
British Standard Method for

Penetrant flaw detection

Méthode de détection des défauts par ressuage

Fehlernachweis mit dem Eindringverfahren

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Foreword

Several British Standards have been published that describe the application of penetrant flaw detection to specific products. It was accordingly considered that it would now be opportune to prepare a standard describing the basic techniques for this method of non-destructive testing. This British Standard has accordingly been prepared under the direction of the Mechanical Engineering Standards Committee and due account has been taken of the corresponding aerospace standard, British Standard M 39 : 1972 'Method for penetrant inspection of aerospace materials and components', which provided a basis for this standard.

This standard provides detailed information on penetrant flaw detection to which BSI committees and others responsible for the application of appropriate techniques to specific products and for establishing acceptance criteria can make reference. It is, however, recognized that some variation from the basic techniques described in this standard may be required for particular applications.

Penetrant flaw detection is used for locating discontinuities of finite volume, such as laps, folds, cracks and porosity that are open to the surface in a material or component. The method can be used on materials regardless of their physical properties, provided the surface is normally non-absorbent and compatible with the process materials and the conditions under which they are applied to the surface. The effectiveness of the method is dependent on each stage

in the procedure being carried out correctly by competent persons. Any departure from correct procedure can seriously affect the validity of a penetrant test and in interpreting results it is very important to distinguish between relevant indications from flaws and spurious indications from other causes.

Penetrant flaw detection is often complementary to other methods of flaw detection. The use of any method of non-destructive testing should always be considered in relation to testing and inspection as a whole. When such methods are specified, the most suitable and economic method of inspection compatible with the ultimate application for the product should always be employed.

The manufacturers of process materials for penetrant flaw detection provide comprehensive technical services and it is recommended that these services be used when selecting a process for a particular inspection.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people, for whose guidance it has been prepared.

Compliance with a British Standard does not of itself confer immunity from legal obligations. In particular, attention is drawn to the Health and Safety at Work, etc. Act 1974.

British Standard Method for Penetrant flaw detection

Section one. General

1. Scope

This British Standard describes a method for detecting surface flaws in materials and components, during manufacture and in service, by penetrant flaw detection.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2. Definitions

For the purposes of this British Standard the definitions given in BS 3683 : Part 1 apply, together with the following.

2.1 aqueous liquid developer. A suspension of inert white powders in a water-based carrier medium, usually incorporating corrosion inhibitors.

2.2 aqueous wash. A water rinse used as part or all of the penetrant removal stage.

2.3 colour contrast penetrant. A solution of dyes, typically red, in an organic carrier system.

2.4 combined colour contrast and fluorescent penetrant. A solution of dyestuffs in an organic carrier medium that is capable of reflecting visible light and of absorbing radiation in the ultraviolet region with consequent emission of radiation in the visible region.

2.5 hydrophilic remover. A water-based penetrant remover that is miscible in all proportions with water.

2.6 lipophilic remover. An oil-based penetrant remover that is miscible in all proportions with post-emulsifiable penetrants.

2.7 non-aqueous liquid developer. A suspension of inert white powders in a volatile organic solvent carrier.

2.8 thixotropic penetrant. A gelatinous penetrant in which the viscosity is reduced with the duration of an applied shear stress.

3. Principle of method and types of process materials

The penetrant flaw detection method consists essentially of the sequence of operations listed in (a) to (e) below and illustrated for the general case in figure 1.

(a) Preparation of the surfaces of the components to be inspected by pre-cleaning, degreasing and drying (see clause 8).

(b) Application of penetrant to the prepared surfaces and a period of time allowed for it to enter any discontinuities open to the surfaces (see clause 9).

The three types of penetrant included in this standard that may be applied to prepared surfaces are:

- (1) fluorescent;
- (2) colour contrast;
- (3) combined colour contrast and fluorescent.

(c) Removal of excess penetrant in such a manner that will ensure retention of penetrant in any discontinuities (see clause 9).

This standard describes four ways in which the removal of excess penetrant may be achieved:

- (1) by application of a solvent in liquid form;
- (2) by application of water only;
- (3) by application of water usually before, and always after, application of a penetrant removal solution that is water-soluble (hydrophilic remover);
- (4) by application of an emulsifier that is oil-soluble (lipophilic remover) followed by application of water.

(d) Application of a developer and a period of time allowed for the penetrant liquid to be drawn out of the discontinuities, so as to give enhanced indications (see clause 9).

The types of developer included in this standard are:

- (1) dry powders;
 - (2) aqueous liquid developers, of which there are two types, i.e. powder suspensions and solutions;
 - (3) non-aqueous liquid developers, which consist of a suspension of powders in a non-aqueous liquid carrier.
- (e) Examination and assessment of the indications under appropriate viewing conditions (see clauses 10 and 11).

On completion of inspection and assessment the treated surfaces may be cleaned and, as necessary, a corrosion preventive applied.

4. Compatibility of materials

4.1 It is essential that the penetrant process materials are compatible with the material to be inspected and the ultimate use of the component.

NOTE 1. The compatibility of the process materials will require special consideration:

(a) for components associated with high-test peroxide rocket fuel, explosive stores (these include all items containing explosive, propellant, initiating or pyrotechnic materials), oxygen equipment or nuclear applications;

(b) where there is a possibility of stress-corrosion or of corrosion fatigue, particularly if the process materials can remain in internal features after post-inspection cleaning.

NOTE 2. In most cases, the compatibility of penetrant process materials with a material or family of materials being inspected can be assessed by the corrosion test described in BS 6443 : 1984.

In the absence of a particular requirement, it is recommended that the residual halogen content of penetrant process materials should be limited to 1 %.

4.2 As the chemical or physical properties of some non-metallics can be adversely affected by penetrant process materials, their compatibility has to be established before inspecting components manufactured from, and assemblies that include, such materials.

4.3 In situations where contamination might occur it is essential that care be taken to ensure that the penetrant process materials do not have a deleterious effect on fuels, lubricants, hydraulic fluids, etc.

4.4 It is essential that a surface containing flaws that has been treated with a colour contrast penetrant is not subsequently processed using a fluorescent penetrant unless it has been subject to further preparation as described in clause 8, since residual colour penetrant can mask the fluorescent penetrant, resulting in complete or partial quenching of the fluorescence.

The same applies to the use of a fluorescent penetrant followed by a colour contrast penetrant.

5. Safety guidance and statutory requirements

5.1 Siting. Installations for carrying out penetrant flaw detection on a continuous basis should not be sited near manufacturing processes that are likely to give rise to airborne contamination. Penetrant flaw detection should only be carried out where there is adequate ventilation and lighting and sufficient space for cleaning and access to equipment and materials.

5.2 Fire hazard. Before any electrical equipment is used, it should be thoroughly inspected to ensure that there will be no danger of fire as a result of any overheating or sparking.

NOTE. Attention is drawn to the British Standard codes of practice, e.g. BS 5345, concerning the use of electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour and in mining applications.

Consideration should be given to the dangers of vapour ignition and to the possibility of igniting accumulations of flammable materials in the vicinity of the test area. Penetrant flaw detection should not be carried out in confined spaces, unless adequate ventilation is provided. It is recommended that all electrical equipment has attached to it, or is accompanied by, a fire extinguisher complying with BS 5423 suitable for petrol, gas and electrical fires.

5.3 Electrical safety. Equipment employed in this method requiring the use of mains electricity is subject to statutory requirements and, in addition, to any local rules applicable at its place of use. Where there are no specific rules and the equipment has a mains supply voltage of 110 V and above, it is recommended that it be fitted with an earth-leakage current circuit breaker that trips with a leakage current to earth of not more than 30 mA. For portable equipment, and particularly if reaction injuries are possible, it is recommended that consideration be given to more stringent electrical safeguards by reducing the leakage current for trip to 12 mA and incorporating a concomitant earth continuity monitor.

5.4 Toxic materials. Some of the materials used in penetrant flaw detection can be toxic, therefore, it is essential that suitable precautions to avoid hazards be taken and that all materials be used in accordance with the supplier's instructions.

NOTE 1. Two types of hazard exist as a result of spraying aerosols of non-destructive testing products in confined spaces. The first is due to the creation of a mist which, at low concentrations, is a nuisance particulate (see Health and Safety Executive Guidance Note ET 15/80 'Threshold Limit Values 1980'). The second is the result of evaporation of propellant and contents to form a gaseous contamination.

NOTE 2. The mist hazard is prevented by the use of face masks capable of absorbing the mist while working in confined spaces. The vapour/gas contamination requires fan extraction from a confined space and a knowledge of the threshold limit value (TLV) of the aerosol contents. The minimum volume of a confined space into which an aerosol can be discharged without exceeding the TLV can be estimated by methods that are detailed in 'Threshold Limit Values 1980'.

5.5 Safe use of UV-A (black light). It is essential that direct viewing of sources of UV-A (black light) radiation is avoided, as this can cause temporary fluorescence of the eyeballs. It is essential that ultraviolet filters be checked periodically for evidence of cracking, as radiation at wavelengths below 320 nm can be very dangerous.

NOTE. For guidance on the safe use of UV-A, see 'Protection against ultraviolet radiation at the workplace' by the National Radiological Protection Board and published by HMSO.

5.6 Effluent control. Adequate control of effluent has to be provided in accordance with relevant Home Office requirements and local bye-laws.

6. Selection of process

The technical factors affecting the selection of an appropriate process for penetrant flaw detection are:

- (a) the sensitivity of inspection required;
- (b) the surface finish of the component to be inspected;
- (c) the compatibility of process materials with the component to be inspected;
- (d) the size, shape and accessibility of the component to be inspected;
- (e) the ultimate use of the component to be inspected.

The process selected for a particular component is required to reveal consistently the presence of flaws of the specified minimum significant size, without deleterious effect on the component or its intended use. The choice of process for a particular component needs to be specified in all relevant drawings and work instructions.

NOTE. Full details of the process used are required in accordance with clause 12.

Section two. Equipment

7. Equipment

7.1 General. The equipment required for carrying out penetrant flaw detection depends on the number of tests to be made and on the size of the components to be tested. Three types of equipment are included in this standard, i.e.:

- (a) portable inspection kits suitable for carrying out routine checks, for example on site;
- (b) fixed installations for testing components on a continuous basis comprising a series of processing stations placed in sequential order to form a flow line;

- (c) self-contained processing booths used in the testing of large components where no movement or only limited movement of the component is possible during testing.

NOTE 1. Fixed installations may comprise individual processing units (or 'stations'), or several units may be combined, provided the processing sequence is maintained.

NOTE 2. The processing units may be manually operated or incorporate automatic control systems.

7.2 Equipment for portable inspection kits

7.2.1 Pre-cleaning materials.

7.2.2 Penetrant.

7.2.3 *Penetrant remover*, suitable for the particular penetrant in use.

7.2.4 *Developer*, suitable for the particular penetrant in use.

7.2.5 *Brushes, swabs, cleaning rags, etc.*

7.2.6 *A UV-A lamp of suitable intensity*, for use with fluorescent penetrants (see 10.1).

7.3 Fixed installations

7.3.1 *Pre-cleaning station*. Pre-cleaning stations shall be equipped for pre-cleaning the components in accordance with clause 8.

7.3.2 *Degrease/cool station*. Degrease/cool stations shall be equipped for degreasing the components in accordance with clause 8 and shall include an area for cooling the components prior to the application of penetrant. The degreasing and cooling facilities shall be of adequate size to handle the flow of components.

7.3.3 *Penetrant application station*. Penetrant application stations shall comprise equipment for applying penetrant by conventional or electrostatic spraying, brushing, flow-on techniques or immersion in tank of penetrant liquid. Immersion tanks and penetrant storage tanks shall be provided with a lid and shall be kept covered when not in use. Immersion tanks shall be fitted with a stopcock. Where fluorescent penetrants are applied by manual spraying equipment, a source of UV-A shall be provided for checking coverage of penetrant. Where spray application is employed, suitable extraction facilities shall be provided.

7.3.4 *Penetrant drain station*. Penetrant drain stations shall consist of a shallow tray having a sloping base, arranged so that the penetrant is collected in a separate container.

7.3.5 *Spray-wash station*. Spray-wash stations shall comprise either manual or automatic spraying equipment.

Manual spraying equipment shall be equipped with a water or air/water spray gun capable of delivering a suitable spray at a pressure of up to 2 bar* and at a temperature between 15 °C and 30 °C. Where manual spraying equipment is employed a suitable source of illumination shall be provided, either white light for colour contrast penetrant or UV-A for fluorescent penetrant.

Automatic spraying equipment shall be designed such that it provides the spray conditions specified for manual equipment and such that the spray head does not approach the surfaces of the components closer than 0.3 m. A suitable drain shall be provided where automatic spraying equipment is employed.

NOTE. Spray-washing is used for the removal of surface excess water-washable penetrant, for rinsing parts prior to and after the application of hydrophilic remover, or for rinsing after the application of lipophilic emulsifier.

7.3.6 *Remover/emulsifier station*. Remover/emulsifier stations shall comprise the equipment given in (a) to (d), as appropriate to the process used.

(a) Where a hydrophilic remover is to be applied by an immersion technique the station shall comprise a tank suitable to allow components to be immersed completely in the solution for a controlled time.

(b) Where a hydrophilic remover is to be applied by spraying, the station shall comprise suitable spraying equipment.

(c) Where a lipophilic emulsifier is to be applied by an immersion technique, the station shall comprise a tank which will allow complete immersion of components followed by drainage and, where drainage does not take place over the tank, a separate area for drainage.

(d) Where a lipophilic emulsifier is to be applied by spray and drainage, the station shall comprise suitable spraying equipment.

NOTE. Whether a hydrophilic remover or a lipophilic emulsifier is used, facilities for washing the components rapidly after completion of the contact time with these reagents need to be provided. This is in order to stop their activity and prevent over-removal of penetrant. Where small components are processed, this may be carried out in a spray-wash station, as described in 7.3.5. Where large components are processed, the washing facilities should include a large tank with a weir in which sufficient water may be maintained so that the complete component may be immersed in water rapidly, so stopping the remover or emulsifier action rapidly and uniformly.

7.3.7 *Agitated wash station*. Agitated wash stations shall comprise a tank with a weir, together with a water supply to enable contaminated wash water to be replaced. Facilities for agitating the wash water shall be provided by use of air or by mechanical means.

7.3.8 *Hot-wash station*. Hot-wash stations shall comprise a tank of suitable size and shape to allow total immersion of the components to be effected immediately it is required. The tank shall be fitted with a weir to enable water contaminated by penetrant to be replaced. Means shall be provided to control the temperature of the water within the range recommended by the manufacturer of the penetrant.

7.3.9 *Drying station*. Drying stations shall be equipped for drying the components by one of the methods given in 9.5.

7.3.10 *Developer station*. Developer stations shall comprise the equipment given in (a) to (c), as appropriate to the developer used.

(a) *Powder developer*. The station shall comprise equipment for applying the developer by one of the following techniques:

- (1) dust storm;
- (2) electrostatic spraying;
- (3) flock gun;
- (4) tumbling;
- (5) insufflator;
- (6) fluidized bed.

Where a cabinet is used, it shall be of sufficient size to accommodate the work in its entirety, either as single components or as multiples placed in wire baskets. It shall have a sealed, hinged lid and be fitted with heaters to prevent contamination of the powder by moisture. Where an electrostatic spray or a flock gun is used, suitable extraction means shall be provided.

*1 bar = 10⁵ N/m² = 10² kPa.