MMPDS Framework for Characterization and Use of Additive Metals

Empowering Small and Medium Size Enterprises Through Effective Additive Manufacturing Data Management

June 8, 2023

Doug Hall
Sr. Mechanical Engineer
Program Manager – MMPDS
Battelle Memorial Institute
614-424-6490
halld@battelle.org

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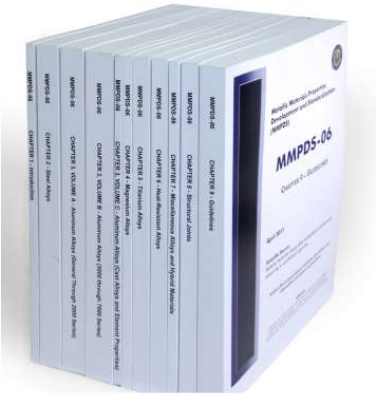
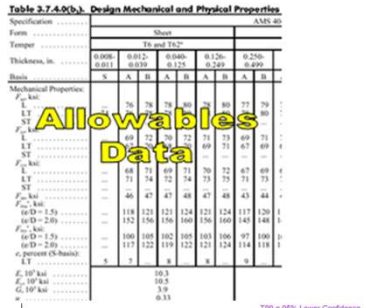
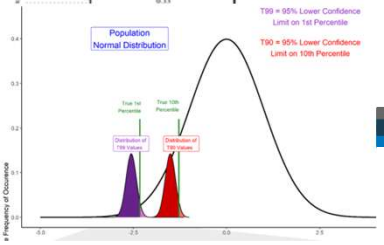
Metallic Materials Properties Development and Standardization







History

- ANC5 (1937-1954), MIL-HDBK-5 (USAF: 1954 – 2003), MMPDS (FAA: 2003-today)
- Battelle Memorial Institute - program Secretariat since 1956.
- MMPDS Handbook is the primary source of statistically-based design allowable properties for metallic materials and fasteners used in many different commercial and military weapon systems around the world.
- The MMPDS General Coordinating Committee is a collaboration between government agencies, aerospace companies, testing and data service companies, and metallic material producers.
- Biannual meetings to review and approve statistical analyses and guidelines.

Scope

- The Handbook currently contains 600+ A/B-Basis and 1000+ S-Basis entries, 400+ unique metal specifications.
- Two to five new alloys are added each year.†
- For more information visit www.mmpds.org

† Pandemic rate has been slower.

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MIL-HDBK-5 to MMPDS to

MILITARY HANDBOOK

DOT/FAA/AR-MMPDS-01

Metallic Materials Pro
Development and Sta
(MMPDS)

MIL-HDBK-5:

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Industry and Government Collaboration in Transition of MIL-HDBK-5 to MMPDS Handbook

by
Richard C. Rice
Battelle; Columbus, OH

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MMPDS & Additive Metals

SAE AMS AM Metals Committ
October 4, 2022

Doug Hall
Sr. Mechanical Engineer
Program Manager - MMPDS
Battelle Memorial Institute
614-424-6490
halld@battelle.org

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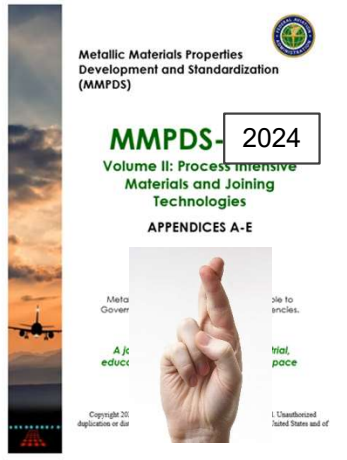
Metallic Materials Properties Development and Standardization (MMPDS)

MMPDS-17

CHAPTERS 1-9

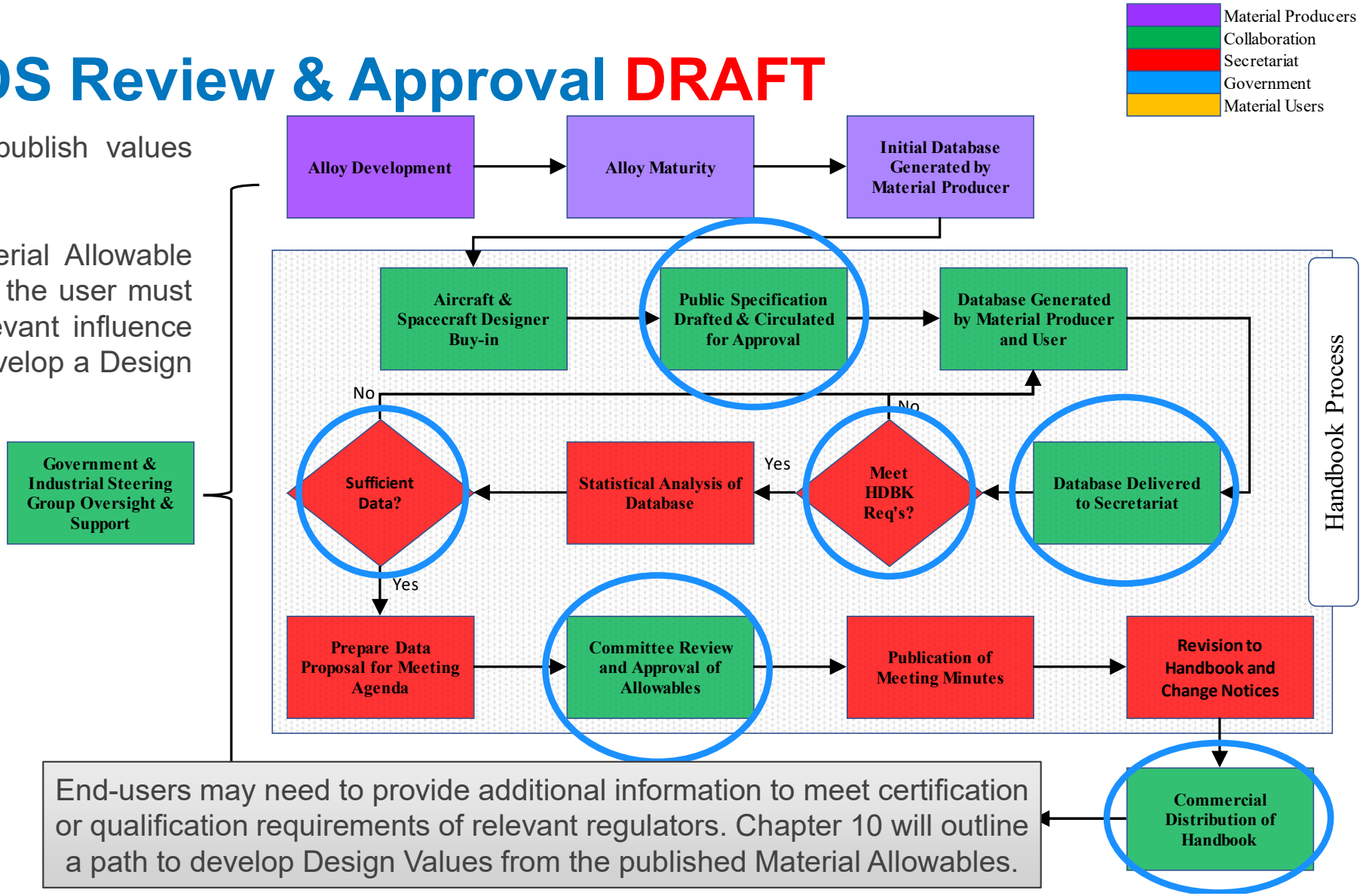
July 2022



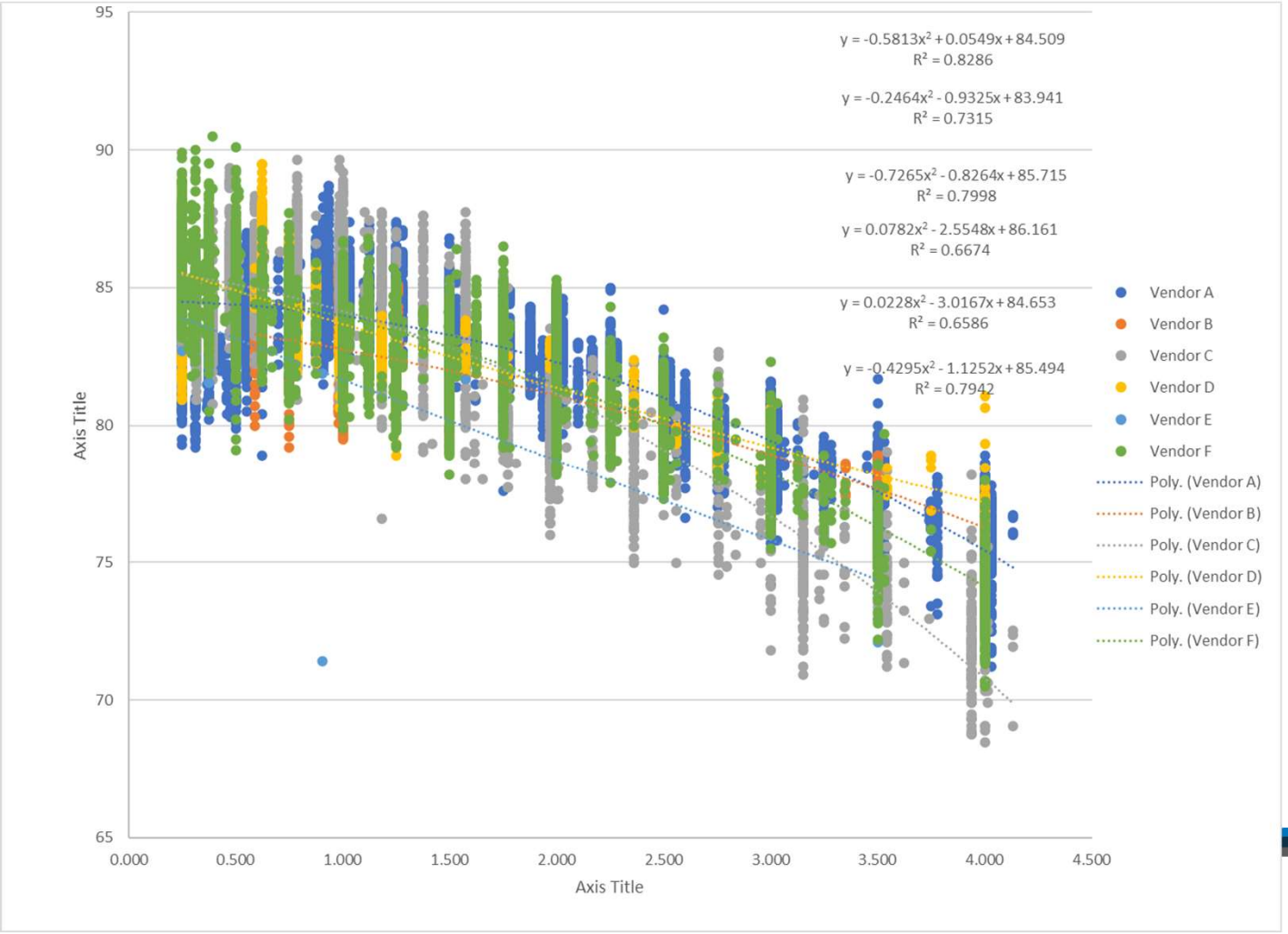
MMPDS Review & Approval DRAFT

Process to publish values in Volume II.

Once a Material Allowable is published, the user must consider relevant influence factors to develop a Design Value.



Conventional Material



- Four major aluminum producers, making plate & sheet in six separate factories
- All producers of 7075-T6 per AMS4045 are not making identical material

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9.2.2 Specification Requirements

- A material ". . . must be covered by a public, industry, or government specification that includes sufficient quality controls to ensure stable statistically valid mechanical properties. These controls shall include, but are not limit to, lot-release acceptance criteria for composition limits and mechanical properties, control of thermal-mechanical processing, sampling, and testing methodologies, and internal soundness/quality."
- "Test data meeting or exceeding requirements for S-Basis or better statistically based mechanical properties for properties included in the specification for lot-release shall be submitted to the MMPDS Secretariat for analysis."
- Additional requirements for Material Properties (9.2.2.1), Manufacturing and/or Processing (9.2.2.2), Feedstock (9.2.2.3), Recycling (9.2.2.4), Machine Qualification (9.2.2.5), Product Lot-Release Data (9.2.2.6)

Table 9.2.4. Summary of Data Requirements within MMPDS Volume II

Mechanical or Physical Property	Customary Statistical Basis	Relative Importance in MMPDS Volume II	Extenuating Circumstances for Special Material Usage Requirements	Minimum Data Requirements				
				Sample Size	No. of Heats[a]	No. of Mfg. Lots	Machines[b]	Build Cycles
Bearing Yield and Ultimate Strength[c] (Direct)	S-Basis	Mandatory	Except for elevated temperature applications	30	3	3	3	3
Bearing Yield and Ultimate Strength[c] (Indirect)	C- and D-Basis	Strongly Recommended	Except for elevated temperature applications	20 indirect /20 reference	10	10	5	10
Coefficient of Thermal Expansion	Typical	Strongly recommended	Especially for anticipated range of usage	6	3	3	3	3
Compression Yield Strength[c] (Direct)	C- and D-Basis	Mandatory	Except for elevated temperature applications	30	3	3	3	3
Compression Yield Strength[c] (Indirect)	C- and D-Basis	Strongly recommended	Except for elevated temperature applications	20 indirect /20 reference	10	10	5	10
Creep and Rupture	Raw Data w/ Best-Fit Curves	Recommended	Especially for elevated temperature applications	6 tests per creep strain level and temp, at least 4 temps over usage range				
Density	Typical	Mandatory		3	3	3	3	3
Effect of Temperature Curves	Same as Room Temperature Properties	Recommended	Especially for elevated temperature applications	5[d]	2[e]	5	5	5
Effect of Thermal Exposure	Same as Baseline Properties	Recommended	Especially for elevated temperature applications	5[d]	2[e]	5	5	5
Elastic Modulus - Tension Compression Dynamic Shear	Typical	 Mandatory Mandatory Recommended Recommended	Dynamic modulus is strongly recommended for some engine applications	9	3	3	3	3
Elastic Modulus (T, C, D) - Elevated Temperatures	Typical	Mandatory	For anticipated usage temperature range	9	3	3	3	3

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Table 9.2.4. Summary of Data Requirements within MMPDS Volume II *(continued)*

Mechanical or Physical Property	Customary Statistical Basis	Relative Importance in MMPDS Volume II	Extenuating Circumstances for Special Material Usage Requirements	Minimum Data Requirements				
				Sample Size	No. of Heats[a]	No. of Mfg. Lots	Machines[b]	Build Cycles
Elongation	S-Basis	Mandatory	Two-inch gage length preferred	30	3	3	3	3
Fatigue-Load Control	Raw Data w/Best-Fit Curves	Recommended	Especially for high-cycle fatigue critical applications	6 test per stress ratio (R), 3 stress ratios, no minimum heat or lot requirements				
Fatigue-Strain Control	Raw Data w/Best-Fit Curves	Recommended	Especially for low-cycle fatigue critical applications	10 tests for R_ε = -1.0, 6 tests other strain ratios				
Fatigue Crack Growth	Raw Data w/Best-Fit Curves	Recommended	Especially for damage tolerance critical applications	Duplicate da/dN results for relevant stress ratios and stress intensity range				
Fracture Toughness - Plane Strain	Max., Avg., Min., Coef. Of Variance, S-Basis	Recommended	Mandatory for materials with spec minimum requirements for plane strain fracture toughness	30	3	10	3	10
Fracture Toughness - Plane Stress	Raw Data w/Best-Fit Curves	Recommended	Mandatory for materials with spec minimum requirements for plane stress toughness	f	2	5	3	5
Poisson's Ratio	Typical	Strongly recommended		6	3	3	3	3
Reduction In Area	Typical	Recommended		When tested, use same criteria as for elongation				
Shear Ultimate Strength[c] (Direct)	S-Basis	Mandatory	Except for elevated temperature applications	30	3	3	3	3
Shear Ultimate Strength[c] (Indirect)	C- and D-Basis	Strongly recommended	Except for elevated temperature applications	20 indirect/ 20 reference	10	10	5	10
Specific Heat	Typical	Strongly recommended	For anticipated usage temperature range	6	3	3	3	3
Stress Corrosion Cracking	Letter Rating	Recommended		Conform to replication requirements in ASTM G 47				

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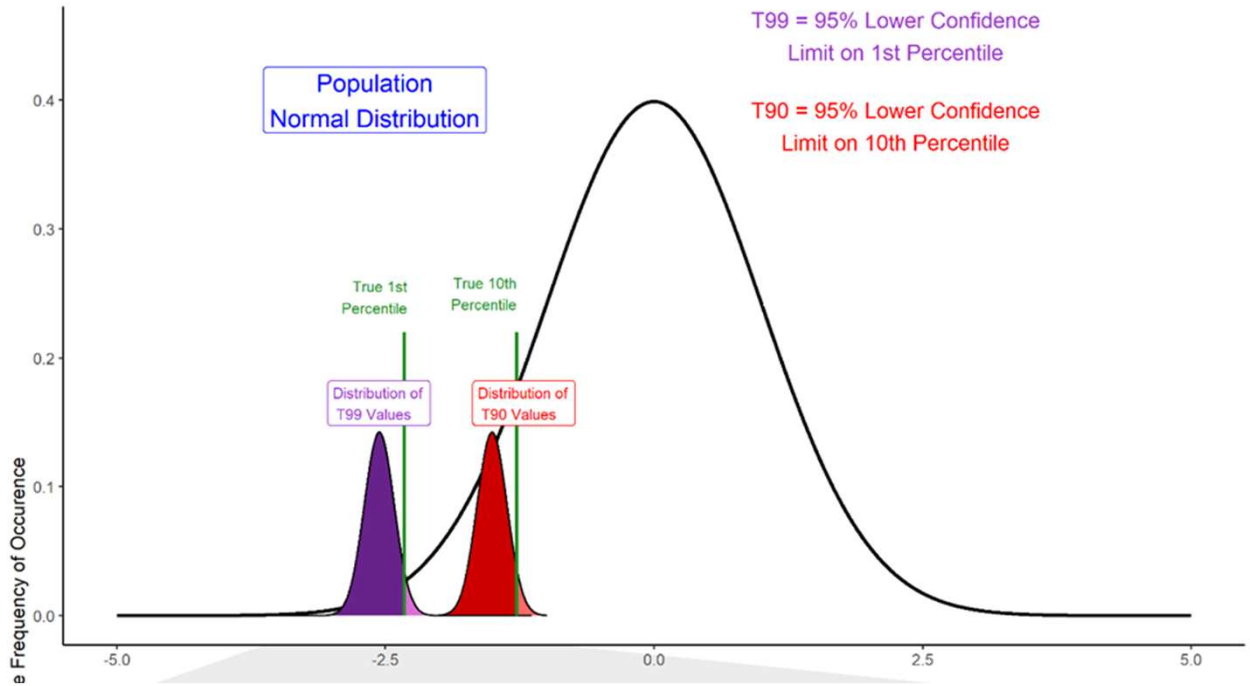
Table 9.2.4. Summary of Data Requirements within MMPDS Volume II *(continued)*

Mechanical or Physical Property	Customary Statistical Basis	Relative Importance in MMPDS Volume II	Extenuating Circumstances for Special Material Usage Requirements	Minimum Data Requirements				
				Sample Size	No. of Heats[a]	No. of Mfg. Lots	Machines[b]	Build Cycles
Stress/Strain Curves (To Yield) Tension and Compression	Typical	Mandatory	Desirable to have accurate plastic strain offsets from 10^{-6} to 3 x 10^{-2}	6	3	3	3	3
Stress/Strain Curves (Full Range) Tension	Typical	Mandatory	The strain rate should be constant through failure	6	3	3	3	3
Tension Yield and Ultimate Strength (Direct)	S-Basis	Mandatory		30	3	3	3	3
Tension Yield and Ultimate Strength (Direct)	D-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is possible	100	10	10	5	10
Tension Yield and Ultimate Strength (Direct)	C-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is possible	100	10	20	5	20
Tension Yield and Ultimate Strength (Direct)	C- and D-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is not possible	299	10	20	5	20
Tension Yield and Ultimate Strength (Indirect)	C- and D-Basis	Recommended	For grain directions not required for lot release in specification	20 indirect/ 20 reference	10	10	5	10
Tension Yield and Ultimate Strength - Elevated Temps	Typical	Recommended	Mandatory for elevated temperature applications	g	2	5	5	5
Thermal Conductivity	Typical	Strongly recommended	For anticipated usage temperature range	6	3	3	3	3

a Heats refers to different input chemistries of the feedstock production process.
b Builds must be executed on the number of machines listed in the table or all existing machines if fewer machines exist.
c Optional direct property determination involves same minimum data requirements as tension yield and ultimate.
d Tests per temperature, at least 4 temperatures over usage range.
e 5 heats required for single form and thickness.
f Minimum sample size not specified, testing should be conducted at 6 or more panel widths to confidently represent trends over the panel widths of interest. Refer to ASTM E561 for testing details.
g Minimum sample size not specified, testing should be conducted at 6 or more temperatures to confidently represent trends over the temperature range of interest. Testing in regions where properties are expected to change rapidly with changes in temperature must be done at temperature intervals sufficiently small to clearly identify mean trends.

Volume II C-Basis, D-Basis, S-Basis: Material Allowables



T_{99} and T_{90} are one-sided lower tolerance bounds. Both are calculated from data.

C-Basis = the lower of the specification minimum or T_{99} value.

D-Basis = is the T_{90}. It is not related to the spec minimum.

S-Basis = is a T_{99} that does not meet C-Basis requirements for sample size or distribution fit.

Metallic C-/D-/S-Basis published in MMPDS Volume II require "further showing." A large sample is required.

MMPDS is the primary gov't approved source for A/B/C/D/S-Basis metallic material allowables. Proprietary values require extra effort by the CEO.

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It can be done

800.201.2011 | solutions@battelle.org | www.battelle.org