materials Directorate ATTN: AMSRL-MA-S Watertown, MA 02172-0001		b TELEPHONE (Include Area Code) (1) Commercial 617-923-5286	(2) AUTOVON DSN955-5286
IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA, 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340			