International Council on Systems Engineering
A better world through a systems approach

A Systems Engineering Approach to Standards Development

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SAE International

MISSION: *To advance mobility knowledge and solutions for the* ***benefit of humanity***

NEUTRAL FORUMS

Address society's mobility needs

RESOURCES

Engineering resources to advance mobility

EDUCATION

STEM programs and professional courses, building the workforce

COMMUNITY

Global community pulling from each other's collective wisdom

STANDARDS

Consensus-based standards that advance quality, safety and innovation

ROLES IN INDUSTRY: Professional Association, SDO, Publisher, STEM Educator, Professional Workforce Development, Knowledge & Networking Resource

Our Community
Aerospace and Ground Vehicle

11,000+
Participants

105+
Years

44,000+
Standards

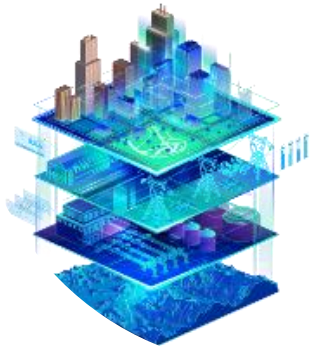
59+ Countries

570+
Technical Committees

1,800+
Works in Progress

550+
Committees & steering groups

How Do We Get to a Digital Ecosystem?



When Starting from Here?

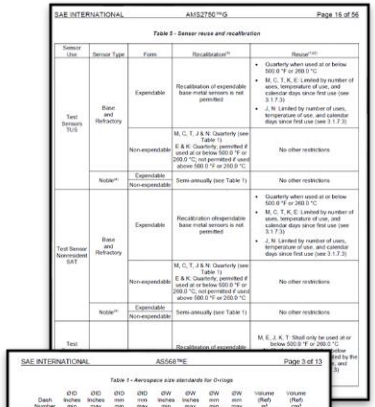

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Table 3 - Sensor reuse and recalibration

Sensor Use	Sensor Type	Form	Recalibration[1]	Reuse[1,2]
Test Sensors TUS	Base and Refractory	Expendable	Recalibration of expendable base metal sensors is not permitted	• Quarterly when used at or below 500.0 °F or 260.0 °C • M, C, T, K, E: Limited by number of uses, temperature of use, and calendar days since first use (see 3.1.7.3) • J, N: Limited by number of uses, temperature of use, and calendar days since first use (see 3.1.7.3)
		Non-expendable	M, C, T, J & N: Quarterly (see Table 1) E & K: Quarterly; permitted if used at or below 500.0 °F or 260.0 °C; not permitted if used above 500.0 °F or 260.0 °C	No other restrictions
	Noble[3,4]	Expendable	Semi-annually (see Table 1)	No other restrictions
		Non-expendable		
Test Sensor Nonresident SAT	Base and Refractory	Expendable	Recalibration ofexpendable base-metal sensors is not permitted	• Quarterly when used at or below 500.0 °F or 260.0 °C • M, C, T, K, E: Limited by number of uses, temperature of use, and calendar days since first use (see 3.1.7.3) • J, N: Limited by number of users, temperature of use, and calendar days since first use (see 3.1.7.3)
		Non-expendable	M, C, T, J & N: Quarterly (see Table 1) E & K: Quarterly; permitted if used at or below 500.0 °F or 260.0 °C; not permitted if used above 500.0 °F or 260.0 °C	No other restrictions
	Noble[3,4]	Expendable	Semi-annually (see Table 1)	No other restrictions
		Non-expendable		
Test			Recalibration of expendable	M, E, J, K, T: Shall only be used at or below 500.0 °F or 260.0 °C

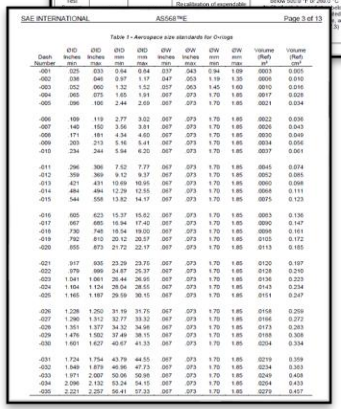
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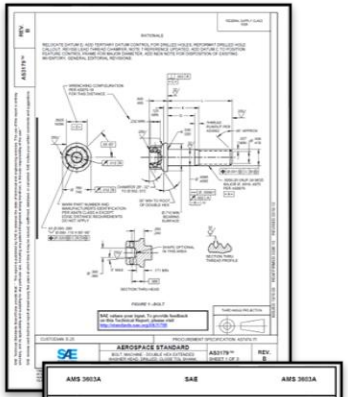
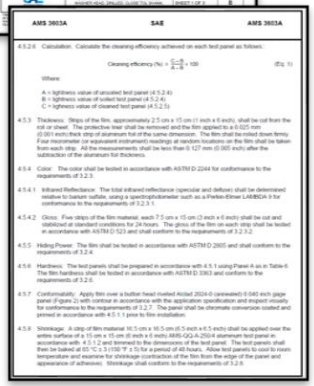
Table 1 - Aerospace size standards for O-rings

Dash Number	ØID inches	ØID mm	ØID inches tolerance	ØID mm tolerance	ØW inches nom	ØW inches tolerance	ØW mm nom	ØW mm tolerance	Volume (Ref) in³/in	Volume (Ref) cm³/cm
-001	.025	.033	0.64	0.84	.037	.043	0.94	1.09	.0003	0.005
-002	.038	.040	0.97	1.17	.047	.053	1.19	1.35	.0006	0.010
-003	.052	.060	1.32	1.52	.037	.063	1.45	1.60	.0010	0.016
-004	.065	.075	1.65	1.91	.067	.073	1.70	1.85	.0017	0.028
-005	.096	.106	2.44	2.69	.067	.073	1.70	1.85	.0021	0.034
-006	.109	.119	2.77	3.02	.067	.073	1.70	1.85	.0022	0.036
-007	.140	.150	3.56	3.81	.067	.073	1.70	1.85	.0026	0.043
-008	.171	.181	4.34	4.60	.067	.073	1.70	1.85	.0030	0.049
-009	.203	.213	5.16	5.41	.067	.073	1.70	1.85	.0034	0.056
-010	.234	.244	5.94	6.20	.067	.073	1.70	1.85	.0037	0.061
-011	.296	.306	7.52	7.77	.067	.073	1.70	1.85	.0045	0.074
-012	.359	.369	9.12	9.37	.067	.073	1.70	1.85	.0052	0.085
-013	.421	.431	10.69	10.95	.067	.073	1.70	1.85	.0060	0.098
-014	.484	.494	12.29	12.55	.067	.073	1.70	1.85	.0068	0.111
-015	.544	.556	13.82	14.17	.067	.073	1.70	1.85	.0075	0.123
-016	.665	.623	15.37	15.62	.067	.073	1.70	1.85	.0083	0.136
-017	.067	.680	16.94	17.40	.067	.073	1.70	1.85	.0090	0.147
-018	.730	.748	18.54	19.00	.067	.073	1.70	1.85	.0098	0.161
-019	.792	.810	20.12	20.57	.067	.073	1.70	1.85	.0105	0.172
-020	.855	.873	21.72	22.17	.067	.073	1.70	1.85	.0113	0.185
-021	.917	.935	23.29	23.75	.067	.073	1.70	1.85	.0120	0.197
-022	.979	.999	24.87	25.37	.067	.073	1.70	1.85	.0128	0.210
-023	1.041	1.061	26.44	26.95	.067	.073	1.70	1.85	.0136	0.223
-024	1.104	1.124	28.04	28.55	.067	.073	1.70	1.85	.0143	0.234
-025	1.165	1.187	29.59	30.15	.067	.073	1.70	1.85	.0151	0.247
-026	1.228	1.250	31.19	31.75	.067	.073	1.70	1.85	.0158	0.259
-027	1.290	1.312	32.77	33.32	.067	.073	1.70	1.85	.0166	0.272
-028	1.351	1.377	34.32	34.98	.067	.073	1.70	1.85	.0173	0.283
-029	1.476	1.502	37.49	38.15	.067	.073	1.70	1.85	.0188	0.308
-030	1.601	1.627	40.67	41.33	.067	.073	1.70	1.85	.0204	0.334
-031	1.724	1.754	43.79	44.55	.067	.073	1.70	1.85	.0219	0.359
-032	1.849	1.879	46.96	47.73	.067	.073	1.70	1.85	.0234	0.383
-033	1.971	2.007	50.06	50.98	.067	.073	1.70	1.85	.0249	0.408
-034	2.096	2.132	53.24	54.15	.067	.073	1.70	1.85	.0264	0.433
-035	2.221	2.257	56.41	57.33	.067	.073	1.70	1.85	.0279	0.457




AMS 3603A SAE AMS 3603A

4.5.2.6 Calculation. Calculate the cleaning efficiency achieved on each test panel as follows:

$$\text{Cleaning efficiency (\%)} = \frac{C-B}{A-B} \times 100 \qquad \text{(Eq. 1)}$$

Where:

A = lightness value of uncoated test panel (4.5.2.4)
B = lightness value of soiled test panel (4.5.2.4)
C = lightness value of cleaned test panel (4.5.2.5)

4.5.3 Thickness. Strips of the film, approximately 2.5 cm x 15 cm (1 inch x 6 inch), shall be cut from the roll or sheet. The protective liner shall be removed and the film applied to a 0.025 mm (0.001 inch) thick strip of aluminum foil of the same dimension. The film shall be rolled down firmly. Four micrometer (or equivalent instrument) readings at random locations on the film shall be taken from each strip. All the measurements shall be less than 0.127 mm (0.005 inch) after the subtraction of the aluminum foil thickness.

4.5.4 Color. The color shall be tested in accordance with ASTM D 2244 for conformance to the requirements of 3.2.3.

4.5.4.1 Infrared Reflectance. The total infrared reflectance (specular and diffuse) shall be determined relative to barium sulfate, using a spectrophotometer (such as a Perkin-Elmer LAMBDA 9 for conformance to the requirements of 3.2.3.1.

4.5.4.2 Gloss. Five strips of the film material, each 7.5 cm x 15 cm (3 inch x 6 inch) shall be cut and stabilized at standard conditions for 24 hours. The gloss of the film on each strip shall be tested in accordance with ASTM D 523 and shall conform to the requirements of 3.2.3.2.

4.5.5 Hiding Power. The film shall be tested in accordance with ASTM D 2805 and shall conform to the requirements of 3.2.4.

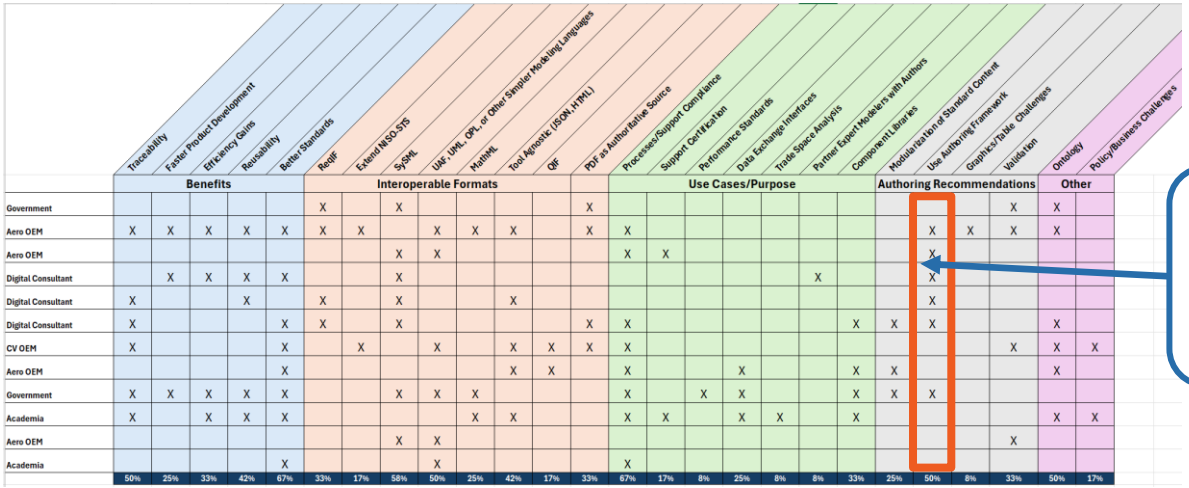
4.5.6 Hardness. The test panels shall be prepared in accordance with 4.5.1 using Panel 4 as in Table 6. The film hardness shall be tested in accordance with ASTM D 3363 and conform to the requirements of 3.2.6.

4.5.7 Conformability. Apply film over a button head riveted Alclad 2024-0 (unbeveled) 0.040 inch gage panel (Figure 2) with contour in accordance with the application specification and inspect visually for conformance to the requirements of 3.2.7. The panel shall be chromate conversion coated and primed in accordance with 4.5.1.1 prior to film installation.

4.5.8 Shrinkage. A strip of film material 10.5 cm x 10.5 cm (5.0 inch x 5.0 inch) shall be applied over the entire surface of a 15 cm x 15 cm (6 inch x 6 inch) AMS-QQ-A-250/4 aluminum test panel in accordance with 4.5.1.2 and trimmed to the dimensions of the test panel. The test panels shall then be baked at 65 °C ± 3 (150 °F ± 5) for a period of 48 hours. Allow test panels to cool to room temperature and examine for shrinkage (contraction of the film from the edge of the panel and appearance of adherence). Shrinkage shall conform to the requirements of 3.2.8.

We Need to Evolve the Starting Point

VOC from Systems Engineers

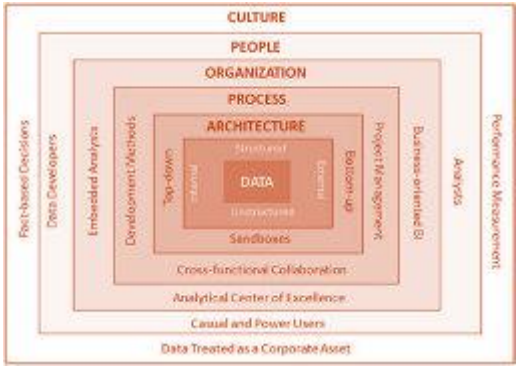


	Benefits					Interoperable Formats								Use Cases/Purpose							Authoring Recommendations				Other	
	Traceability	Faster Product Development	Efficiency Gains	Reusability	Better Standards	ReqIF	Extend MBSE/SysML	SysML	UAF, UPAF, OPM, or Other Simpler Modeling Languages	MathML	Tool Agnostic (JSON, HTML)	QIF	PDF as Authoritative Source	Processes/Support Compliance	Support Certification	Performance Standards	Data Exchange Interfaces	Trade Space Analysis	Partner Expert Modelers with Authors	Component Libraries	Modularization of Standard Content	Use Authoring Framework	Graphics/Table Challenges	Validation	Ontology	Policy/Business Challenges
Government						X		X					X											X	X	
Aero OEM	X	X	X	X	X	X	X		X	X	X		X	X							X	X	X	X	X	
Aero OEM								X	X					X	X						X					
Digital Consultant		X	X	X	X			X											X		X					
Digital Consultant	X			X		X		X			X										X					
Digital Consultant	X				X	X		X					X	X						X	X	X			X	
CV OEM	X				X		X		X		X	X	X	X										X	X	X
Aero OEM					X						X	X		X					X	X					X	
Government	X	X	X	X	X			X	X	X				X		X	X		X	X	X					
Academia	X		X	X	X					X	X			X	X		X	X	X						X	X
Aero OEM								X	X															X		
Academia					X				X					X												
	50%	25%	33%	42%	67%	33%	17%	58%	50%	25%	42%	17%	33%	67%	17%	8%	25%	8%	8%	33%	25%	50%	8%	33%	50%	17%

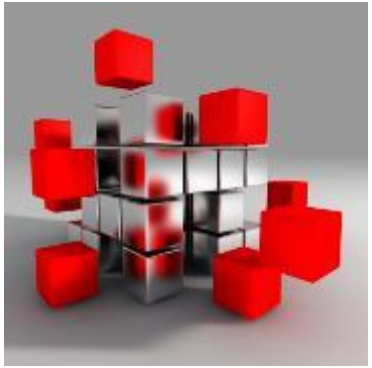
Need **authoring framework** for standards

Inconsistency Not Acceptable | **Interoperability Required** | **Automation-Ready Solutions Demanded** | **Ambiguity Not Tolerated**

How Should Standards Organizations Address This?



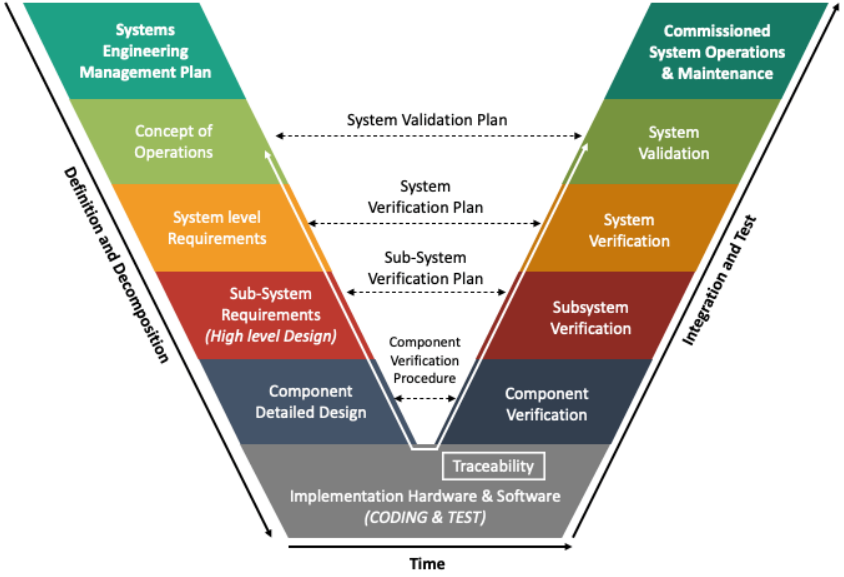
Implement an Authoring Framework



Modularize Standards Documents

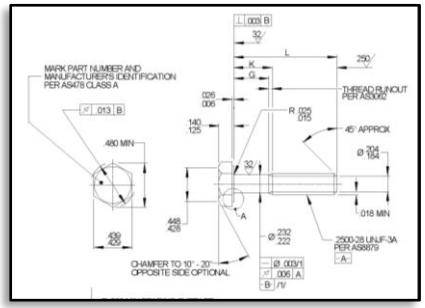
Implement a Framework

Approach, Methodology, Etc.

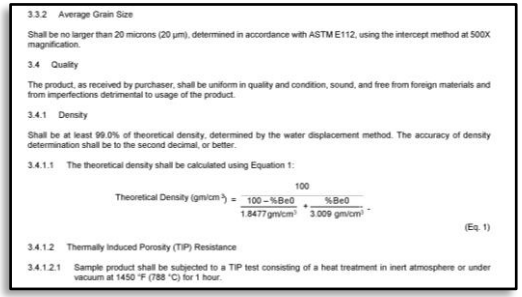


Editorial and Structure Recommendations are a Start

Drawings and Variables



Content



3.3.2 Average Grain Size

Shall be no larger than 20 microns (20 µm), determined in accordance with ASTM E112, using the intercept method at 500X magnification.

3.4 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.4.1 Density

Shall be at least 99.0% of theoretical density, determined by the water displacement method. The accuracy of density determination shall be to the second decimal, or better.

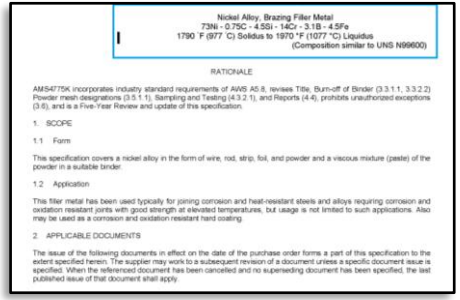
3.4.1.1 The theoretical density shall be calculated using Equation 1:

$$\text{Theoretical Density (gm/cm}^3\text{)} = \frac{100}{\frac{100 - \%\text{Be0}}{1.8477\,\text{gm/cm}^3} + \frac{\%\text{Be0}}{3.009\,\text{gm/cm}^3}} \quad \text{(Eq. 1)}$$

3.4.1.2 Thermally Induced Porosity (TIP) Resistance

3.4.1.2.1 Sample product shall be subjected to a TIP test consisting of a heat treatment in inert atmosphere or under vacuum at 1450 °F (788 °C) for 1 hour.

Document Structure



Nickel Alloy, Brazing Filler Metal
73Ni - 0.75C - 4.5Si - 14Cr - 3.1B - 4.5Fe
1790 °F (977 °C) Solidus to 1970 °F (1077 °C) Liquidus
(Composition similar to UNS N99600)

RATIONALE

AMS4775K incorporates industry standard requirements of AWS A5.8, revises Title, Burn-off of Binder (3.3.1.1, 3.3.2.2) Powder mesh designations (3.5.1.1), Sampling and Testing (4.3.2.1), and Reports (4.4), prohibits unauthorized exceptions (3.6), and is a Five-Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a nickel alloy in the form of wire, rod, strip, foil, and powder and a viscous mixture (paste) of the powder in a suitable binder.

1.2 Application

This filler metal has been used typically for joining corrosion and heat-resistant steels and alloys requiring corrosion and oxidation resistant joints with good strength at elevated temperatures, but usage is not limited to such applications. Also may be used as a corrosion and oxidation resistant hard coating.

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.

Table Structure

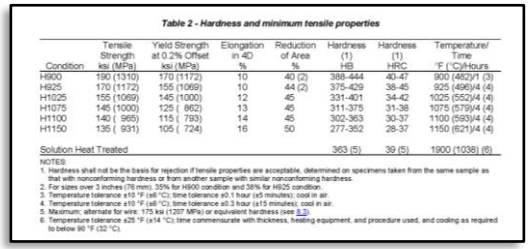
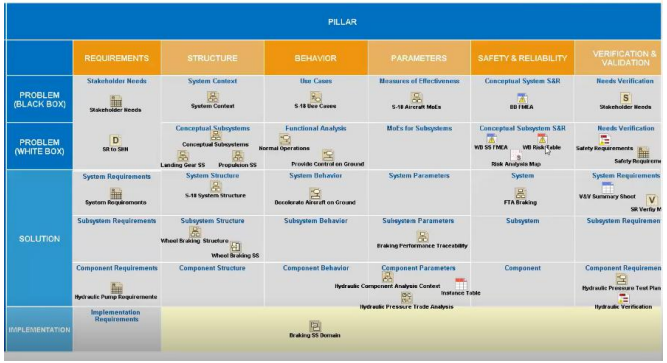


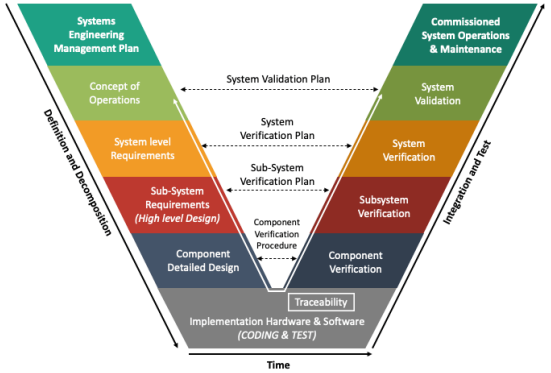
Table 2 - Hardness and minimum tensile properties

Condition	Tensile Strength ksi (MPa)	Yield Strength at 0.2% Offset ksi (MPa)	Elongation in 4D %	Reduction of Area %	Hardness (1) HB	Hardness (1) HRC	Temperature/ Time °F (°C)/Hours
H900	190 (1310)	170 (1172)	10	40 (2)	388-444	40-47	900 (482)/1 (3)
H925	170 (1172)	155 (1069)	10	44 (2)	375-429	38-45	925 (496)/4 (4)
H1025	155 (1069)	145 (1000)	12	45	331-401	34-42	1025 (552)/4 (4)
H1075	145 (1000)	125 (862)	13	45	311-375	31-38	1075 (579)/4 (4)
H1100	140 (965)	115 (793)	14	45	302-363	30-37	1100 (593)/4 (4)
H1150	135 (931)	105 (724)	16	50	277-352	28-37	1150 (621)/4 (4)
Solution Heat Treated					363 (5)	39 (5)	1900 (1038) (6)

NOTES:
1. Hardness shall not be the basis for rejection if tensile properties are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.
2. For sizes over 3 inches (76 mm), 35% for H900 condition and 38% for H925 condition.
3. Temperature tolerance ±10 °F (±6 °C); time tolerance ±0.1 hour (±5 minutes); cool in air.
4. Temperature tolerance ±10 °F (±6 °C); time tolerance ±0.3 hour (±15 minutes); cool in air.
5. Maximum; alternate for wire: 175 ksi (1207 MPa) or equivalent hardness (see 8.2).
6. Temperature tolerance ±25 °F (±14 °C); time commensurate with thickness, heating equipment, and procedure used, and cooling as required to below 90 °F (32 °C).

Systems Engineering Framework → Better Standards






Stakeholders
Context
Use Cases
Measures
Requirements
Structures
Behaviors
Functional Analysis
AEROSPACE MATERIAL SPECIFICATION
AMS2610™
Issued 2003-09
Reaffirmed 2023-05
Pressure Testing, Gaseous Media
Pressure as Specified
RATIONALE
AMS2610 has been reaffirmed to comply with the SAE Five-Year Review policy.
1. SCOPE:
This specification provides requirements and procedures for gas-pressure leak testing of parts.
2. APPLICABLE DOCUMENTS:
There are no referenced publications specified herein.
3. TECHNICAL REQUIREMENTS:
3.1 Equipment:
3.1.1 Fixtures: Test fixtures and apparatus shall be designed and constructed to seal off only the ports and passages required to pressurize the part, and to permit 100% evaluation of all areas of the part where leakage could occur. The design shall not induce any stress on the part other than that provided by the test media. If pressure testing cannot be accomplished without inducing additional stresses, the design, including fitting types, shall be approved by the purchaser.
3.1.2 Gaskets: Gasket material shall be used with plugs or blanking plates to prevent damage to finished surfaces. Flanges or fittings designed for use with specific O-rings or gaskets shall use those seals for test. Formed-in-place gaskets that could mask dimensions or surface flaws shall not be used except on unmachined castings when sealing.
3.1.3 Bleeder Ports: Valved bleeder ports shall be provided to release entrapped gas.
3.1.4 Gauges: Pressure gauges and flow meters shall have sufficient dial divisions or readability to permit monitoring within plus or minus 5% of specified pressure and shall have been calibrated, within one year of use, using either primary standards or standards traceable to the National Institute of Standards and Technology (NIST).

Pressure Testing for Gaseous Media

A Framework Makes the Implicit More Explicit

Stakeholders

- Designers
- Planners
- Testers
- Others

Context

- Why
- When
- Relationships to Other Standards

Use Cases

- Who Plans
- Who Preps
- Who Performs
- Who Validates
- Who Evaluates

Measures

- Acceptance Criteria

Pressure Testing for Gaseous Media (cont)

A Framework Makes the Implicit More Explicit

Requirements

- Planning and Prep
- Procedure
- Results Analysis
- Reporting
- Equipment Calibration

Structures

- Fixtures
- Gauges
- Gaskets
- Data

Behaviors

- Interactions between Personas and Equipment and Media and Process Steps

Functional Analysis

- Apply Equations and Evaluations to Structures and Behaviors

Benefits of Using a Framework

- Better analysis
- More complete standards
- Less ambiguity
- Easier application

Where Do We Go from Here?

Hope is Not a Plan

SDOs Must Determine Framework Appropriate to their Standards

Existing Stabilized Standards

- Need
- Relevance
- Priority

Existing Standards on Revision Cycle

- Leverage Existing Cycle
- Consider Need, Relevance, Priority
- Minimize Volunteer Time

New Standards

- Relevance
- Minimize Volunteer Time

Modularize Standards

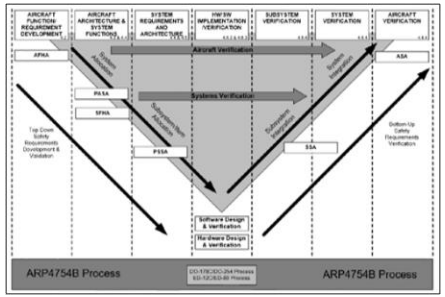
Processes in Standards

Manufacturing

Operational

Testing

Organizational



Modularity

3.4.1.3 Bending

Product 0.275 inch (6.98 mm) and under in nominal thickness shall be tested in accordance with ASTM E290 using a sample prepared nominally 0.75 inch (19.0 mm) in width with its axis of bending parallel to the direction of rolling and shall withstand without cracking when bending at room temperature through the angle and bend diameter shown in Table 3. In case of dispute, the results of tests using the guided bend test of ASTM E290 shall govern.

Table 3 - Bending requirements

Nominal Thickness Inch	Nominal Thickness Millimeters	Type of Bend	Angle Deg. Min	Bend Factor
Up to 0.1874, incl	Up to 4.760, incl	Free Bend	180	1
Over 0.1874 to 0.275, incl	Over 4.760 to 6.98, incl	Free Bend	180	3

This test is included in over 50 materials standards!

Prerequisites

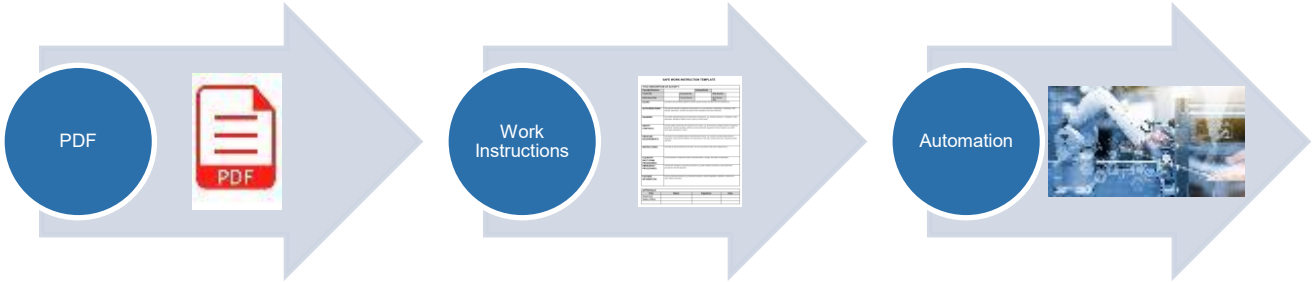
Process

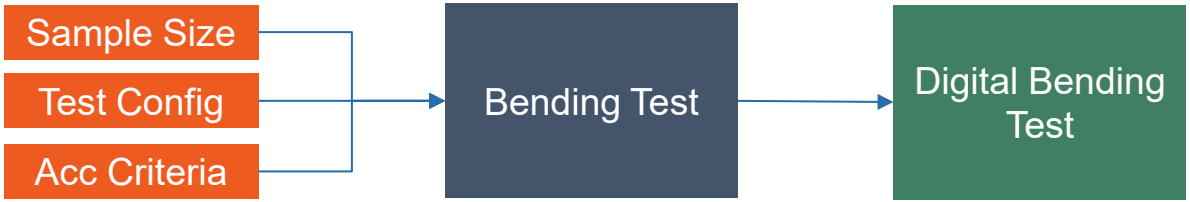
Outcomes

How can we create reusable modules for this test to be leverage across standards and committees?

Reusability Scaled to Support Automation

Digital Modules can Map Directly to Automated Modules





Standards Provide Data Parameters

Bending Test Defined Once

Automation Deployed in Multiple Applications

Benefits of Modularity

- More consistency
- Reusability
- Less work for standards authors
- Easier to identify and convert to digital assets
- Fewer assets to manage

Where Do We Go from Here?

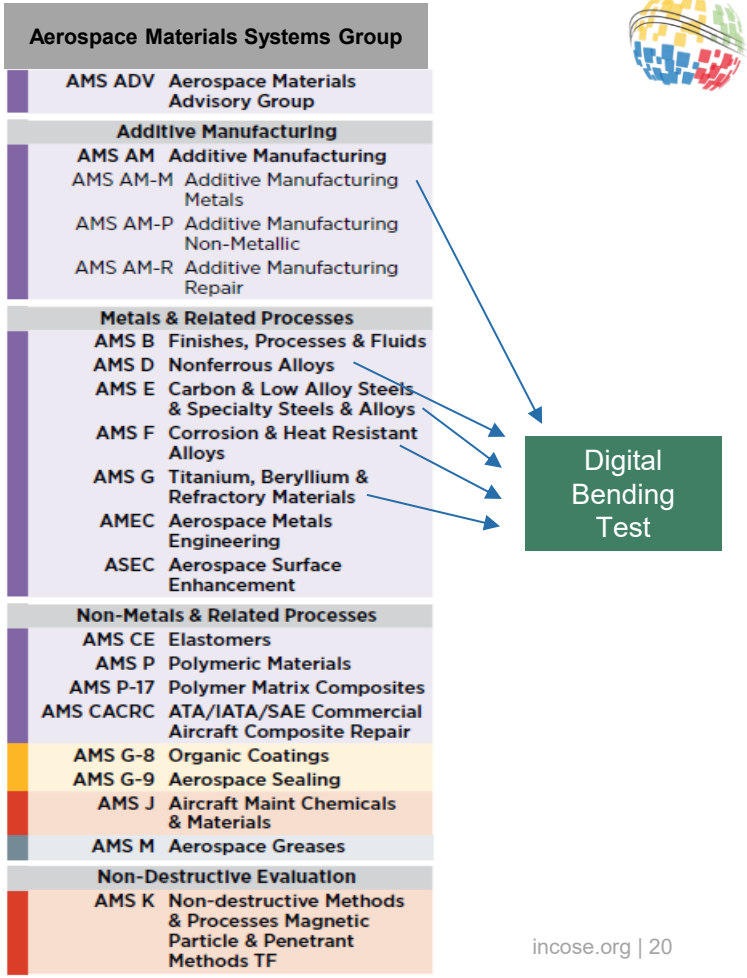
Modularity Not a Factor in Current Committee Structures

SDOs

- Identification
- Storage and Access
- Reference
- Stabilized, Revised, New Standards
- Support Staff and Tools

Standards Authors

- Education
- Existing Standards
- New Standards



Standards Must Work in Digital Ecosystems

Problem	Mitigated By
Inconsistency Not Acceptable	✓ Applying Framework ✓ Modularity
Automation-Ready Solutions Demanded	✓ Modularity
Interoperability Required	✓ Applying Framework ✓ Modularity
Ambiguity Not Tolerated	✓ Applying Framework

Leslie McKay

Director, Digital Standards Development

Professional experience

- Over 20 years' experience leading software and hardware product development projects.
- Over 10 years' developing solutions that leverage artificial intelligence and machine learning.
- Dedicated to establishing best practices for authoring and use of digital standards.

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