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PENETRANT, MAGNETIC PARTICLE AND ULTRASONIC INSPECTION REQUIREMENTS FOR, SPECIFICATION FOR

DESIGN ENGINEERING DIRECTORATE

APPROVED:

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JOHN F. KENNEDY SPACE CENTER, NASA

PENETRANT, MAGNETIC PARTICLE AND ULTRASONIC INSPECTION

REQUIREMENTS FOR

SPECIFICATION FOR

1. SCOPE

1.1 This specification covers the requirements for nondestructive testing, using penetrant, magnetic particle and ultrasonic inspection methods. Inspection testing as defined herein shall be used when required by engineering drawings.

2. APPLICABLE DOCUMENTS

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

SPECIFICATIONS

Military

MIL-I-6866	Penetrant Method of Inspection
MIL-I-6868	Magnetic Particle Inspection Process
MIL-I-25135	Inspection Materials, Penetrant

PUBLICATIONS

George C. Marshall Space Flight Center

~~MSFC-RQA/MI-5330.13~~	~~Programmed Instruction Course in Principles of Ultrasonics~~

Item no longer in print

(Copies of specifications, standards, drawings, and publications may be obtained from the Kennedy Space Center Library.)

2.2 Other Publications.- The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or requests for proposals shall apply.

American Society for Testing and Materials, ASTM

A340	Magnetic Testing, Definition of Terms, Symbols and Conversion Factors Relating to
A435	Longitudinal-Wave Ultrasonic Testing of Steel Plates for Pressure Vessels, Standard Method and Specification for
A462	Liquid Penetrant Inspection of Steel Forgings, Standard Method for
A577	Ultrasonic, Shear-Wave Inspection of Steel Plates, Tentative Specification for
A578	Longitudinal-Wave Ultrasonic Testing and Inspection of Plain and Clad Steel Plates for Special Applications, Tentative Specification for
E109	Dry Powder Magnetic Particle Inspection, Standard Method for
E113	Ultrasonic Testing by the Resonance Method, Recommended Practice for
E114	Ultrasonic Testing by the Reflection Method, Using Pulsed Longitudinal Waves Induced by Direct Contact, Recommended Practice for
E125	Standard Reference Photographs for Magnetic Particle Indications of Ferrous Castings
E127	Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks, Recommended Practice for
E138	Wet Magnetic Particle Inspection, Standard Method for
E164	Ultrasonic Contact Inspection of Weldments, Standard Method for
E165	Liquid Penetrant Inspection, Standard Method for
E213	Ultrasonic Inspection of Metal Pipe and Tubing for Longitudinal Discontinuities, Tentative Method for

E214	Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves, Tentative Recommended Practice for
E269	Magnetic Particle Inspection, Tentative Definitions of Terms Relating to
E270	Liquid Penetrant Inspection, Tentative Definitions of Terms Relating to
E273	Ultrasonic Inspection of Longitudinal and Spiral Welds of Welded Pipe and Tubing, Tentative Method for

(Applications for copies of the above should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Penna. 19103.)

American Welding Society

AWS - A2.2 - 58 Nondestructive Test Symbols

(Applications for copies should be addressed to the American Welding Society, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017.)

3. REQUIREMENTS

3.1 General.- The selection of the nondestructive testing (NDT) method, (penetrant, magnetic particle, or ultrasonic) shall be based on variables such as:

a. Type and origin of discontinuity (inherent, process, or service)
b. Material manufacturing processes (heat treating, machining, plating or welding)
c. Limitations (metallurgical, structural, processing) and precautions
d. Accessibility of article
e. Level of acceptability desired
f. Equipment available
g. Cost

To satisfactorily develop knowledge of the above applicable variables, a planned analysis of the task shall be made for each article requiring nondestructive testing.

3.2 Penetrant Inspection.

3.2.1 General.- Testing with liquid penetrant offers the advantages of fast inspection, excellent performance, and low cost, but it is specific in application, being suitable only for detecting discontinuities open to exposed surfaces. This test method is applicable only to nonporous materials since leakage from the porous surface would act to mask individual defects.

3.2.2 Applications of Penetrant Inspection.- Liquid penetrant inspection can be used on all types of nonporous metallic material including ferrous and nonferrous alloys, glasses and ceramics, nonporous powder metal parts and certain plastics and synthetic materials. This method will reveal cracks of extreme tightness, and testers can inspect entire surfaces of complex shapes in one sequence of operations.

3.2.3 Qualification.- Personnel performing and interpreting penetrant and fluorescent penetrant testing shall be qualified in accordance with MIL-I-6866.

3.2.4 Materials for Penetrant Inspection.- All materials used for penetrant inspection shall be in accordance with MIL-I-25135.

3.2.4.1 Penetrants.- Penetrants are classified into two groups; visible dye penetrant, and fluorescent penetrant. Fluorescent penetrant methods require subsequent visual examination to be performed under a filtered ultraviolet lamp instead of visual examination in normal daylight as is possible with the other type penetrant. Each penetrant group is subdivided into three types (I, II, and III), each relating to the manner by which the excess penetrant is removed from the surface of the item that is under inspection.

3.2.4.1.1 Type I are water-washable penetrants consisting of a penetrant that contains a 5 to 15 percent emulsifier, and a developer.

NOTE: (1) A fifteen percent emulsifier is considered optimum since emulsifiers are not good penetrants and would bring about a loss of testing sensitivity at a higher percentage.

(2) In the fluorescent method, the ultraviolet lamp or "black light" has a power value which decreases with use, and therefore periodic check of black light intensity must be made.

3.2.4.1.2 Type II are solvent penetrants that require both special cleaners and developers. However, as solvent penetrants do not contain any additives (other than soluble dyes or finely dispersed fluorescent particles), they are more sensitive than the Type I.

3.2.4.1.3 Type III are post-emulsifiable penetrants, also requiring special cleaners and developers. These differ from the water-washable types in that the emulsifier is not applied to the part under inspection until the inspector desires to remove the excess penetrant.

3.2.4.2 Developers.- Developers are needed for each penetrant inspection method. The developers produce a thin, uniform layer of porous material upon the surface of the test article through which any trapped penetrant can rise to the surface. There are two classifications of developers; dry and wet.

3.2.4.2.1 Dry developers consist of dry, light-colored, powdery materials that are applied to the testing surface either from an immersion tank or a blower gun after the excess penetrant has been removed and the part is dry.

3.2.4.2.2 Wet developers, consisting of powdered material suspended in a liquid (water or a volatile solvent), are also applied either through immersion or spraying. This method requires time for the developer to dry so that the penetrant can rise through the powdery layer, but this method is useful for either rapid inspection of a large number of parts or handling items of complicated configuration.

3.2.5 Methods of Penetrant Inspection.- Each penetrant inspection shall be performed in accordance with MIL-I-6866. There are six different methods of performing penetrant inspection.

3.2.5.1 Method I.- The penetrant inspection method using a solvent removable visible dye penetrant, in accordance with Specification MIL-I-6866, Type II, Method C, shall be used for spot inspection of small quantities in field or shop and when the water rinsing method is not feasible due to either part size, weight, surface condition or lack of sensitivity.

3.2.5.2 Method II.- The penetrant inspection method using a post-emulsified visible dye penetrant, in accordance with Specification MIL-I-6866, Type II, Method B, shall be used when inspecting large quantities where a greater sensitivity is required than is obtainable using water-washable visible dye penetrants (Method III below).

3.2.5.3 Method III.- The penetrant inspection method using a water-washable visible dye penetrant, in accordance with Specification MIL-I-6866, Type II, Method A, shall be used when inspecting large quantities where the lowest sensitivity is acceptable.

3.2.5.4 Method IV.- The penetrant inspection method using a water-washable fluorescent dye penetrant, in accordance with Specification MIL-I-6866, Type I, Method A, shall be used when the lowest penetrant sensitivity is sufficient to detect inherent defects (deeper than wide) of either large areas or large quantities involving either surfaces of rough castings or threads and keyways.

3.2.5.5 Method V.- The penetrant inspection method using a post-emulsifiable fluorescent dye penetrant, in accordance with Specification MIL-I-6866, Type I, Method B, shall be used when defects are wider than deep and a higher penetrant sensitivity is required than is obtainable using water-washable fluorescent dye penetrant (Method IV above), as when inspecting for grinding cracks.

3.2.5.6 Method VI.- The penetrant inspection method using a high sensitivity post-emulsifiable fluorescent dye penetrant, in accordance with Specification MIL-I-6866, Type I, Method B, shall be used when a higher penetrant sensitivity is required than is obtainable from Method IV or Method V as when inspecting for either stress corrosion or intergranular corrosion.

3.2.6 General Procedure Steps of Penetrant Inspection.- Although the techniques of each step vary with the type of penetrant used, any one of the six methods of penetrant inspection requires performance of the following five general procedure steps. (Refer to ASTM-E165 and ASTM A462 for standard inspection methods.)

a. Precleaning
b. Applying penetrant
c. Removing excess penetrant
d. Applying developer
e. Inspecting

3.3 Magnetic Particle Inspection.

3.3.1 General.- The magnetic particle inspection is used for detecting discontinuities on or near the surface in suitably magnetized materials by employing finely divided magnetic particles that tend to congregate in regions of the magnetic nonuniformity. Since ordinary carbon steels have a permeability about 1,000 to 1,500 times greater than that of air, voids on a piece of steel present considerable resistance to the passage of magnetic lines of force. When the void is at or near the surface of the piece, resistance may be so great as to distort lines of force sufficiently causing them to leave the surface of the piece, penetrate the surrounding air, bridging the void, and re-entering on the other side of the void. It is these distorted lines of force that act upon the dry, finely divided, ferromagnetic particles placed upon the surface of the piece to give the indication of the void. Under certain conditions, it is preferable to immerse the magnetized specimen in a light petroleum distillate in which the iron powder is held in suspension. Within the limits of saturation, it may be stated that the sensitivity of the test is directly proportional to the number of lines of force traversing the piece, since more lines of flux will be distorted to act on the magnetic particles. To obtain a fair test, caution must be exercised in the selection of the magnetizing currents.

3.3.2 Applications.- All surface and near surface defects commonly encountered in ferromagnetic materials (iron, nickel, cobalt, and their alloys) are detectable by magnetic particle inspection.

3.3.3 Qualification.- Personnel performing and interpreting magnetic particle testing shall be qualified in accordance with MIL-I-6868 before conducting operational magnetic particle inspections. In addition, the inspectors shall be able to interpret the results and shall be thoroughly familiar with the standards and codes under which they are working.

3.3.4 Methods.- Ferromagnetic parts shall be magnetic particle inspected in accordance with Specification MIL-I-6868, as indicated in the test document generated by the responsible NASA design agency. The test document shall indicate:

a. Method of magnetization
b. Method of particle application
c. Type of particle (dry, wet, or wet fluorescent)
d. Acceptance criteria

Magnetic particle inspection shall be performed in such manner as to ensure satisfactory detection of harmful discontinuities having axis in any direction. A complete magnetic particle inspection test shall consist of one or more distinct magnetizing and inspection operations so conducted that the magnetic lines of force will be transverse, insofar as is practicable, to any discontinuity that may exist in the item under inspection. Refer to ASTM E109 for dry powder magnetic particle inspection method, to ASTM E138 for wet magnetic particle inspection method, and to ASTM E125 for standard reference photographs applicable to ferrous casting indications.

3.4 Ultrasonic Inspection.

3.4.1. General.- Ultrasonic testing methods sometimes are capable of locating defects in excess of the effective range of X-ray testing, due to sound waves being able to penetrate solid materials to greater depths. X-rays are neither reflected nor refracted to any great extent from the material under test, whereas ultrasonic waves are generally reflected or greatly refracted. Since the sound propagation property of a material is a function of its density and stiffness, either a very thin slit or a lamination in the material will create a severe alteration in the medium (stiffness property) at the boundary of either the slit or the material. The sound waves are especially sensitive to flaws of the thin lamination type. As with sonic testing, the longitudinal waves are altered in velocity, or lose some energy, when the sound column strikes a portion of the tested material which is nonhomogeneous, due to presence of either a crack, a separation, a blowhole, an inclusion, or some other defect. However, properly calibrated ultrasonic equipment can locate material separations as small as 0.001 inch thick. Ultrasonic inspection procedures are basically manual but through automation can both eliminate human error and permit the use of harmonics, with reliability, for investigating the interiors of various sizes of masses.

3.4.2 Applications.- The basic characteristics of ultrasonic testing permit it being used to test a variety of either metallic or nonmetallic products, such as welds, forgings, castings, sheet, tubing, plastics, ceramics, etc. The selection of the method of ultrasonic inspection depends on type and location of defect, geometry of part, and other factors. It shall be incumbent upon the contractor to assure that proper method and technique are applied.

3.4.3 Qualifications.

3.4.3.1 Operator Qualification.- All personnel who will perform ultrasonic inspection shall have training in ultrasonic procedures to assure that proper scanning techniques and equipment are used. In addition to scanning techniques and equipment, the training shall consist of valid interpretation of cathod-ray tube indications and their comparison with those from applicable reference standards.

3.4.3.1.1 Inspector Requirements.- The qualification of an inspector shall be as follows:

a. Training.- Satisfactory completion of the requirements of MSFC RQA/MI-5330.13
b. Examinations.- Performance and written examinations to requirements in MSFC RQA/MI-5330.13.

3.4.3.1.2 Personnel Requirements.- Personnel who have been previously qualified but have not been engaged in ultrasonic testing for 12 months shall be requalified by examination in accordance with MSFC RQA/MI-5330.13.

3.4.3.2 Equipment Qualifications.

3.4.3.2.1 General.- In ultrasonic testing, all discontinuity indications are compared to a reference standard. The reference standard may be of any one of many reference blocks or sets of blocks specified for a given test. Ultrasonic standard reference blocks, often called test blocks, are used in ultrasonic testing first to calibrate the ultrasonic equipment and then (using blocks of same material as test part) to evaluate the discontinuity indication from the test part. The latter is called standardization. Calibrating and standardizing do two things: verifies that the instrument/transducer combination is performing as required; establishes a sensitivity or gain setting at which all discontinuities of the size specified, or larger, will be detected. Evaluation of discontinuities within the test specimen is accomplished by comparing the indications from them with the indication from an artificial discontinuity of known size, at the same depth in a standard reference block of the same material. Ultrasonic standard reference blocks are made from carefully selected, ultrasonically-inspected aluminum alloy bar stock (ASTM Recommended Practice E127) to meet predetermined standards of sound attenuation, grain size, and heat treat. Discontinuities are represented by carefully drilled flat-bottomed holes. Test blocks are made with painstaking care so that the only discontinuity present is the one that was added intentionally. Various other types of blocks are made from plastic, steel, magnesium, carbon, etc. The ASTM basic set consists of ten 2-inch blocks that have 3/4-inch-deep, flat-bottomed holes drilled in the center at one end. One block has a 3/4-inch-diameter flat-bottom hole (FBH) and a metal distance of 3 inches from the test surface to the flat-bottom hole. The next seven blocks each have a 5/64-inch FBH and metal distances of 1/8, 1/4, 1/2, 3/4, 1-1/2, 3, and 6 inches from the test surface to the FBH. The two remaining blocks have an 8/64-inch-diameter FHB and metal distances of 3 inches and 6 inches. In this basic set, the three No. 3, 5, and 8 blocks with the 3-inch metal distance provide the area/amplitude relationship, and the seven blocks with the 5/64-inch-diameter FBH (No. 5) and varying metal distances provide the distance/amplitude relationship.

3.4.3.2.2 Calibration of Ultrasonic Test Equipment.- Periodic calibration of ultrasonic testing units is required to establish linearity of displayed indications and to ensure proper instrument performance. Irrelevant effects within the testing unit are eliminated by calibrating the instrument system to reference standards. All ultrasonic test instruments that are to be used for flaw detection shall be calibrated for sensitivity and horizontal sweep, just prior to the ultrasonic instrument being used for flaw detection. This shall be accomplished by using reference blocks that shall conform to the dimensional and finish requirement of ASTM E127.

3.4.3.2.3 Recalibration of Ultrasonic Test Equipment.- Recalibration shall be made each time there is a change of operators, when new batteries are installed, or when the equipment being operated from a 110-volt source is connected to a different power outlet.

3.4.3.2.4 Standardization of Ultrasonic Test Equipment.- It is important that the test block material be the same, or similar to that of the test specimen. Alloy content, heat treatment, degree of hot or cold working from forging, rolling, etc., all affect the acoustical properties of the material. If test blocks of identical material are not available, they shall be similar in sound attenuation, velocity, and impedance. Once the equipment is calibrated to known standards, the operator may confidently adjust or standardize the unit to the values of the test material and expect an accurate display of discontinuities within the test sample. When testing the materials, sensitivity corrections and adjustments for metal distance are most reliable when made on special reference blocks of a material that most nearly matches the material of the test specimen. Standardizing the calibrated instrument to values of the test sample shall be accomplished by using special reference blocks made in a specific shape and size of material that matches, as nearly as possible, the dimensions and the physical properties of the test sample. Since acceptance of the test sample is based upon a rigid testing standard, considerable attention shall be given to the calibration of the instrument system and to the standardizing of the instrument to the test sample variables. The position and angle of the transducer mounting on the wheel axle may be constructed to project straight-beams or to project angled beams.

3.5 Vision.- The following minimal vision requirements shall apply for visual acuity of inspection personnel:

a. Distant vision, either corrected or uncorrected, shall equal 20/30 in at least one eye.
b. Near vision, either corrected or uncorrected, shall be such that the applicant can read Jaeger type No. 2 at a distance of 16 inches, or pass the Diopter method of near vision examination.
c. Vision tests shall be performed by an oculist or optometrist or by any other professionally recognized person. At qualification, and one year from the effective date of qualification, and each year thereafter, qualified personnel shall be required to pass the vision tests specified herein.

4. QUALITY ASSURANCE PROVISIONS

4.1 General.- Before any nondestructive testing inspections are performed, each inspector shall be qualified through having demonstrated his ability to calibrate equipment for and to perform nondestructive tests in accordance with established procedures as set forth under Section 3.

4.2 Qualification of Technicians.- Qualification tests shall be conducted in the presence of a duly authorized NASA Quality representative. A technician who has successfully passed an original qualification test is automatically qualified for the nondestructive test procedure used. The technician shall demonstrate his ability to perform acceptable nondestructive test inspections through receiving actual test results substantiating known defects. A technician failing to meet the test requirements may be allowed to retest as follows:

a. One immediate retest may be made that shall consist of two performances of the type nondestructive testing inspection failed; the test results in each case shall coincide with known data.
b. A second retest may be allowed only after a further minimum of 16 hours of added training or practice. In this case, one nondestructive testing inspection shall be performed for each type failed.

4.2.1 Requalification.- A technician must be requalified whenever the nondestructive testing procedure is changed in any of its essentials: equipment, etc.

4.3 Inspection.- Nondestructive test inspection shall be performed to determine that the tests were conducted exactly in accordance with the test documents generated by the responsible NASA design agency.

4.3.1 Visual.- Prior to start of any nondestructive test, the test items shall be visually inspected and any defects shall be recorded.

4.3.2 Dye Penetrant.- Dye Penetrant inspection shall be performed in accordance with the test document generated per responsible NASA design agency.

4.3.3 Magnetic Particle.- Magnetic particle inspection shall be performed in accordance with the test documents generated per the responsible NASA agency.

4.3.4 Ultrasonic.- Ultrasonic inspection shall be performed in accordance with inspection procedure and acceptance standards of ASTM publications A435, A577, A578, E113, E114, E164, E213, E214 and E273 as applicable to the test documents generated by the responsible NASA design agency.

4.4 Acceptance Criteria.- Acceptance criteria shall be that indicated in the test documents generated by the responsible NASA design agency for the required nondestructive test.

4.4.1 Unacceptable Defects.- The following shall be considered unacceptable, when examining welds, castings, and wrought material using dye penetrant, magnetic particle or ultrasonic testing as applicable:

a. Cracks
b. Porosity open to surface
c. Incomplete penetration
d. Craters
e. Lack of fusion
F. Burn Through
g. Arc strikes
H. Notches
i. Shrinkage cracks
j. Laminations

4.5 Rework Procedures.- Rework and repair procedures required shall be approved by the responsible NASA design agency prior to performance.

4.6 Records.- The results of all nondestructive tests shall be appropriately recorded. All results shall be identified, filed, and made available to the responsible NASA design agency upon request.

5. PREPARATION FOR DELIVERY

5.1 There are no applicable requirements.

6. NOTES

6.1 Intended Use.- This specification is intended for use in the nondestructive testing and inspection of castings, extrusions (bar, tube and shapes), rolled bar and plate, sandwich materials, weldments, wrought metals, (including forgings), and composite fabricated assemblies that comprise the launching facilities of John F. Kennedy Space Center, NASA, when specified by either the engineering drawings or the testing documents generated by the responsible NASA design agency.

6.2 Definitions.- This paragraph includes data applicable to nondestructive testing symbols and to nondestructive testing nomenclature and definitions.

6.2.1 Nondestructive Testing Symbols.- For interpretation of nondestructive testing symbols used, see American Welding Society publication AWS-A2.2-58.

6.2.2 Magnetic Particle Inspection Terms.- For definition of terms relating to magnetic particle inspection, see American Society for Testing and Materials (ASTM) publication ASTM E269; and for terms relating to magnetic testing, see ASTM publication ASTM A340.

6.2.3 Liquid Penetrant Inspection Terms.- For definition of terms relating to liquid dye penetrant inspection, see American Society for Testing and Materials publication ASTM E270.

6.2.4 General Discontinuities.- There are three general categories of discontinuities: inherent, processing, and service. Each of these categories is further classified as to whether the discontinuity is associated with ferrous or nonferrous materials, the specific material configuration, and the manufacturing processes, if applicable.

6.2.4.1 Inherent Discontinuities.- Those discontinuities that are related to the solidification of the molten metal. There are two types:

a. Wrought - Inherent wrought discontinuities cover those discontinuities which are related to the melting and original solidification of the metal or ingot.
b. Cast - Inherent cast discontinuities are those discontinuities that are related to the melting, casting, and solidification of the cast article. It includes those discontinuities that would be inherent to manufacturing variables such as inadequate feeding, gating, excessively high pouring temperature, entrapped gases, handling, and stacking.

6.2.4.1.1 Processing Discontinuities.- Processing discontinuities are those discontinuities that are related to the various manufacturing processes such as machining, grinding, etching, pickling, forming, extruding, rolling, welding, heat treating, and plating.

6.2.4.1.2 Service Discontinuities.- Service discontinuities cover those discontinuities that are related to the various service conditions such as stress corrosion, fatigue, and erosion.

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Preparing activity:

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