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British Standard Method for

Penetrant flaw detection

Méthode de détection des défauts par ressuage

Fehlernachweis mit dem Eindringverfahren

British Standards Institution

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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 appendix A.

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.

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*1 bar = 10^5 N/m² = 10^2 kPa.

(b) *Non-aqueous liquid developer.* The station shall comprise equipment for spray application of the developer within a cabinet. The spray gun shall be actuated by dry, clean filtered air or by an aerosol container. The cabinet shall be so constructed that unrestricted spraying of the component can take place.

(c) *Aqueous liquid developer.* The station shall comprise a tank complying with either type 1 or type 2 as follows.

(i) *Type 1. Immersion tank (powder suspension developer).* The tank shall be fitted with a lid and shall be of such a size that total immersion of components can be achieved. It shall have facilities for continuous agitation of the developer either by clean air or by mechanical means, be capable of maintaining the developer at the temperature recommended by the manufacturer and include a system for permitting excess developer to drain back freely into the tank.

(ii) *Type 2. Immersion tank (solution developer).* The tank shall be fitted with a lid and shall be of such a size that total immersion of components can be achieved. It shall be capable of maintaining the developer at the temperature recommended by the manufacturer and include a system for permitting excess developer to drain back freely into the tank.

NOTE. With both types of tank, the components are dried after the application of the developer and not prior to it, as is the case with dry powder developer.

7.3.11 *Inspection station.* Inspection stations shall comprise a booth or area, with suitable means of reducing the level of ambient lighting, of sufficient size to permit the free movement of inspection personnel and components, and, if required, to accommodate a work table with a non-reflecting surface. Suitable UV-A lamps shall be provided, which shall be focused on the inspection area. Tubular ultraviolet lamps shall be provided for background UV-A illumination. A source of white light shall be available to maintain satisfactory colour contrast for colour contrast penetrants.

NOTE. Attention is drawn to the safety guidance given in clause 5, in particular to the need for adequate ventilation.

7.4 *Self-contained processing booths.* Self-contained processing booths shall essentially comprise the facilities specified for fixed installations in **7.3** suitably provided so that in the testing of very large components each processing step can be carried out with the components remaining in the same position. Hand-held lamps shall be provided for viewing the components.

Section three. Preparation of surfaces and application of process materials

8. Pre-cleaning

8.1 General considerations

8.1.1 *Surface conditions.* Components for penetrant flaw detection may have a wide variety of surface conditions, as a consequence of the wide range of production methods available. In addition to the basic forming techniques (i.e. casting, forging, machining, etc.) surfaces may also have been:

(a) subject to cleaning and preparation in accordance with CP 3012 as part of the manufacturing process;

(b) coated with corrosion preventives, oil, grease or magnetic ink;

(c) painted;

(d) subject to corrosion, deposition of combustion products or biological growth.

Where surfaces have been cold worked by shot peening, abrasive blasting or similar treatments, distortion of the surface layers may close the outcropping edges of existing discontinuities, preventing the ingress of penetrant and thus reducing the effectiveness of the test. The use of such treatments should be avoided wherever possible.

8.1.2 *Removal of scale.* In order to decide on the most appropriate method of removal of scale from iron and steel, it is necessary to seek the advice of a metallurgical analyst. The solutions required for the removal of scale depend on the type of scale present but invariably they are strongly acidic or alkaline and require to be handled with great care. It is very important that only inhibited products are used to avoid risk of attack on the parent metal. In general, proprietary rust and scale removers contain inhibitors and are supplied with warning notices regarding their safe use.

It is important to note that acids and alkalis have an adverse effect on the fluorescence and brilliance of penetrant dyes.

8.1.3 *Presence of acid or alkali.* The effectiveness of a penetrant in revealing flaws in a surface may be affected in two ways by the presence of aqueous alkali or aqueous acid solutions from manufacturing processes or from preparation for penetrant flaw detection, viz:

(a) the presence of the solution in a discontinuity may prevent the entry of penetrant or dilute that which does enter;

(b) the acid or alkali properties of residual solution in a discontinuity may adversely affect the brilliance of the penetrant.

Etching may be specified after any physical or chemical method has been used for pre-cleaning or removing contaminants.

CP 3012 gives details of methods for cleaning and preparing most commonly encountered types of contaminant or coating on metal surfaces. The most suitable method for a particular application should be selected from CP 3012 and reference made to this standard for particular precautions associated with penetrant flaw detection.

8.2 Requirements

8.2.1 *General.* Before applying penetrant process materials, the surface of the component shall be free from solid and liquid contaminants. All traces of oil, grease, wax, paint, scale, rust, carbon, varnish, oxide, forging or heat-treatment scale, welding flux, corrosion preventives, plating or polishing compounds, residues, biological growth, etc., shall be removed. Surfaces carrying oxidants (e.g. chromates and chromic acid) suppress the fluorescence of penetrants and, where present, they shall be removed by dipping the component in aqueous acid or aqueous alkali followed by a detergent wash and drying.

8.2.2 *Surfaces which have been exposed to aqueous alkali or aqueous acid solutions.* Where an aqueous alkali or aqueous acid solution is applied during the preparation of the surface it shall be preceded by a suitable degreasing, using a method given in CP 3012 and a water soak for 5 min. In all cases, components that have been subject to such solutions shall be rinsed thoroughly in running water and dried in an air blast at a temperature between 30 °C and 50 °C for a sufficient period to allow the evaporation of water to take place from any discontinuity.

Where etching is specified to provide a more critical inspection for the detection of fine discontinuities, it shall be carried out as described in British Standard M 37.

8.2.3 *Degreasing.* Immediately prior to application of penetrant process materials, components shall be degreased as described in method A.1 of CP 3012 : 1972.

NOTE 1. Reference should be made to section 1 of CP 3012 : 1972 for particular limitations for certain materials, such as titanium.

NOTE 2. The method specified in **8.2.3** may be supplemented by ultrasonic agitation in hot solvent liquid.

NOTE 3. Special precautions are necessary for aluminium, magnesium and their alloys, and the use of 1,1,1-trichloroethane is not advised.

9. Procedures for application of penetrant process materials to prepared surfaces

9.1 Temperature. Ensure that the surface temperature of the component lies within the range specified by the penetrant manufacturer.

NOTE. Higher temperatures tend to degrade the effectiveness of the penetrant and to make it harder to remove excess penetrant from the surface. At low temperatures, some precipitation of the dye (colour or fluorescent) may occur which reduces the efficacy of the process.

9.2 Application of penetrant. Apply the penetrant by immersion, flooding, spraying or brushing. Keep the surface wet with penetrant for at least 10 min or for the minimum period specified by the manufacturer.

NOTE. Prolonged drainage times have to be avoided as the penetrant tends to dry on the surface and this makes it more difficult to remove the excess.

9.3 Self-drying of penetrant. If penetrant dries on the surface, re-apply the penetrant in accordance with **9.2.**

9.4 Removal of excess penetrant. Excess penetrant shall be removed by the appropriate method described in (a) to (d) below.

(a) *Liquid solvent removers.* Apply the remover sparingly by spraying or wiping with a lint-free cloth. Immediately following the application of the solvent remover, wipe the surface to leave a barely discernible background. Keep the period of contact with the remover to a minimum consistent with satisfactory removal.

NOTE 1. Where solvent removers are applied by spraying or by an aerosol, the remover should not be applied directly to the area under test.

(b) *Aqueous wash (water-washable penetrant).* Wash the surface of the components to remove excess penetrant by any of the following means:

(1) water spray from a spray nozzle or an air/water spray gun not closer than 0.3 m from component;

(2) immersion in an agitated wash;

(3) a combination of (1) and (2).

With a fluorescent penetrant, monitor this stage under UV.A.

The maximum water pressure for penetrant removal shall not exceed 2 bar.

NOTE 2. A water temperature of between 15 °C and 30 °C is recommended.

NOTE 3. Aqueous liquid developers are applied directly after this washing stage (see **9.6**).

(c) *Aqueous removal (hydrophilic process).* Aqueous removers supplied as concentrates shall be diluted in accordance with the manufacturer's instructions, and the removal process shall be carried out as described in (1) to (3) below.

(1) *First aqueous wash (optional).* Wash surfaces of the components under the conditions given in **9.4**(b) by a water-spray nozzle or an air/water spray gun to remove obvious excess penetrant.

(2) *Application of aqueous remover.* Immerse the components completely in the aqueous remover or apply the remover by spraying. Keep the period of contact with the remover to a minimum consistent with an acceptable background and do not exceed the maximum period of contact specified by the manufacturer. Apply the second aqueous wash immediately after the specified contact period with the remover has elapsed.

(3) *Second aqueous wash.* Subject the components to an agitated aqueous wash or, for small components, to a spray-wash (see note to **7.3.6**) for a period of 0.5 min to 2 min under the conditions given in **9.4**(b).

NOTE 4. The principal object of this wash is to arrest the action of the remover. A final aqueous spray rinse with a water-spray nozzle or air/water spray gun may be required to remove surface penetrant and care has to be taken not to overwash. With a fluorescent penetrant, this stage should be monitored under UV.A.

NOTE 5. Aqueous liquid developers are applied directly after this washing stage (see **9.6**).

(d) *Post-emulsifier (lipophilic process).* The process shall be carried out as detailed in (1) and (2) below.

(1) *Application of emulsifier.* Apply the emulsifier by immersion and draining, spraying or flow-on in accordance with the manufacturer's instructions. Do not apply the emulsifier by brush. Take care to avoid local entrapment of the emulsifier caused by the geometry of the component. Keep the period of contact with the remover to a minimum and do not exceed the manufacturer's recommended maximum period.

NOTE 6. The actual contact period includes the total period during which the emulsifier is on the component and varies according to the type of penetrant and the nature of the surface.

(2) *Aqueous wash.* Immediately after the contact period with the emulsifier has elapsed, immerse the components in an agitated aqueous wash, or spray-wash small components (see note to **7.3.6**), for a period of at least 30 s. Maintain the temperature of this aqueous wash between 15 °C and 30 °C.

NOTE 7. The object of an aqueous wash is to remove the emulsifier from the surface of the components and to arrest its action before it has time to mix with penetrant trapped in flaws.

NOTE 8. A final aqueous spray rinse with water or water/air from a spray gun may be used to remove final traces of the emulsified penetrant, the water temperature and pressure being in accordance with **7.3.5**. When a fluorescent penetrant is in use, the process should be monitored under UV.A.

NOTE 9. Aqueous liquid developers are applied directly after this washing stage (see **9.6**).

9.5 Drying of components. Components shall be dried by one of the methods given in (a) to (c) below.

(a) In a hot air circulating oven, such that the temperature of the components does not normally exceed 50 °C and that the drying period is kept to a minimum and not in excess of 10 min.

(b) By the action of forced, warm air, with the drying time being kept to a minimum and the surface temperature of the component not normally being allowed to exceed 50 °C.

(c) By the action of dry, clean, compressed air from a supply at a pressure not exceeding 2 bar.

NOTE. With some process materials, it may be possible for components to be dried at a temperature higher than 50 °C, in which case the recommendations of the penetrant manufacturer may be followed.

9.6 Application of developer. The developer shall be applied by the appropriate method given in (a) to (c) below. Irrespective of the type of developer and the method of application, the surfaces shall be allowed to remain covered with a dry film of developer for the period stated in the manufacturer's instructions.

(a) *Dry powder developers.* Apply the developer by one of the methods listed in **7.3.10** immediately after drying the component.

NOTE 1. In general, dry powder developers should not be used with colour contrast penetrants because of the resulting lack of contrast between the background and the indication.

(b) *Liquid developers (aqueous liquid).* Apply the developer by method (1) or (2) below, as appropriate, directly after the aqueous washing removal steps given in **9.4**(b), **9.4**(c)(3) and **9.4**(d)(2) and subsequently dry the components by one of the methods given in **9.5**.

(1) *Suspensions in water.* Immerse the components in an agitated suspension for at least 30 s and withdraw them in such a manner that heavy accumulations in the corners and other regions of the components are avoided prior to drying.

(2) *Solutions in water.* Apply the developer either by immersing the components in it for a period of at least 30 s, or by wet spray, or by brush, or by flow-on. Allow excess developer to drain from the components and take care to guard against the retention of reservoirs of developer in the surface features of the components prior to drying.

(c) *Liquid developers (non-aqueous liquid).* Thoroughly agitate the developer prior to use.

Where a non-aqueous liquid developer is to be used as part of a colour contrast penetrant system, apply, by spraying, a thin regular coating of developer (after evaporation of the volatile carrier) sufficient to obscure the surface of the component. Where a non-aqueous liquid developer is to be used as part of a fluorescent penetrant system, apply, by spraying, a coating such that the surface texture of the component is still discernible through the layer of developer.

NOTE 2. Application of developer by means other than spraying causes loss of indications by masking or by leaching-out of penetrant from defects.

9.7 Control of process materials. Any penetrant flaw detection line involving repeated use of materials shall be subject to control by means of a range of tests carried out at regular and frequent intervals as described in appendix B.

10. Viewing conditions

10.1 Fluorescent penetrants. When using fluorescent penetrants, the room or area where the inspection is to be made shall either be darkened or be illuminated by a low output amber light and inspection shall be carried out under UV-A. The lamp(s) shall be allowed to reach full brilliance before being used in inspection. Prior to viewing, at least 5 min shall be allowed for the person carrying out the inspection to become accustomed to the lighting conditions.

The UV-A irradiance level at the surface being inspected shall be not less than 0.5 mW/cm^2 or 500 μW/cm^2 (see BS 4489).

NOTE 1. Photochromic spectacles should not be worn when working with UV-A as exposure to it, like exposure to bright sunlight, may cause darkening and therefore lower the ability of the wearer to detect flaws.

NOTE 2. For checking the performance of UV-A lamps and irradiance at the working surface, see BS 4489.

10.2 Colour contrast penetrants. When using colour contrast penetrants, the area under inspection shall be illuminated by daylight or artificial light from either a normal tungsten filament lamp or a fluorescent tube, to a level of illumination not less than 500 lux* so as to enable a proper evaluation to be made of the indications revealed. The viewing conditions shall be such that no glare will be experienced during inspection of the component.

NOTE. As aids to viewing penetrant indications, contrast-aid spectacles are useful. Such spectacles, made with sodium glass lenses, give an increased contrast with fluorescent penetrant and eliminate any objectionable ultraviolet or blue light, particularly where components with highly reflecting surfaces are being inspected. Clip-on lenses are available for persons who normally wear spectacles.

11. Inspection

11.1 General. When the development time has elapsed (see **9.6**) inspect the surface under appropriate viewing conditions specified in clause **10**. If the background is such that the interpretation of indications is impaired, the surface shall be completely re-tested in accordance with **11.2**. Mark the location of indications and evaluate those that are relevant in accordance with an agreed level of acceptance.

NOTE 1. 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. Where excessive bleed-out of penetrant occurs, wiping and re-development to achieve clearer indications may be undertaken.

NOTE 2. The maximum continuous viewing period for inspection of components should be limited as the sustained concentration involved causes fatigue and unreliability. Between consecutive viewings, periods should be allowed during which operators should not be engaged on tasks requiring similar viewing concentration.

NOTE 3. Persons carrying out penetrant processing or inspection should be able to read the Jaeger J.2 chart at a distance of 0.5 m. This ability should be checked annually and recorded. The Jaeger J.2 chart is obtainable from the American Society for Non-destructive Testing, 3200 Riverside Drive, Columbus, Ohio 43221, USA.

11.2 Re-tests. Re-tests shall be carried out by the process initially used.

NOTE. Any changes of process necessitate a particularly careful intermediate cleaning stage (see clause **4** on compatibility of materials and clause **8** on the preparation of components).

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*As a guide, this can be achieved by using either a fluorescent tube of 80 W at a distance of about 1 m or a tungsten filament pearl lamp of 100 W at a distance of about 0.2 m.

12. Technique sheets and presentation of data

12.1 Technique sheets. Comprehensive process instructions shall be prepared for each penetrant process or variation of a process carried out in accordance with this standard. These instructions shall contain the minimum information listed in appendix C.

12.2 Presentation of data. The results of all penetrant flaw detection tests carried out in accordance with this standard shall be recorded and the following information shall be included:

(a) job identification reference;

(b) date of test;

(c) identity and status of person(s) responsible for the test;

(d) process used;

(e) summary of results and action taken;

(f) identification of defective components;

(g) status of component.

13. Cleaning after testing

If the presence of residual testing materials would be objectionable, treated surfaces shall be cleaned after testing. Where a corrosion preventive needs to be applied and there is a requirement for the surface to be cleaned after the final test, this shall be stated on the technique sheet.

Appendix A

Corrosion tests

A.1 Test pieces. The corrosion test pieces should be of the same general composition as the metal on which the penetrant test is to be made, and should be in the form of right circular rods, 40 ± 1 mm long and 20 ± 1 mm diameter. The sides of the rods constitute the test surfaces and should have a surface roughness of 0.4 µm R_a in accordance with BS 1134.

Immediately before using the test pieces, abrade their surfaces with P.240 (240 grit) aluminium oxide metal-working cloth, with either 'J' or 'X' backing weight, as specified in BS 871.

A.2 Corrosion test. Place the test pieces on end at a minimum distance apart of 10 mm, in a flat-bottomed glass dish at least 50 mm deep, in an enclosure having an ambient temperature within the range 20 °C to 25 °C.

Pour in the process liquid (penetrant, developer, pre-cleaner, remover, etc.) so as to cover the test pieces to a height of 4 mm to 6 mm. Cover the dish and leave in the enclosure for 16 h in the case of penetrants and developers or for 30 min in the case of pre-cleaners and removers.

A.3 Examination of test pieces after test. After the required time has elapsed, remove the test pieces from the dish, wipe their surfaces and examine for visual signs of deterioration.

Magnesium alloys should be free from etching, pitting or corrosion. The level of staining should be less than that shown on specimens of these alloys that have been partially immersed, as described in **A.2**, for 30 min in a sample of 'standard hard water' as defined in appendix A of BS 1427 : 1962.

Appendix B

Control tests

B.1 General. Control tests can be carried out on test pieces specially prepared for the purpose (e.g. chromium-plated artificially cracked blocks or aluminium blocks with quench cracks) or on cracked components obtained from production.

B.2 Storage and preparation of test pieces. Immediately after use, clean the test pieces and inspect them for residual penetrant using a developer. Allow 30 min for development. Remove the developer, thoroughly clean the test pieces and store them in envelopes made of plastics material, or wrapped in tissue paper, or in a suitable solvent.

B.3 Sampling of process materials. Take samples of the fresh penetrant, developer and remover at the time of filling containers and also when replenishing containers where the volume of fresh material represents 30 % or more of the volume of the contents of a container after replenishment. Store the samples away from heat and light in clean, new tins or bottles clearly labelled with their identity, manufacturer's batch number and date of filling.

B.4 Functioning tests. Process the test pieces for the process being monitored and compare the results with a photographic or transfer lacquer developer reproduction of behaviour with the samples taken in **B.3**.

NOTE. Where a transfer lacquer is used to record original performance, the lacquer acts as the developer. Where a difference is noted, stepwise substitution of the 'in-use' materials with standard materials will isolate the defective stage of the process.

Where specially prepared test pieces are used, carry out the test by applying standard material to one half of the test piece and used material to the other half and compare the results obtained on the two halves.

B.5 Control of process materials

B.5.1 *Colour or fluorescent intensity.* Check the intensity of colour contrast and fluorescent penetrants weekly as described in **B.7.** Discard the penetrant if its loss of colour is greater than 20 % in the case of a colour contrast penetrant or greater than 25 % in the case of a fluorescent penetrant.

B.5.2 *Penetrant comparator check.* Prepare a simple checking device from a thin plaque of austenitic steel as follows. Subject one surface of the plaque to a blast of grit, of average particle size 150 µm, at a pressure of 4 bar, from a gun at a distance of 450 mm.

At weekly intervals carry out the following test. Clean the plaque thoroughly and apply fresh penetrant to one half of it and used penetrant to the other half. After 10 min remove the penetrant from the plaque by the technique in use and compare the behaviour of the penetrant samples.

B.5.3 *Efficacy of penetrant removers.* Apply fresh penetrant to each of two austenitic steel plaques prepared as described in **B.5.2** and allow the penetrant to remain on the surface for 10 min. Process one of the plaques by used remover (hydrophilic or lipophilic) and the other by standard remover, under standard conditions for the installation, and compare the plaques.

B.5.4 *Fluorescence in developers.* Test dry powders by directing radiation from a UV-A lamp into the reservoir. Fluorescence in the developer is a reason for rejection. In the case of aqueous liquid developers, immerse austenitic steel plaques prepared as described in **B.5.2** in the solutions or suspensions, in both the used and standard conditions. Compare the plaques after drying.

B.5.5 *Coverage by aqueous liquid developers.* Apply aqueous liquid developers to the surfaces of smooth austenitic steel plaques and check that the surfaces are covered completely and evenly, leaving neither bare spots nor lumps.

B.5.6 *Concentration of aqueous liquid developers.* Test the concentration of aqueous liquid developers in accordance with the manufacturer's instructions.

B.6 Control of working levels in tanks. Where process materials are contained in tanks during use, check daily that the minimum level of the material in the tank is sufficient to ensure complete immersion of the components, as defined in the process instructions (see **C.8**).

B.7 Control tests for colour contrast and fluorescent penetrants

B.7.1 *Control of colour contrast penetrants.* To check the colour of a used penetrant, add 5 mL of it to 95 mL of dichloromethane in a 100 mL cylinder. Prepare a solution of the same concentration with fresh penetrant taken from the same batch. View the two cylinders against an illuminated white background. If the used penetrant appears lighter than the fresh penetrant, darken it by the addition of a further 0.2 mL of used penetrant, shake well and compare it again with the fresh penetrant. Add used penetrant in increments of 0.2 mL until the colour of the test solution is the same as that of the fresh penetrant.

Record the total volume, V, of the additions required to make the used penetrant match the fresh penetrant and report the loss of colour as:

$$\frac{100\,V}{5+V}\,\%$$

where V is expressed in mL.

B.7.2 *Control of fluorescent penetrants.* Take a sample of the used penetrant together with a sample of fresh penetrant from the same batch and dilute each in the proportions of 1 part penetrant to 19 parts dichloromethane. Soak filter papers, 55 mm x 55 mm, in each solution, allow them to dry in air at ambient temperature for 1 min and then transfer them to an oven at a temperature of 70 ± 3 °C for 5 min. Measure the reading of fluorescence of the fresh sample paper in a test apparatus having the general features shown in figure 2 with the plane of the filter paper holder parallel to the plane of the photometer that reads over the range 0 lux to 500 lux and is fitted with a colour correction filter conforming to the CIE* recommendations on standard observer response. Adjust the distance, d, of the UV-A lamp to give a convenient reading, A, close to the full-scale mark. Substitute the used sample for the fresh sample and take the reading, B. Place a clean, blank filter paper of the same size in the apparatus and take a further reading, C.

Record the loss of fluorescence as:

$$\left\{1-\frac{(B-C)}{(A-C)}\right\}\times 100\,\%$$

Appendix C

Example of technique sheet

C.1 General information

(a) The name of the organization authorizing the instructions.

(b) A unique identification for the process or variation of it.

(c) Date of issue.

(d) Issue number.

(e) Page number.

(f) The types of process materials (see clause **3**).

(g) Details of any limitations, restrictions or special circumstances governing the use of the process.

C.2 Pre-cleaning

(a) The cleaning agent to be used.

(b) The method of application.

(c) The allowable range of the controllable parameters (i.e. grit size, pressure range, temperature range, acid acceptance level and dilution, as appropriate).

(d) Criteria that define the completion of the operation.

C.3 Application of the penetrant

(a) The type of penetrant to be used.

(b) The method of application.

(c) The range of permissible contact and drainage times.

(d) The range of permissible temperatures for the component and the penetrant.

C.4 Removal of penetrant

(a) The sequence of operations required for the removal of the penetrant.

(b) The cleaning agent to be used in each operation.

(c) The method of application for each agent.

(d) The operating conditions for each agent (i.e. permissible temperature range, range of dilutions, etc.).

(e) Criteria that define the completion of each operation.

C.5 Drying of components

(a) The method of drying.

(b) The permissible temperature range.

(c) Criteria that define the completion of drying.

C.6 Developing

(a) The type of developer to be used.

(b) The method of application.

(c) The range of permissible development times.

C.7 Inspection. Details of the conditions under which processed components are inspected.

C.8 Process control. Details of the appropriate control checks for monitoring the performance of the process in use and for checking the performance of new stock process materials.

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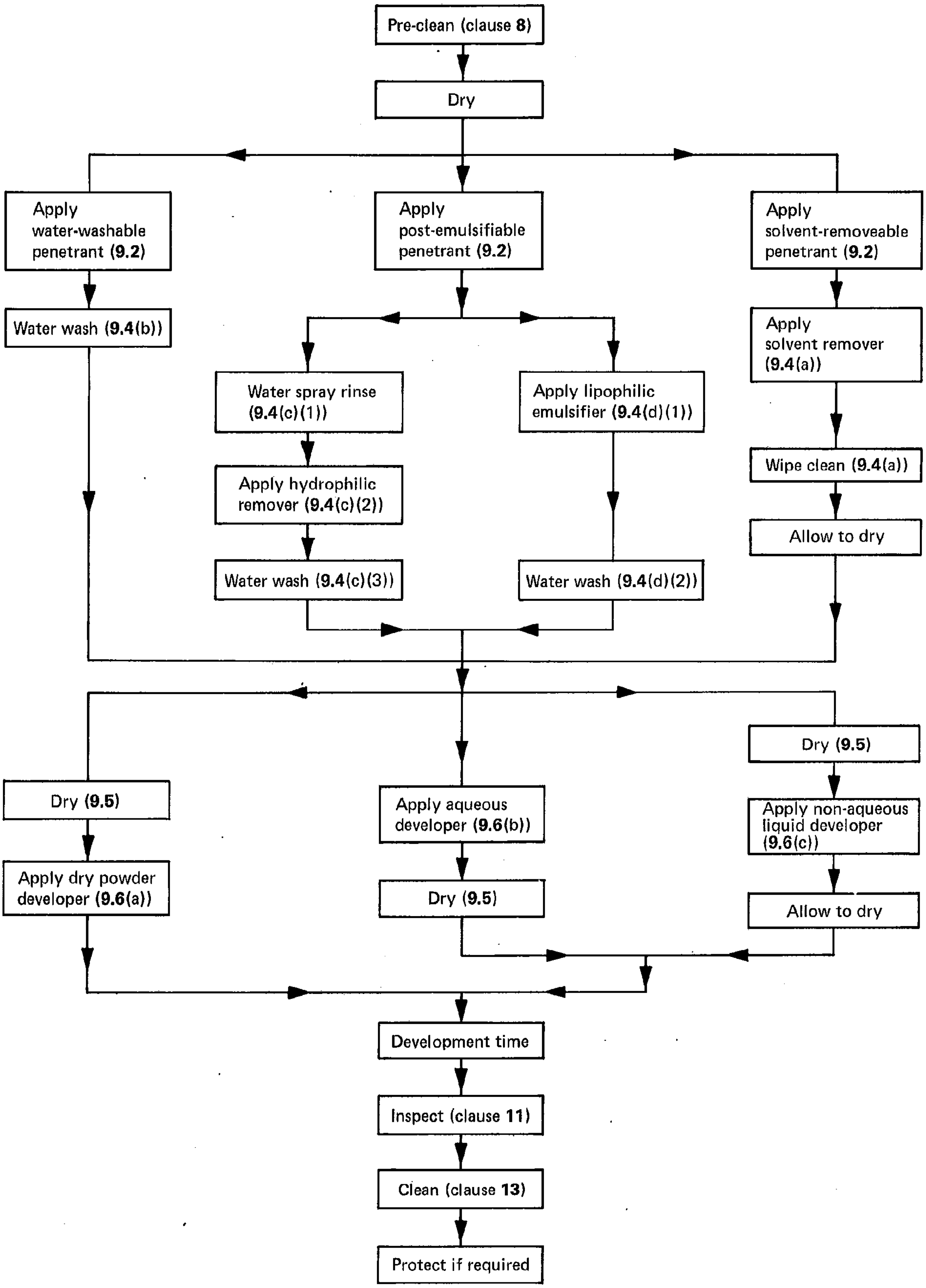
*Commission Internationale d'Eclairage.



NOTE. The numbers refer to the corresponding clauses in the text.

Figure 1. Flow diagram illustrating the various processes possible in penetrant flaw detection

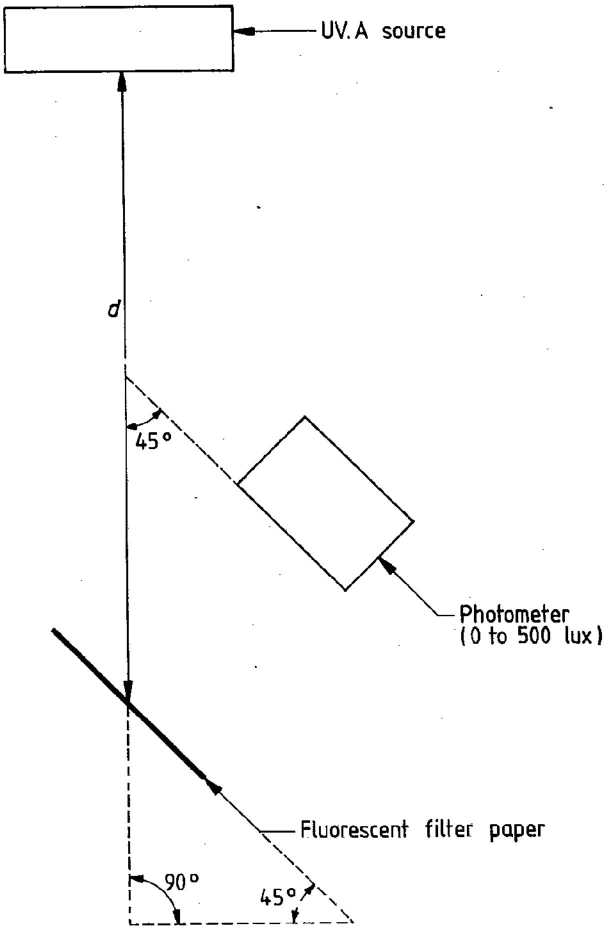


Figure 2. Apparatus for checking the fluorescence of a fluorescent penetrant

Publications referred to

BS 871	Specification for abrasive papers and cloths
BS 1134	Method for the assessment of surface texture
BS 1427	Routine control methods of testing water used in industry
BS 3683	Glossary of terms used in non-destructive testing Part 1 Penetrant flaw detection
BS 4489	Method for measurement of UV-A radiation (black light) used in non-destructive testing
BS 5345	Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture)
BS 5423	Specification for portable fire extinguishers
CP 3012	Cleaning and preparation of metal surfaces
British Standard M 37	Method for the etch inspection of metallic material and components
British Standard M 39*	Method for penetrant inspection of aerospace materials and components

National Radiological Protection Board. Protection against ultraviolet radiation at the workplace. Published by HMSO.

*Referred to in the foreword only.

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