International Standard 3452

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Non-destructive testing — Penetrant inspection — General principles

Essais non destructifs — Contrôle par ressuage — Principes généraux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 3452 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*.

It embodies the content of ISO 3879-1977 which is therefore withdrawn.

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Contents

Annexes

Non-destructive testing — Penetrant inspection — General principles

1 Scope and field of application

1.1 This International Standard provides general guidance on methods of carrying out penetrant inspection on materials and components both during manufacture and in service, for example *in situ* inspection.

1.2 It does not deal with levels of acceptance or rejection, which should be the subject of separate International Standards or of agreement between the parties concerned.

1.3 Penetrant inspection is used to locate discontinuities, such as laps, folds, cracks, porosity and fissures, which are open to the surface of a material or component.

Penetrant techniques can be used on materials irrespective of their physical properties, provided that the surface is normally non-absorbent and compatible with the penetrant process; see also 6.1.

1.4 For means of verification when carrying out penetrant inspection, reference should be made to ISO 3453.

NOTE — Definitions of terms used in this International Standard will be included in a future International Standard vocabulary of non-destructive testing.

2 References

ISO 3059, *Non-destructive testing — Method for indirect assessment of ultra-violet radiation sources.*

ISO 3453, *Non-destructive testing — Penetrant inspection — Means of verification.*

3 Principle

Penetrant inspection consists essentially of the following sequence of operations:

a) Preparation of the surface of the material or component to be inspected by precleaning and degreasing.

b) Application of penetrant to the prepared surface and leaving for a period of time to allow the penetrant to enter any discontinuity open to that surface.

c) Removal of the excess penetrant in such a manner as to ensure retention of penetrant in any discontinuities.

d) Application of a developer in order to draw the penetrant from the discontinuity to the surface and thereby give an enhanced indication of the discontinuity.

e) Visual examination and assessment under appropriate viewing conditions.

f) Cleaning of the surface tested and, if necessary, application of a corrosion preventative.

It should be noted that testing at temperatures other than those specified for the materials may lead to erroneous results.

4 Safety precautions

4.1 As penetrant inspection techniques may require the use of toxic, flammable and volatile materials, the precautions prescribed and applicable to the use of all such materials shall be observed. Working areas shall be sufficiently ventilated and distant from heat sources, open fires and flames.

4.2 Care shall be taken to ensure that under no circumstances can unfiltered radiation from an ultra-violet radiation source be directed at the eyes. The filter used with an ultra-violet radiation source, either as an integral part of the lamp or as a separate component, shall always be maintained in good condition. (Attention is drawn to ISO 3059.)

4.3 Penetrant inspection materials and equipment shall be used with caution and always in accordance with the instructions provided by the manufacturer.

5 Classification of penetrant inspection materials

5.1 General

Penetrant inspection materials are formulated or selected according to the material or component to be tested and its surface condition, and according to the conditions under which the inspection is to be performed.

Sets of mutually compatible materials are constitued for particular purposes [called "systems" (see annex A)], each set comprising (either partially or fully)

- indicator penetrant (penetrant),
- excess penetrant remover (remover),
- penetrant developer (developer),

and characterized by data given in a prescription form (see annex B).

NOTES

1 The penetrant inspection materials constituting a set should not adversely affect the material or component to be tested.

2 Materials for preliminary cleaning of test surfaces are not considered to be penetrant inspection materials.

5.2 Penetrants

For the purposes of this International Standard, penetrants are classified as:

A: fluorescent penetrants

B: visible dye penetrants

C: dual-purpose (fluorescent/visible dye) penetrants

D: special purpose penetrants.

5.3 Excess penetrant removers

Penetrant removal operations fall into three main classes, i.e. those involving the use of:

A: water only

B: emulsifiers:

1 oil-based emulsifiers

2 water-based emulsifiers

C: solvent in liquid form.

5.4 Developers

Developers may be:

A: dry powders

B: aqueous suspensions or solutions:

1 suspension of powder in water

2 solution of powder in water

C: suspensions of powder in volatile, non-aqueous solvents, that are:

1 non-flammable

2 flammable

5.5 Classification of penetrant systems

For the purposes of this International Standard, penetrant systems are classified

- according to the method of inspection

A: fluorescent penetrant inspection

B: visible dye penetrant inspection

C: dual-purpose (fluorescent/visible dye) penetrant inspection

- according to the type of penetrant (method of removing excess penetrant):

1 water washable

2 post-emulsifiable

3 solvent removable.

NOTES

1 It should not be inferred that all proprietary penetrant inspection materials of the same type and for one method are necessarily fully interchangeable or are of comparable sensitivity; intermixing of materials from various manufacturers is not recommended. Care should therefore be taken when selecting penetrant materials to ensure that they are compatible with each other and appropriate to the application.

2 Fluorescent penetrant inspection should not be carried out after visible dye penetrant inspection unless the procedure has been previously qualified.

3 It is recommended that both manufacturers and users adopt the same classification system.

6 Test conditions

6.1 Compatibility of materials

6.1.1 All penetrant inspection materials shall be compatible with the material to be examined, particulary with regard to long-term corrosion effects.

6.1.2 For checking compatibility, it may be necessary to carry out a special test, the nature of the test depending on the materials under examination.

6.1.3 In situations where contamination of fuels, lubricants, hydraulic fluids, etc., by penetrant inspection materials exerting deleterious effects might occur, great care shall be taken in the post-inspection cleaning operation. See also 11.1.

6.1.4 Care shall be taken to ensure that the pre-cleaning, degreasing and drying operations do not affect the results of the inspection.

6.2 Pre-cleaning and surface preparation

6.2.1 All cleaning materials and processes shall be compatible with the penetrant inspection materials and with the material to be examined. For the removal of protective finishes, for example paint, an agreed chemical method that avoids ingress of the products into any surface discontinuities should be used.

6.2.2 Surfaces, and any discontinuities therein, shall be clean and free from contamination. Surface cleanness and roughness should meet specified requirements.

NOTES

1 Chemical methods are preferred for the removal of contaminants and should be used wherever possible. Physical methods essentially remove contaminants from the surface and generally are incapable of removing contaminants from within surface discontinuities. Physical cleaning methods, such as shot-blasting, which produce plastic deformation of a metal surface, may completely or partially seal the discontinuities and so prevent or restrict the ingress of penetrant.

2 Where permissible, etching is recommended after the use of any physical method for removing contaminants. The use of a pre-cleaning agent can, for instance, increase inspection sensitivity, especially for compressed discontinuities. In order that the properties of the penetrant are not adversely affected, it is essential that residual etchant be chemically neutralized and subsequently removed.

6.3 Degreasing

Prior to the application of penetrant, the surface under examination shall be degreased provided that there are no incompatibilities with the degreasing solvents. After degreasing, the penetrant liquid shall be applied after the shortest period compatible with the necessity of effectively reaching the temperature specified in 7.1.1.

6.4 Drying

It is essential that the surface to be examined be thoroughly dried after cleaning so that no water or solvent remains in or over the discontinuities, as this may prevent the ingress of penetrant. Slight heating of the piece or blowing warm air over it reduces the drying time. (See 7.1.1.)

7 Inspection procedures

7.1 Application of penetrant

7.1.1 Temperature of application

In general, the temperature of the test surface and of the penetrant inspection materials should be within the limits indicated in the specification for the set of materials to be used (see annex A). Other temperatures may be used provided that the manufacturer approves the use of the materials under such conditions.

7.1.2 Method of application

The surface to be examined shall be thoroughly and uniformly wetted with the penetrant. The penetrant may be applied with a brush, with a spray-can, by electrostatic spraying, by flooding or by immersion.

7.1.3 Penetration time

The penetration time depends on the properties of the penetrant, the test temperature, the test material and specific defects. In no case shall the penetrant be allowed to dry during the penetration time; if necessary, the surface shall be rewetted with the penetrant. The time during which the surface remains completely wetted shall not be less than that recommended by the manufacturer of the penetrant; long penetration times do not reduce sensitivity, but, in general, the longer the penetration time, the more clearly will the discontinuities be indicated.

7.2 Application of emulsifier

7.2.1 When required by the type of penetrant, and after the penetration time has elapsed, the appropriate emulsifier shall be applied to the test surface, by immersion, flooding, or spraying.

7.2.2 The emulsifying time is critical and depends on prevailing conditions, surface texture and the type of discontinuities sought. The manufacturer's instructions shall, therefore, be followed. In general, the emulsifying time shall be sufficient to allow effective water washing of the test surface, but shall not be excessive, because of the risk of leaching penetrant from any discontinuities.

7.3 Excess penetrant removal

7.3.1 General

After the appropriate penetration time, and emulsifying time if required, the surface film of penetrant and emulsifier shall be removed. Insufficient removal will leave a background which will interfere with the subsequent indication of discontinuities and possibly give rise to erroneous indications. However, excessive cleaning shall be avoided as it will remove penetrant from the larger surface discontinuities. For fluorescent penetrant inspection, cleaning shall be checked under ultraviolet radiation. For visible dye penetrant inspection, cleaning shall be continued until no visible evidence of coloured dye remains on the surface.

7.3.2 Solvent-removable penetrants

These are preferably removed in two stages:

a) as much penetrant as possible is removed by wiping with a clean, dry, absorbent lint-free cloth or with paper towels;

b) the remaining surface film of penetrant is removed by wiping the surface with a lint-free cloth or paper towels, lightly moistened with suitable solvent, until all remaining traces of excess penetrant have been removed.

Other methods of removal are not excluded, but, in all cases, care shall be taken to minimize the possibility of removing penetrant from discontinuities.

7.3.3 Water-washable and post-emulsified penetrants

These shall be removed by rinsing, swabbing or spraying with water. Warm water is recommended, but its temperature shall be within the limits recommended by the manufacturer of the penetrant. For fluorescent penetrants, rinsing shall be carried out under ultra-violet radiation to ensure complete cleaning of all surfaces (see 8.1).

For visible dye penetrants, rinsing shall be carried out until no visible evidence of coloured dye remains on the surface (see 8.2).

If a part cannot be completely washed because of insufficent emulsification of the penetrant, the part should be dried, recleaned and the application of penetrant and emulsifier repeated.

7.4 Drying

7.4.1 After removal of excess penetrant and before applying the developer, the surface shall be dried again by one of the following means:

a) clean, dry, lint-free cloth or paper towels;

b) dry, clean, compressed air from a filtered supply;

c) forced warm-air circulation;

d) hot-air circulating oven.

NOTE — In general, the temperature of the test surface and of the air should be within the limits indicated in the specification for the set of materials being used (see annex A). Other temperatures may be used provided that the manufacturer approves the use of the materials under such conditions.

7.4.2 Drying shall be carried out with particular care when dry or non-aqueous wet developers are to be used. The approach of the required degree of dryness is indicated when surface wetness begins to disappear.

7.4.3 Excessive drying times or high temperatures and air pressures shall be avoided in order to prevent evaporation of the penetrant in the discontinuities.

7.4.4 For some types of solvent-removable and water washable penetrants used in conjunction with solvent-based and water-based wet developers, drying is not necessary.

7.5 Application of developer

7.5.1 Dry powder developer

A developer compatible with the penetrant shall be uniformly applied to the test surface immediately after the surface has been dried. It shall be applied in such a manner, for example by electrostatic spraying, that the surface presents a uniform, dusty appearence, with no remaining agglomerated masses of powder.

7.5.2 Liquid developer

After drying, a developer compatible with the penetrant shall be uniformly applied to the test surface within the period recommended by the manufacturer. The developer may be applied by spraying, by electrostatic spraying, by a flow-on technique, or by immersion, as recommended by the manufacturer. Immediately before use, it shall be agitated to ensure uniform dispersal of solid particles in the carrier fluid. Thick coatings and the formation of pools of liquid developer may result in the masking of indications and shall be avoided. The developing conditions and the quantity of developer required to obtain a uniform matt white surface after drying shall be established.

NOTE — When the developer dries, a film of powder is left on the surface. The liquid in which the developer is suspended often has good penetration properties itself and may accidentally remove penetrant from a discontinuity (particulary in the case of wide discontinuities) before the developer has stabilized itself on the surface. The result is that the penetrant would then spread over the surface and produce smudged indications. To prevent this happening, it is advisable to apply the developer in such a way that it is nearly dry when it reaches the surface. This can be done by increasing the spraying distance or by working at temperatures at the upper end of the recommended range.

7.6 Development time

After application of the developer, which, if liquid, shall be permitted to dry, the workpiece shall be allowed to stand for a sufficient time (development time) for any indications to appear. This time will depend on the testing media being used, the material examined and the nature of the defects present. However, in general, it will be of the order of 50 % of the penetration time (see 7.1.3) up to the full penetration time for fine discontinuities. The standard maximum development time is normally twice the penetration time. Excessively long development times may cause penetrant in large, deep discontinuities to bleed back, thereby producing broad smudged indications.

8 Viewing conditions

8.1 Fluorescent penetrants

When using fluorescent penetrants, the room or area where the inspection is to be made shall be darkened, but may be illuminated with a dull amber light, and inspection of the test surface shall be carried out under ultra-violet radiation, preferably at a wavelength of 320 to 400 nm. The lamp(s) shall be allowed to achieve full brilliance before inspection. Prior to inspection, at least 5 min shall be allowed for the eyes to become accustomed to the reduced ambient lighting. The intensity of ultra-violet radiation at the surface under examination shall be not less than required in accordance with ISO 3059 and in the unit metre kilowatt per square centimetre.

8.2 Visible dye penetrants

When using visible dye penetrants, the area under inspection should be illuminated by daylight or artificial light with an illuminance of not less than 500 lx[1] to enable a proper evaluation to be made of the indications revealed on the test surface. The viewing conditions shall be such that glare is avoided.

8.3 Aids to viewing

Means of magnification and, if necessary, contrast spectacles should be provided. Such spectacles, made with lenses of sodium glass, give an increased contrast with fluorescent penetrants and block any objectionable ultraviolet or blue light, particularly when components with highly reflective surfaces are being inspected. Clip-on lenses for personnel who normally wear spectacles are available.

NOTES

1 Due consideration should be given to loss of inspection efficiency due to operator fatigue.

2 Light sensitive corrective lenses should not be used while carrying out fluorescent penetrant inspection.

9 Inspection and interpretation

9.1 Examination

When the developing time has elapsed (see 7.6), examination of the test surface shall be made under the appropriate viewing conditions (see clause 8). If the background is such that the interpretation of indications has been impaired, the surface shall be completely retested (see 10.1). The location of indications shall be marked and associated discontinuities shall be evaluated in accordance with an agreed level of acceptance.

NOTE — In special circumstances, it may be advisable to examine the test surface continuously during the development time and also after a further period to see whether there are any changes in the indications.

9.2 Interpretation of results

Discontinuities appear as spots or lines broadening with development time. The characteristics of the indications, such as the rapidity with which they develop and their final shape and size, provide information as to the nature of the discontinuity revealed. Any area with questionable or doubtful indications shall be retested (see 10.1) to verify whether actual discontinuities are present.

10 Further tests

10.1 Retesting

If retesting is necessary, the complete procedure, using the same materials and including the same cleaning processes (see 6.2), shall be repeated. If retesting has to be carried out a long time after the first examination, special attention shall be given to cleaning, as penetrant residue from the previous test may lodge in discontinuities and prevent fresh penetrant from entering.

10.2 Subsequent testing

If a different penetrant is used in subsequent testing, the procedure shall include a cleaning process which ensures complete removal from any discontinuities of any corrosion preventatives previously applied and of the penetrant initially used. In particular, it should be noted that residual visible dye penetrant will react with a fluorescent penetrant resulting in complete or partial quenching of fluorescence.

11 Cleaning after inspection

11.1 After inspection, removal of the penetrant and of the developer will be necessary only in those cases where they interfere with subsequent processing or with service requirements. It is particularly important, however, if residual inspection materials might interact with other factors in service to produce a corrosive action. In the case of water-based liquid developers, it is recommended that cleaning be carried out as promptly as possible after inspection to facilitate removal of the developer.

11.2 After removal of the developer and penetrant, the component shall be dried and, if necessary, protected against corrosion.

12 Sensitivity of tests

12.1 The sensitivity of penetrant inspection processes can be very high, for example minute cracks having widths of the order of 10^{-6} m can be revealed. In general, the more elaborate the test technique, the finer or smaller the discontinuity which can be detected. However, in some cases, penetrants are used to locate quickly and reliably discontinuities which, although visible to the eye, using, if necessary optical aids, would necessitate time-consuming and laborious examination for their location.

12.2 Sensitivity has to be specified in terms of the nature of discontinuities of a particular type in a particular material, for example sensitivity for fine cracks or open cracks, for deep cracks or shallow cracks. Specific penetrants and techniques will be needed to obtain a specified sensitivity. In practice, use is made of reference or comparison pieces, i.e. specimens containing controlled artificial defects or natural defects, generally in the form of cracks.

1) As a guide, this would be achieved by using an 80 W fluorescent tube at a distance of about 1 m.