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MIL-P-47158(MI)
7 June 1974
SUPERSEDING
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1 November 1968

MILITARY SPECIFICATION
PENETRANT INSPECTION, SOUNDNESS REQUIREMENTS FOR MATERIALS, PARTS AND WELDMENTS

This specification is approved for use by all departments and agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification describes the defect limits allowed under four quality level classifications for the penetrant inspection of forgings, castings, tubes, sheets, bars, etc., (usually nonmagnetic) in the following fabrication stages:

a. Unmachined or unwelded parts or materials.

b. Machined parts.

c. Weldments; for purposes of this specification, the term weldment refers to deposited filler metal and areas of base metal adjacent thereto which are likely to be affected by the welding operation. Brazed joints may also be considered as weldments under this specification.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

FSC 6850

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MIL-I-6866	Inspection, Penetrant Method of
MIL-I-25135	Inspection Materials, Penetrant

STANDARDS

Military

MIL-STD-109	Quality Assurance Terms and Definitions
MIL-STD-410	Qualification of Inspection Personnel (Magnetic Particle and Penetrant)

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents from a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

American Society for Testing Materials

ASTM D 445	Test for Kinematic Viscosity

(Copies of ASTM publications may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3. REQUIREMENTS

3.1 Inspection standard classification. At the fabrication stage indicated (see 6.3), weldments, materials, structures, parts or areas thereof shall be inspected to quality level classifications A, B, C, or D as specified in the drawing, purchase order or other applicable document.

3.1.1 Grade A. The grade A classification is applicable to units which are critical with regard to mechanical finishes or dynamic

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stresses and which warrant the use of selected materials or above-average practices. Grade A represents the highest degree of surface soundness obtainable under this specification and normally is called for only in areas of fillets, mechnical grooves, holes, sharp edges or other sections subject to fatigue or shock in service. Grade A also may be called for as a requirement for machined surfaces of castings if only very small discontinuties are allowable.

3.1.2 Grade B. The Grade B classification is applicable to units subject to high but well-distributed static stresses.

3.1.3 Grade C. The Grade C classification is applicable to moderately stressed units.

3.1.4 Grade D. The Grade D classification is intended primarily for use in identifying and controlling soundness of low stressed areas of castings adjacent to Grade A, B, or C areas. Grade D is rarely applicable as a callout for all sections of a casting.

3.2 Soundness requirements. For the grade specified, defects as revealed by the penetrant process shall not exceed the limits shown in Table I, II, and III, as applicable, Both clear and borderline indications (the latter are indications that do not clearly identify defects as to type, depth, or cross-sectional path) shall be subject to rejection or further exploration if critically located or patterned. Defects that will be removed by machining operations are not rejectable.

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Table I. - Maximum defect sizes (in inches) and distribution; wrought products, areas other than weldments

Type of defect (see section 6)	Grade A	Grade B	Grade C
Nonmetallic inclusions, rounded	1/32 dia D-3*	3/64 dia D-3*	1/16 dia D-3*
Nonmetallic inclusions, stringers	1/8 long DD-1*	3/8 long DD-1*	3/4 long DD-1*
Seams or laps (unmachined surfaces)	1/2 long DD-1*	1 long DD-1*	1-1/2 long DD-1*
Seams or laps (machined surfaces)	0	0	1/4 long DD-1*
Propagating defects (cracks, flakes, pronounced laminations, etc.)	0	0	0

*Distribution designations signify the following:

D-3 Defects no closer to each other than three times the maximum size.

DD-1 Defects no closer to each other than 1/2 inch lineally and 1/4 inch in a parallel direction.

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Table II. - Maximum defect sizes (in inches) and distribution; castings

Type of defect (see section 6)	Grade A	Grade B	Grade C	Grade D
Nonmetallic inclusions	1/32 dia D-3*	3/64 dia D-3*	1/16 dia D-3*	1/8 dia D-2*
Gas hole porosity	1/32 dia** D-3*	3/64 dia** D-3*	1/16 dia** D-3*	1/8 dia** D-2*
Discrete shrinkage cavities	1/32 dia or length D-3*	3/64 dia or length D-3*	1/16 dia or length D-3*	1/8 dia or lenght*** D-2*
Cracks, hot tears, or cold shuts	0	0	0	1/4 long***
Shrinkage sponge areas (may include small cavities, cavity stringers, and semi-fused seams)	0	0	0	1-1/4 dia***

*Distribution designations signify the following:

D-2 Defects no closer to each other than two times the maximum size.

D-3 Defects no closer to each other than three times the maximum size.

**The requirements for gas hole porosity for the individual grades do not apply if the voids are less than one half the maximum sizes specified and are well dispersed.

***Significant shrinkage defects are not allowed if within 1/2 inch of an outer edge of a casting section.

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Table III. - Maximum defect sizes (in inches) and distribution; weldments

Type of defect (see section 6)	Grade A	Grade B	Grade C
Cracks, weld or base metal (longitudinal, transverse, star or crater, underbead, underside, etc.)	0	0	0
Weld undercutting or lack of bead edge fusion			
Base metal less than 3/16 inch thick	1/64 deep, 1/8 long D-5*	1/64 deep, 1/4 long D-5*	1/32 deep, 1/4 long D-5*
Base metal 3/16 inch thick and over	1/32 deep, 1/8 long D-5*	1/32 deep, 1/4 long D-5*	3/64 deep, 3/8 long D-5*
Weld metal voids or inclusions, rounded			
Base metal less than 3/16 inch thick	1/64 dia D-5*	1/32 dia D-5*	1/16 dia D-5*
Base metal 3/16 inch thick and over	1/32 dia D-5*	1/16 dia D-5*	1/8 dia D-5*
Weld metal voids or inclusions, elongated			
Base metal less than 3/16 inch thick	1/16 long D-5*	1/8 long D-5*	3/16 long D-5*
Base metal 3/16 inch thick and over	1/8 long D-5*	1/4 long D-5*	3/8 long D-5*

*Distribution designations signify the following:

D-5 Defects no closer to each other than five times the maximum size.

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3.2.1 Review of indications. All questionable indications shall be carefully reviewed, preferably under low power magnification. If dimensional tolerances and other circumstances permit, exploration of defects by lightly filing or grinding surfaces (with reapplication of indicating medium) is recommended. The judicious use of a suitable tool such as a feeler gage or scriber may be helpful in establishing the significance of indications.

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 assure supplies and services conform to prescribed requirements.

4.2 Verification inspection (Government). All quality assurance operations performed by the contractor will be subject to Government verification at scheduled or unscheduled intervals. Verification will consist of (a) surveillance of the operations to determine that practices, methods, and procedures of the written inspection plan are being properly applied, and (b) Government product inspection to measure the quality of the product offered for acceptance. Deviation from the prescribed or agreed upon procedures, or instances of poor practices which might have an effect on the quality of the product, will be immediately called to the attention of the contractor. Failure of the contractor to promptly correct deficiencies discovered shall be cause for suspension of acceptance until correction has been made or until conformance of product to prescribed criteria has been demonstrated. To avoid interference with operations, the contractor shall designate a responsible official or officials to whom the Government inspector will report such instances.

4.3 Definitions. The definition of inspection terms shall be in accordance with MIL-STD-109.

4.4 Equipment verification. The Government inspector, when examining the contractor's inspection equipment, will determine that the contractor has available and utilizes correctly, gaging, measuring, and test equipment of required accuracy and precision and that the instruments are of a proper type and range to make measurements within the required accuracy.

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4.5 Examination schedule. Unless otherwise specified, 100 percent of the items in an inspection lot shall be examined. Any sampling plan shall be as agreed upon by the contractor and the procuring activity.

4.6 Certification of personnel. Penetrant inspection personnel shall be certified in accordance with MIL-STD-410.

4.6.1 Responsibility. The inspector shall be responsible for interpreting defects and determining acceptance or rejection.

4.7 Inspection method. Either of the following types of penetrant inspection as covered by MIL-I-6886 may be used:

Type I - Fluorescent methods

Type II - Nonfluorescent methods.

4.8 Inspection equipment. Either portable or fixed equipment may be used for containing and applying penetrants and adjunctive materials. For Type I inspection, a darkness booth and a suitable source of "black light" as defined in MIL-I-6866 shall be provided.

4.9 Inspection materials. Penetrants, emulsifiers, dye removers and developers as required for the inspection method selected shall be as specified in MIL-I-25135.

4.9.1 Inspection material maintenance. If inspection materials are applied from tanks or similar equipment which are not a part of the supplier's original packaging unit, periodic checks shall be made to guard against contamination, lack of contrast, undue thickening, dilution, and other adverse occurrences. Tests to determine lack of contrast and brightness of Type I penetrant shall be in accordance with MIL-I-25135. The viscosity of Type I penetrant shall be maintained from 8 to 20 centistokes at 100 degrees Fahrenheit (F) with tests in accordance with ASTM D-445. Where otherwise practicable, the supplier's recommendations for maintaining inspection materials shall be followed.

4.10 Cleaning before inspection. Units undergoing inspection shall be thoroughly cleaned and dried before application of the penetrant and adjunctive materials. Units cannot be inspected by the penetrant method unless they are free of oil, scale, paint, etc. Treatment such as electroplating, blast cleaning and impregnation tend to limit the effectiveness of this method.

4.11 Heating. Units undergoing inspection shall not be heated to a temperature higher than 250 degrees F before, during, or after application of the penetrant and adjunctive materials.

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4.12 Inspection procedures. The following basic operations shall be used for both Type I and Type II methods:

a. Application of penetrant.

b. Removal of penetrant from surfaces.

c. Application of developer.

d. Evaluation of indications.

4.12.1 Application of penetrant. As specified in MIL-I-6866, the penetrant shall be applied to the units and materials being inspected by immersion, painting or spraying. Nominal dwell times (periods of time allowed for penetration) at room temperatures shall be in accordance with Table IV unless the need for shorter or longer periods is demonstrated. Unless otherwise specified, the presence of cracks or other fine defects should be assumed, and generous dwell times used when units of unfamiliar types are first examined.

4.12.2 Removal of penetrant. After penetration and emulsification, when required, the units or areas being examined shall be rinsed thoroughly with water or solvent to remove all the penetrant from the surfaces of the parts. When the water rinse is used, standard line pressure is acceptable providing it is applied by using a spray nozzle. The water temperature for rinsing shall not exceed 110 degrees F.

4.12.3 Application of developer. For the Type II method and as an alternate under the Type I method, developers in the form of liquid suspension of powders shall be applied by spraying or other suitable means. When a dry developing powder is used under the Type I method, it may be applied by dusting, blowing, immersion or tumbling.

4.12.3.1 Drying and developing temperatures. When elevated temperatures are used, they shall be not higher than the maximum temperatures recommended by the penetrant manufacturer. These temperatures shall not exceed 250 degrees F.

4.12.3.2 Developing time. Approximately one half of the penetration dwell time shall be allowed for developing.

4.12.4 Evaluation of indications. Examination of parts, weldments and materials shall be to the quality level specified on the applicable design or procurement document. Allowable discontinuties under the specified level, at the fabrication stage indicated, shall be as shown in Table I, II, and III and related requirements.

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4.12.4.1 Areas for particular surveillance. Special attention should be given to the surveillance (within specified requirements) of highly finished surfaces, weldments, abrupt changes in section, and areas around drilled holes.

4.12.4.2 Removable defects. Parts containing defects which may be removed by subsequent work will require reinspection after completion of subsequent work.

4.13 Cleaning after inspection. After acceptance or rejection, units shall be thoroughly cleaned of developer and any remaining penetrant. Materials subject to corrosion shall be properly protected after cleaning.

4.14 Identification. Unless otherwise specified, units that have been inspected by the penetrant method shall be etched with the applicable symbol shown in Table V. When etching is not practicable, the inspected units shall be tagged or impression stamped with ink. Impression stamping, when approved by the procuring activity, shall be adjacent to the part number. Tags shall be stamped with ink for use on units whose construction, finish, or functional requirements preclude the use of etching or stamping.

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Table IV. - Nominal dwell (penetration) times in minutes*

Material	Type of defect	Type I penetrants (fluorescent) water washable**	Type I penetrants (fluorescent) post emulsification	Type II penetrants (dye)
Wrought metals	Inclusions, seams, laminations	30	15	10
	Cracks, laps, flakes	45	30	10
Cast metals	Inclusions, voids, shrinks	20	10	5
	Cracks, cold shuts	40	20	10
Metal weldments (including brazed joints)	Inclusions, voids, undercuts	20	15	5
	Cracks, lack of fusion	40	30	10
Plastics	Cracks	30	5	5
Glass	Cracks	30	5	5

*In general, the dwell times needed for light alloys such as aluminum and magnesium will be less than the periods shown; however, the dwell times needed for titanium and the high-temperature alloys may be twice the times shown.

**Water washable fluorescent penetrants should not be used in examining titanium and the high-temperature alloys.

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Table V. - Inspection symbols

Inspection	Symbol
Physically inspected and accepted	P
Accepted on sampling plan but not physically accepted	P
Unacceptable	Reject

4.14.1 Serial identification. When serial identification is required, the serial number or symbol specified by the procuring activity shall be placed on units, tags, and reports.

4.15 Inspection reports. A report of penetrant inspection shall be submitted to the procuring activity. The report shall include all information necessary for the understanding of the inspection test results such as serial numbers, grade of inspection, unit name, unit number, number of units in the lot, and lot number. If rejected units are reported, the identity of the defects on which rejection is based shall be included. If a sampling plan is authorized by the procuring activity, the report shall include the sampling plan used and the method of selecting the samples.

5. PREPARATION FOR DELIVERY

5.1 There are no applicable requirements.

6. NOTES

6.1 Intended use. This specification, when used with applicable documents, is intended to establish standards of acceptance for units inspected by the penetrant method.

6.2 Ordering data. Procurement documents should include the following:

a. Title, number, and date of this specification.

b. Required soundness grade(s) (see 3.1).

c. Applicable sampling plan if other than 100 percent (see 4.5).

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6.3 Definitions.

6.3.1 Critical areas. In terms of quality level classifications as shown in Section 3, design engineers should indicate on drawings the more critical and the less critical areas of units with regard to stress concentration and mechanical finishes. This is in the interest of overall efficiency, including cost control, and can be particularly important to manufacturing, procurement, and quality control activities.

6.3.2 Fabrication stage. Under ordinary circumstances, it is reasonable for the designer of a finished unit to expect that the soundness levels selected will be enforced as a part of the final inspection procedures and to specify that the requirements are applicable after maching, after welding, etc. It does not necessarily follow, however, that the quality levels specified for the finished unit should be included as part of the purchase requirements for bars, plates, unmachined castings, unmachined forgings, or other forms. In specifying raw stock for units subject to severe, final inspection requirements, due consideration should be given such factors as the availability of premium quality materials and the cost of such materials in relation to the possible cost of rejection of finished parts made of materials of regular quality.

6.4 Identification of defects. Following are discussions of certain of the defects and indications thereof covered in Section 3. When types of indications which cannot be identified otherwise are encountered in critical locations, metallurgical examination of sample parts by destructive methods may be necessary.

6.4.1 Inclusions. Inclusions are round or elongated nonmetallic particles which may appear at the surfaces of various products, but which normally are not considered harmful if relatively small and well dispersed. However, if they appear in clusters or stringers or if abnormally large individually (for the quality level specified), they are indicative of materials or practices of questionable quality.

6.4.2 Laminations. Laminations may appear as inclusion stringers between rolled surfaces of material in the form of rectangles or plates, but in some instances actual separations may occur in these products. If present, laminations would be indicated on the short transverse sections of a unit. Short, intermittent laminations may not be objectionable if the unit is not subject to high bending stresses. The occurrence of laminations can usually be attributed to faulty rolling mill operations.

6.4.3 Laps. Laps are surface defects appearing as folds or tangential seams in wrought products and are usually produced during hot working operations.

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6.4.4 Flakes. Also known as shatter cracks, flakes appear as short, discontinuous fissures in forgings and possibly other wrought products. They are attributed to localized stresses which may occur during cooling from hot work.

6.4.5 Cold shuts. These casting defects are caused by two streams of semi-molten metal coming together inside a mold but failing to fuse. Cold shuts are sometimes referred to as misruns, but the latter term is more correctly used to describe lack of filling of a mold.

6.4.6 Gas hole porosity. Casting discontinuities of this type, usually round or oval shaped, are also known as gas porosity, pin hole porosity, and blow holes. In a relatively common form, cavities may appear on the surfaces of castings and are likely to be caused by the generation of steam when molten metal contacts damp sand, damp chills, inadequately dried mold wash, etc. Porosity may also result from the evolution of absorbed gas during solidification. If the voids are small and well dispersed, they are often harmless, but if relatively large and appear in localized areas, they should be carefully evaluated. Gas holes are probably most insidious when entrapped immediately under thick surface films of castings which are to be machined to exacting finishes, and for which adequate cleanup tolerances have not been allowed.

6.4.7 Shrinks. Casting defects in the category include shrinkage sponge, of which there are a number of manifestations. Shrinkage sponge areas may include small voids in the form of stringers or bunches, or there may be in evidence a "fingerprint" pattern, consisting of semifused seams. Apparently, shrinks are always caused by variations in solidification rates in the mold. In castings of substantial size, shrinks can usually be avoided by proper placement of risers, runners, chills, etc., but in case of small, complex investment castings, it may be feasible only to keep them confined to low stressed areas.

6.4.8 Weldment defects. Sketches of typical weldment defects which may be enhanced by the penetrant inspection method are presented herein as Figures 1 through 6.

6.5 Supersession data. Except for the addition of grade D (Table II), the soundness classifications covered herein are generally equivalent to those shown in MPD's 9154, 9184, and 9675, which are superseded by this specification. This specification includes the requirements of Missile Purchase Descriptions, MPD-9154, 9184, 9675, and 10567A, dated November 1968.

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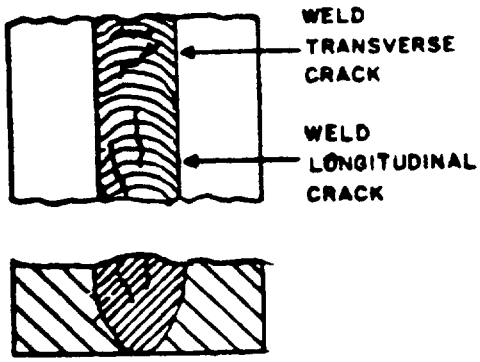

FIGURE 1

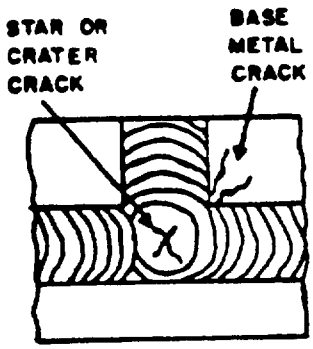

FIGURE 2

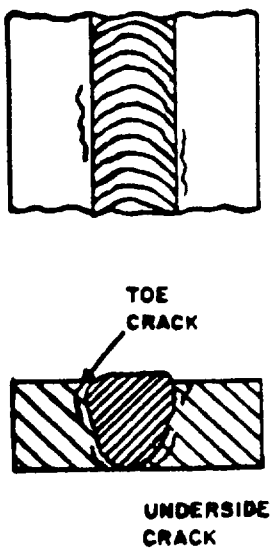

FIGURE 3

Cracks on weldment surfaces which might be difficult to detect unaided are usually revealed by the penetrant process. All cracks are classed as propagating defects and are subject to rejection.

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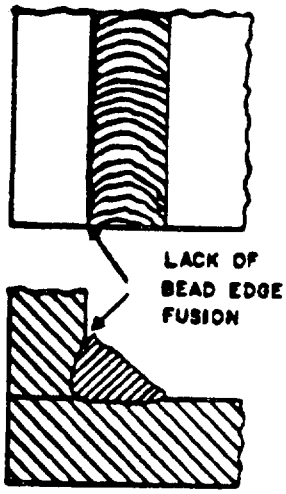

FIGURE 4

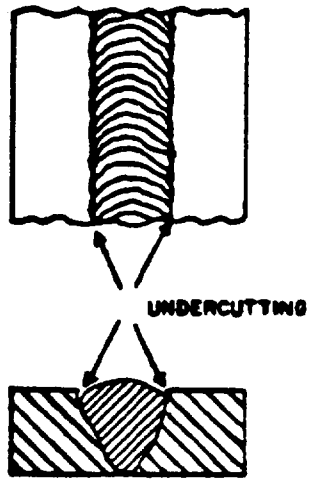

FIGURE 5

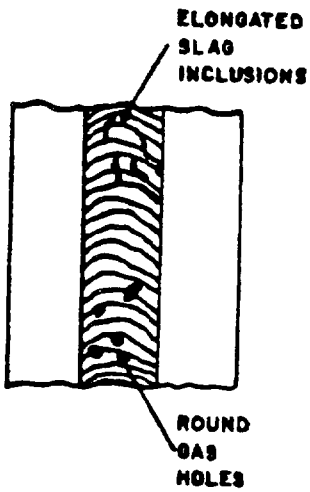

FIGURE 6

Undercutting, lack of bead edge fusion, and inclusions are considered detrimental if they exceed the limits specified herein. Defects of this type are often apparent without the use of the penetrant process.

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   A. GIVE PARAGRAPH NUMBER AND WORDING.

   B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

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