



AEROSPACE MATERIAL SPECIFICATION

AMS2644™**REV. J**Issued 1996-08
Revised 2024-08

Superseding AMS2644H

(R) Inspection Material, Penetrant

RATIONALE

AMS2644J addresses methods that were recently developed for evaluating Method B and D penetrant water solubility and adds reference to Method A(W) throughout. The revision updates references (see Section 2), clarifies definitions (see 2.6.3), adds the water solubility test (see 3.3.8.6), clarifies water content testing (see 3.3.8.8), clarifies scope of concentration requirements (see 3.3.9.5), updates the requirements for acceptance testing (see 4.2.2.1), adds alternative material for testing (see 4.4.2 and 4.4.5.2.1), removes data validity evaluation (see 4.4.5.1.6), increases temperature range for testing (see 4.4.5.2.1), clarifies developer testing (see 4.4.12.1), adds language to address global shipping (see 5.3), updates Table 3 in line with text (Method C, Removers and Developers), revises Method C, Removers, removes specific Developer tests in Table 4, and adds Method A(W) to Tables 5 and 6.

1. SCOPE

1.1 Purpose

This specification establishes the classification, technical requirements, tests, and test procedures for the qualification, approval, and quality verification of all materials used in the liquid penetrant methods of inspection with the exception of those excluded in the application section.

1.1.1 The qualifying agency for direct U.S. Military procurement is the Materials and Manufacturing Directorate of the Air Force Research Laboratory AFRL/RXNS, 2179 12th Street, Wright-Patterson Air Force Base, OH, 45433-7718. AFRL/RXNS will maintain the qualified products list for military procurement of penetrant materials and will audit and approve other testing facilities to perform all or portions of the tests contained herein.

1.2 Application

This specification is applicable to penetrant materials used in manufacturing and maintenance operations. It is intended to be used by prime contractors in establishing an approved products list (QPL) for use by themselves and their suppliers. It does not cover such special application products as liquid oxygen compatible, high or low temperatures, thixotropic, reverse fluorescent, and dye precipitation penetrant systems.

1.3 Safety - Hazardous Materials

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

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1.4 Classification

Penetrant systems covered by this specification are to be classified as follows:

1.4.1 Penetrants shall be of the following types, methods, and sensitivity levels:

Type 1	Fluorescent Dye
Type 2	Visible Dye
Method A	Water washable
Method A(W)	Water washable - water containing ($\geq 20\%$ water by volume)
Method B	Post emulsifiable, lipophilic
Method C	Solvent removable
Method D	Post emulsifiable, hydrophilic
Sensitivity Level 1/2	Ultra low
Sensitivity Level 1	Low
Sensitivity Level 2	Medium
Sensitivity Level 3	High
Sensitivity Level 4	Ultra high

1.4.1.1 Sensitivity level 1/2 applies to Type 1, Method A, and Method A(W) penetrants only. There is no sensitivity level classification for Type 2 penetrant systems.

1.4.2 Developers shall be of the following forms:

Form a	Dry powder
Form b	Water soluble
Form c	Water suspendible
Form d	Nonaqueous Type 1 Fluorescent (solvent based)
Form e	Nonaqueous Type 2 Visible Dye (solvent based)
Form f	Special application

1.4.3 Solvent removers shall be of the following classes:

Class 1	Halogenated
Class 2	Nonhalogenated
Class 3	Special application

2. APPLICABLE DOCUMENTS

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

2.1 SAE Publications

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

AMS4045	Aluminum Alloy Sheet and Plate, 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr 7075: (-T6 Sheet, -T65 Plate), Solution and Precipitation Heat Treated
AMS4120	Aluminum Alloy, Rolled or Cold Finished Bars, Rods, and Wire, 4.4Cu - 1.5Mg - 0.60Mn (2024), Solution Heat Treated and Naturally Aged (T4), Solution Heat Treated, Cold Worked, and Naturally Aged (T351)
AMS4377	Magnesium Alloy, Sheet and Plate, 3.0Al - 1.0Zn - 0.20Mn (AZ31B-H24), Cold Rolled, Partially Annealed

AMS4916	Titanium Alloy Sheet, Strip, and Plate, 8Al - 1Mo - 1V, Duplex Annealed
AMS4919	Titanium Alloy Sheet, Strip, and Plate, 6Al - 2Sn - 4Zr - 2Mo - 0.08Si, Duplex Annealed
AMS5391	Nickel Alloy, Corrosion and Heat-Resistant, Investment Castings, 73Ni - 0.14C - 13Cr - 4.5Mo - 2.3Cb (Nb) - 0.75Ti - 6.0 Al - 0.010B - 0.10Zr, Vacuum Cast, As-Cast
AMS6350	Steel Sheet, Strip, and Plate, 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130)
AS7766	Terms Used in Aerospace Metals Specifications

2.2 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ANSI Z400.1/Z129.1	Hazardous Workplace Chemicals - Hazard Evaluation and Safety Data Sheet and Precautionary Labeling Preparation
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2.3 ASTM Publications

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

ASTM B211/B211M	Aluminum and Aluminum Alloy Rolled or Cold Finished Bar, Rod or Wire
ASTM D93	Flash Point by Pensky-Martens Closed Cup Tester
ASTM D95	Water in Petroleum Products and Bituminous Materials by Distillation
ASTM D445	Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
ASTM D3828	Flash Point by Small Scale Closed Cup Tester
ASTM D4057	Manual Sampling of Petroleum and Petroleum Products
ASTM D4177	Automatic Sampling of Petroleum and Petroleum Products
ASTM E203	Test Method for Water Using Volumetric Karl Fischer Titration
ASTM E1135	Comparing the Brightness of Fluorescent Penetrants
ASTM E1316	Terminology for Nondestructive Examinations
ASTM E1417/E1417M	Liquid Penetrant Inspection
ASTM E2275	Evaluating Water-Miscible Metalworking Fluid Bioresistance and Antimicrobial Pesticide Performance
ASTM E3022	Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing
ASTM G41	Determining Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment

2.4 Code of Federal Regulations (CFR) Publications

Available from United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

29 CFR 1910.1200 Hazard Communication

49 CFR 173 Shippers-General Requirements for Shipments and Packagings

2.5 Orders of Precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

2.6 Definitions

Terms used in AMS are defined in AS7766 and the following:

2.6.1 Refer to ASTM E1316, Terminology for Nondestructive Testing, for definitions of terms related to penetrant inspection.

2.6.2 Qualifying Agency

Until additional qualifying agencies are authorized by AFRL/RXNS, the sole qualifying agent for production penetrant materials by or for Department of Defense shall be AFRL/RXNS.

2.6.3 Qualified System

2.6.3.1 For Methods A (water washable) and A(W) (water washable - water containing) penetrants, the system consists of the qualified penetrant only.

2.6.3.2 For Methods B and D, a penetrant/emulsifier combination furnished by the same manufacturer and qualified together as a system.

2.6.3.3 For Method C, any manufacturer's qualified solvent remover may be used with any manufacturer's qualified (Method C) penetrant, unless classified for special applications in the qualified products list.

2.6.3.4 For all methods, any manufacturer's qualified developer may be used with any manufacturer's qualified penetrant system, unless classified for special application in the qualified products list.

2.6.4 Special Application

Denotes removers and developers that are qualified for use only with a specific penetrant.

3. TECHNICAL REQUIREMENTS

3.1 Materials

Candidate materials and systems must equal or exceed the performance of the appropriate reference material or system. Tables 1 and 2 list the designations assigned to the reference materials. Tables 3 and 4 identify the reference material to be used with candidate materials for qualification testing and the reference materials to which the respective candidates are compared for performance evaluation. For example, a candidate Type 1, Method B, Level 2 system would be used with the D-1 reference dry powder developer and compared to the FP-2PE/FE-B reference system used with the D-1 reference dry powder developer.

3.2 Qualification

Penetrant materials furnished shall be products that are qualified under the requirements of this specification at the time set for the opening of bids.

3.2.1 Qualification Provisions

Penetrant materials shall be qualified in accordance with the following provisions:

3.2.1.1 Type 1 (Fluorescent Dye) Materials

Method A (water washable) penetrants, Method A(W) (water washable - water containing) and Methods B and D (post emulsifiable) penetrants/emulsifiers shall be qualified with the reference dry developer D-1. Method C penetrants shall be qualified either on the basis of their performance as Method A, A(W), B, or D materials or, alternatively, with the reference solvent remover R-2 and reference dry developer D-1.

3.2.1.2 Type 2 (Visible Dye) Materials

Method A, A(W), B, and D penetrant systems shall be qualified with the reference nonaqueous wet developer D-2, and Method C (solvent removable) penetrants shall be qualified based upon their qualification as a component of a Method A, A(W), B, or D system or qualified with the reference solvent remover R-2 and reference nonaqueous developer D-2.

3.2.1.3 Developers

All developers intended for use with Type 1 (fluorescent) penetrant materials, except Form f (special application), shall be qualified with the reference Level 4, Method B penetrant/emulsifier system S-FP-4PE/FE-B (see Tables 1 and 2). All developers intended for use with Type 2 (visible) penetrant materials, except Form f, shall be qualified with the Type 2 reference penetrant and Method B emulsifier VP-PEPE/VE-B. Form f developers shall be qualified in accordance with 3.2.1.5.

3.2.1.4 Solvent Removers

Classes 1 and 2 solvent removers shall be qualified with the reference penetrant FP-4PE and reference developer D-1. Class 3 solvent removers shall be qualified in accordance with 3.2.1.5.

3.2.1.5 Special Application Developers/Removers

Form f developers and Class 3 removers shall be qualified with materials as specified by the manufacturer, and approval shall be specific to those materials.

3.2.2 Qualification Testing Samples

Samples submitted shall be accompanied by mixing instructions and any other pertinent data as required by the qualifying agency. Sample size shall be as required by the qualifying agency, up to 1 quart (0.95 L) but not less than 1 pint of penetrant and hydrophilic emulsifier, 1 gallon (3.8 L) of lipophilic emulsifier, and 2 pounds (0.9 kg) of developer powder. Nonaqueous developers shall be submitted in aerosol containers only and the sample size shall be two containers. Samples shall be submitted in a safety coated glass, non-coated glass, or HDPE plastic. At a minimum, samples shall be durably labeled with the following information: Manufacturer, Product Part Number, Batch Number, Plant of Origin, and Date of Manufacture.

3.2.3 Formulation Review and Certifications

3.2.3.1 Toxicity Characteristics Review

The manufacturer shall submit a Safety Data Sheet (SDS) for each candidate product to the qualifying agency. The SDS shall be prepared in accordance with 29 CFR 1910.1200, App D - Safety Data Sheets.

The manufacturer shall certify that the provided SDS contains all relevant safety information for the product.

3.2.3.2 Formulation Certification

The manufacturer shall certify that the product formulation and method of manufacture are equivalent across all manufacturing plants. The manufacturer shall also provide the Cage Codes for each manufacturing plant and objective evidence that the formulations are equivalent. Fourier Transform Infrared Spectroscopy (FTIR) or Mass Spectroscopy data shall be submitted for each product manufactured at each manufacturing location.

3.2.4 Reference Materials

Reference materials shall serve to demonstrate the minimum acceptable performance requirements. Tables 1 and 2 detail the reference materials required for the qualification of the different penetrant systems, developers, and solvent removers. Identification of reference materials is available from the qualifying agency.

3.2.5 Qualification Testing

All qualification tests shall be conducted by a laboratory or penetrant manufacturer specifically approved by the qualifying agency. A certified test report shall be furnished to the qualifying agency upon submittal of candidate penetrant materials for qualification.

3.2.6 Requalification

Penetrant materials shall be requalified when changes to their formula or method of manufacture are made that are outside of normal manufacturing tolerances. Requalification intervals may be established at the discretion of the qualification agency. Requalification shall require submission of the following test reports and certifications:

Sensitivity (see 3.3.7)

Removability (see 3.3.8.7 for penetrant systems or 3.3.10.4 for developers)

Toxicity Characteristics Review (see 3.2.3.1)

3.3 Physical Properties

3.3.1 Safety

The hazard characteristics of each material shall be properly identified, and the manufacturer shall certify that the provided SDS contains all relevant safety information for the product.

3.3.1.1 Safety Data Sheet Updates

Whenever a material safety data sheet is updated by the manufacturer, a copy of the update shall be sent to the qualifying agency with each subsequent shipment.

3.3.1.2 Prohibited ingredients for any penetrant material include asbestos, compounds of hexavalent chromium, Class 1 Ozone Layer Depleting Substances (OLDS) and OLDS banned by federal regulation.

3.3.2 Corrosive Properties

All inspection materials shall be noncorrosive and nonoxidizing. The materials shall be tested as supplied by the manufacturer or mixed to working concentrations with deionized or distilled water in the case of aqueous developers, hydrophilic removers, and water base penetrants. The test panels shall show no evidence of pitting, etching, cracking, oxidation, or corrosion when examined after testing in accordance with the following requirements. Tarnishing or discoloration that does not result in pitting, etching, or another form of metal removal is not cause for rejection.

3.3.2.1 Moderate Temperature Corrosion

All materials shall be tested for moderate temperature corrosiveness to steel, aluminum, and magnesium in accordance with 4.4.1.

3.3.2.2 High Temperature Stress Corrosion of Titanium

All materials shall be tested for corrosion of titanium in accordance with 4.4.2.

3.3.2.3 High Temperature Corrosion of Cast Nickel Alloys

All materials shall be tested for corrosion of nickel alloys in accordance with 4.4.3.

3.3.2.4 Interpretation

Samples containing water may corrode the portion of the specimen not covered by the sample. This is acceptable. Oxidation, pitting, etching, cracking, or corrosion below the liquid level is not acceptable. Tarnishing or discoloration that does not result in pitting, etching, or another form of metal removal is not cause for rejection.

3.3.3 Flash Point

Penetrants and emulsifiers, in other than aerosol containers, shall have flash points not lower than 200 °F (93 °C). Method A, B, C, D penetrants, Method B emulsifiers, and Method D emulsifiers shall be tested in accordance with ASTM D93. Method A(W) penetrants shall be tested in accordance with Method A, Flash/No-Flash test of ASTM D3828.

3.3.4 Viscosity

The manufacturer shall state the nominal viscosity for each penetrant and emulsifier submitted for qualification. This viscosity, $\pm 10\%$, shall establish the requirement for subsequent batches of material. Viscosity shall be tested in accordance with ASTM D445 at 100 °F ± 5 °F (38 °C ± 3 °C).

3.3.5 Storage Stability

The supplier shall certify that all materials submitted for qualification are capable of meeting specified requirements after a 1-year storage, in fully closed containers, between 60 and 100 °F (16 and 38 °C). Conformance may be confirmed by testing the samples submitted for qualification to specified requirements after the 1-year storage period.

3.3.6 Temperature Stability

All penetrants and emulsifiers shall show no separation when tested in accordance with 4.4.4.

3.3.7 Sensitivity

Candidate systems and materials must equal or exceed the performance of the appropriate reference system or material (see Table 3). Sensitivity shall be tested in accordance with 4.4.5.

3.3.8 Penetrants

3.3.8.1 Condition

All penetrants shall be furnished in a ready-to-use condition requiring no mixing or stirring.

3.3.8.2 Color

Type 2 penetrant shall be red, orange, or purple when viewed under visible light.

3.3.8.3 Fluorescent Properties (Type 1)

3.3.8.3.1 Color

3.3.8.3.2 Type 1 penetrants shall fluoresce green, yellow, or orange when observed under ultraviolet irradiation (UV-A). UV-A sources use for this assessment shall conform to the requirements of ASTM E1417/E1417M and ASTM E3022.

3.3.8.3.3 Brightness

The fluorescent brightness of Type 1 penetrants shall be not less than the following percentages of the brightness of the reference penetrant FP-4PE when tested in accordance with ASTM E1135:

Level 1/2	50%
Level 1	65%
Level 2	80%
Level 3	90%
Level 4	95%

3.3.8.3.4 Ultraviolet Stability

The ultraviolet stability of the fluorescence of Type 1 penetrants shall be tested in accordance with 4.4.7. The minimum acceptable values are as follows:

Level 1/2	50%
Level 1	50%
Level 2	50%
Level 3	70%
Level 4	70%

3.3.8.3.5 Thermal Stability

The thermal stability of the fluorescence of Type 1 penetrants shall be tested in accordance with 4.4.8. The minimum acceptable values are as follows:

Level 1/2	60%
Level 1	60%
Level 2	60%
Level 3	80%
Level 4	80%

3.3.8.4 Tank Life

Penetrants shall show no separation, precipitation, or scum formation when tested in accordance with 4.4.9.

3.3.8.5 Water Tolerance - Method A and A(W) Penetrants

Method A and A(W) penetrants shall tolerate not less than 5% additional water without gelling, separating, or coagulating when tested in accordance with 4.4.10.

3.3.8.6 Water Solubility (Hydrophobic Characteristics Test) - Method B and D Penetrants

Method B and D penetrants shall not be water soluble. Add 25 ml of demineralized water to a graduated cylinder containing 25 ml of test penetrant. The water shall be added using a dropwise method (1 drop every +/- 2 seconds). After the water has been added, allow for 1 hour of settling time for the penetrant-water mixture to separate. Two distinct phases shall be observed between the water and penetrant. The water phase shall exhibit at least 24 ml of separation from the penetrant phase to demonstrate that the test penetrant is not water soluble.

3.3.8.7 Removability

Penetrant systems shall leave no more residual penetrant than the same sensitivity level reference penetrant system (see Table 4) when tested in accordance with 4.4.11.

3.3.8.8 Water Content

Method A, B, C, and D penetrants shall not contain more than 5% water. The water content of Method A(W) penetrants shall be $\geq 20\%$ by volume. The water content of Method A(W) penetrants shall be specified by the manufacturer at the time of qualification. Water content shall be tested in accordance with ASTM D95, ASTM E203, or equivalent.

3.3.9 Emulsifiers

3.3.9.1 Color

The color of Type 1 system emulsifiers shall be distinctly different from the color of Type 1 penetrants when viewed under either visible light or ultraviolet radiation. The color of Type 2 system emulsifiers shall be distinctly different from the color of Type 2 penetrants.

3.3.9.2 Tank Life

Method B emulsifiers shall show no separation, precipitate, or scum formation when tested in accordance with 4.4.9.

3.3.9.3 Penetrant Contamination

Method B emulsifiers mixed in the ratio of four parts emulsifier to one part penetrant (20% concentration) shall leave no more residual background than a comparable mixture of the appropriate reference standards when tested for removability in accordance with 4.4.11.

3.3.9.4 Water Tolerance

Method B emulsifiers shall tolerate not less than 5% additional water without gelling, separation, or coagulation when tested in accordance with 4.4.10.

3.3.9.5 Concentration

For qualification testing, Method A, A(W), B, C, and D penetrants and Method B emulsifiers shall be supplied in ready-to-use form not requiring further mixing. Method D emulsifiers shall be supplied as concentrates to be mixed in accordance with the manufacturer's instructions for specified tests.

3.3.9.6 Water Content

Method B and D emulsifiers shall not contain more than 5% water when tested in accordance with ASTM D95, ASTM E203, or equivalent.

3.3.10 Developers

3.3.10.1 Form

Forms a, d, and e developers shall be supplied ready mixed for use without further dilution. Forms b and c developers shall be supplied as concentrates to be mixed with water according to manufacturer's instructions. Aerosol packaging of Forms d and e developers shall include a pellet to aid in agitation of the contents.

3.3.10.2 General

Developers for Type 1 penetrants, after application, shall exhibit no green, yellow, or orange fluorescence, and fluorescence of other colors shall be no greater than that of the reference developer. Developers for Type 2 penetrants shall provide distinct contrast with the penetrant to be used when viewed under visible light.

3.3.10.3 Coverage

Forms b, c, d, e, and f developers shall provide a smooth, even coating that covers the test surface completely when applied in accordance with manufacturer's instructions.