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Welded joints — Recommended practice for liquid penetrant testing

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FOREWORD

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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.

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It has been approved by the member bodies of the following countries:

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Japan

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Welded joints — Recommended practice for liquid penetrant testing

0 INTRODUCTION

Liquid penetrant testing is a method of non-destructive examination which provides for the detection of discontinuities open to the surface in ferrous and certain non-ferrous materials.

A satisfactory application of this method of testing requires a certain skill in the technique involved and in interpreting the results : hence, the requirements specified herein presume application by suitably experienced personnel.

It should also be noted that the use of certain products for liquid penetrant testing requires the application of appropriate safety precautions.

1 SCOPE AND FIELD OF APPLICATION

This International Standard lays down procedures to be followed when liquid penetrant testing is applied to welded joints; however, it does not state when this method of testing should be employed, nor does it give standards of acceptance. Either dye penetrant products or fluorescent penetrant products may be used.

The procedures laid down in this International Standard apply to the majority of general cases of weld inspection; any variation from these procedures for particular applications, for example at lower or higher temperatures than those indicated in 4.3, shall be the subject of agreement.

2 PRINCIPLE

Liquids enter small openings such as cracks, fissures and porosities by capillary action. The rate and extent of this action are dependent upon such conditions as surface tension, cohesion, adhesion and viscosity. This action is also influenced by other factors such as time, temperature, condition of the surface of the material and interior of the discontinuity.

After proper preparation of the surface, a liquid penetrant is applied to the surface to be examined and allowed to enter such openings, after which excess liquid is removed. A developer is then applied which draws some of the penetrant out of the openings and hence is wetted or otherwise affected by the penetrant. This increases the evidence of the discontinuities so that they may be seen either directly or by the use of "black light".

3 CHARACTERISTICS OF PENETRANTS AND ACCESSORIES

3.1 Penetrants

3.1.1 Penetrants are classified into the following two basic types :

— **Dye penetrants** : These contain a dye, the contrasting colour of which (generally red) with the developer (generally white) can be seen readily in daylight or under normal interior illumination.

— **Fluorescent penetrants** : These carry additives that fluoresce under ultra-violet radiation (black light).

The penetrants must have suitable physical properties to enable them to penetrate into small voids and cracks.

3.1.2 According to the type of penetrants, they can be further classified into the following three basic groups :

— **Water-washable** : The penetrant contains an emulsifying agent which makes the excess removable with water washing.

— **Solvent-removable** : The penetrant can be removed only by appropriate organic solvents.

— **Post-emulsified** : After application of the penetrant, an emulsifying agent has to be applied to the vehicle to make the penetrant water-washable.

3.2 Developers

Developers are classified into the following two basic types :

— **Dry developers** : These consist generally of dry white absorbent powders (such as talc-powder, pulverized silicon dioxide or other types).

— **Liquid-support developers** : These consist either of a powder as above, suspended in volatile liquid, in a solvent or in water.

The developer shall meet the following requirements :

a) it shall provide rapid absorption of the penetrant liquid;

b) it shall not be self-fluorescent if used with a fluorescent penetrant;

c) it shall be possible to apply the developer in a thin and uniform layer of fine particles;

d) in the case of a liquid-support developer, it has to be suspended, according to the characteristics of the penetrant, in a reasonably volatile liquid so as to ensure that penetrant is not washed out of defects.

3.3 Notes on the use of penetrants and developers and safety precautions

It is advisable that the penetrant, emulsifier (if used) and developer should be from the same supplier; in any case they shall be compatible with each other as a complete system.

It is also important that the testing media should not be harmful to the material being tested (for example chlorine compounds may be harmful with austenitic stainless steels and sulphur compounds with high nickel alloys). The testing media should be used with caution and always in accordance with safety requirements; volatile solvents and additives may be relatively toxic and highly inflammable.

4 PROCEDURE

4.1 Cleaning

The success of any liquid penetrant testing procedure is greatly dependent upon the surface being free from any contaminant that might interfere with the penetrant inspection process.

It is therefore essential that the part or surface to be examined be thoroughly clean and dry.

By "clean" is meant the state resulting from the removal of all rust, scale, welding flux, spatter, grease, oil film, water, dirt, etc. not only from the surface but, more particularly, so as to allow the penetrant to enter any flaw that may be present[1].

It is to be noted that excessive surface roughness, for instance very pronounced solidification waves of welds, can produce confusing indications, but grinding or polishing of the surface is not usually necessary. In any case coarse dressing or machining shall be avoided as flaws may be peened-over and become masked; in such cases subsequent polishing (for example by emery paper) may be required to make it possible for penetrant to enter the defects.

Welded joints in new work shall be subjected to penetrant testing prior to any surface treatment that would tend to close or mask flaws. For components which have been in service, the method of surface cleaning shall be adequate to remove contamination from the surface and inside the flaws.

When a suitable surface cannot be produced, then an agreed alternative method of non-destructive examination shall be adopted.

4.2 Drying after cleaning

It is essential that the part or 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 penetrants from entering. Slight heating of the piece or the blowing of warm air on to it shortens the drying time.

1) For information, typical cleaning media and methods applicable for this purpose are as follows :

— **solvents** : residue-free organic solvents may be used as hand-wipe solvents. These solvents are suitable for removing grease and oils, but are generally not adequate if solid foreign material is imbedded in the void areas. Solvents containing chlorides are not to be used on austenitic stainless steels, particularly on those which may be in contact with hot water under pressure;

— **detergents** : they may be alkaline, neutral or acidic in nature but must be non-corrosive to the metal being inspected. The cleaning properties of detergent solutions facilitate complete removal of foreign matter. Concentration of detergent solution and cleaning time and temperature shall conform to the recommendations of the manufacturer of the cleaning compound. After cleaning, parts shall be thoroughly rinsed and completely dried;

— **water vapour degreasing** : this method of cleaning is suitable especially when heavy oils and grease constitute the basic surface contamination. Organic foreign matter can usually be satisfactorily removed by water vapour degreasing but inorganic contamination is generally best removed by water-soluble detergents;

— **descaling solution** : descaling or removal of oxide film may be accomplished by pickling in inhibited acid or hot alkaline rust remover solution. In any case the descaling solution shall be non-corrosive to the metals being processed. Descaling procedure shall conform to the recommendations of the descaling compounds manufacturer. After descaling, parts shall be thoroughly rinsed and completely dried;

— **paint removers** : paint films shall be completely removed to expose the surface of the metal; this can be done by use of bond release solvent paint removers or disintegration-type hot-tank alkaline paint strippers. After paint removal, the parts shall be thoroughly rinsed to remove all contaminants and then thoroughly dried;

— **abrasive blasting or wire brushing** : both abrasive blasting using sand, metallic shot, lignocellulose pellets or aluminium oxide and wire brushing may be used to remove brittle foreign matter, such as rust or scale. This type of cleaning or scale removal is permissible only when the abrasive blasting does not peen-over or fill the voids, as this drastically reduces the accuracy of inspection. New, sharp abrasive shall be used. Abrasive projection cleaning often leads to surface cold working. This type of preparation should therefore be avoided whenever possible, or be followed by etching and subsequent neutralization.

Brushes having wires in ferritic steels shall not be used for cleaning austenitic stainless steels.

4.3 Application of penetrant

4.3.1 *Application temperature*

As a general rule the temperature of the test surface and of the penetrant shall be within the limits recommended by the supplier of the penetrant.

In practice, as a standard technique, the temperature of the part to be examined, the penetrant, the rinse and the developer should be compatible with the characteristics of the products used; for the most common products, in general it should not be below + 15 °C (+ 60 °F) nor above + 50 °C (+ 125 °F) throughout the examination period. Local heating or cooling is permitted provided temperatures remain in the specified temperature range during the examination. Where it is impraticable to comply with the specified temperature limitations recommended by the manufacturers of the products used, other temperatures (and penetration times) may be adopted, by agreement on a qualified procedure.

4.3.2 *Application method*

The surface to be tested shall be thoroughly and uniformly wetted with the penetrant liquid. This can be applied with a brush or a spray-can or by flooding or immersion of the piece in a tank containing penetrant.

When penetrants which may be toxic are used, the application by spray must be carried out in compliance with safety requirements.

4.3.3 *Penetration time*

The time that the surface remains completely wetted shall be not less than that recommended by the supplier of the penetrants; in general the finer and tighter the discontinuity the longer the penetration time should be. According to the temperature and other conditions, in the range indicated above, the penetration time can vary usually from 5 to 20 min (average 10) for post-emulsified and solvent removable penetrants and from 10 to 60 min (average 20) for water-washable penetrants.

4.4 Application of emulsifier

After the penetration time has elapsed and when required by the penetrant type, the appropriate emulsifier shall be applied to the surface to be tested by immersion, flooding, or spraying or by careful brushing.

The temperature of the test surface shall be within the limits recommended by the supplier of the emulsifier or within the general limits given in 4.3 when not specified by the supplier.

The emulsifying time is critical and depends on prevailing conditions, surface roughness and type of flaws sought; it may vary from 10 s to 5 min (average 2 min). This length of time should be held to the minimum that will just give a good water wash.

4.5 Excess penetrant removal

After adequate penetration time or emulsifying time, the surface film of penetrant and emulsifier shall be removed. Insufficient removal will leave a background which will interfere with subsequent indication of defects and possibly give rise to erroneous indications. However, excessive cleaning shall be avoided as it can remove penetrant from the larger surface flaws.

4.5.1 Water-washable and post-emulsified penetrants are to be removed by rinsing or swabbing or spraying with water.

Warm water can be used but its temperature shall not exceed 50 °C (125 °F). For dye penetrant, rinsing shall be carried out until no visible evidence of coloured dye remains on the surface. For fluorescent penetrants, rinsing should be carried out under a black light to ensure complete cleaning of all surfaces.

If a part cannot be completely washed because of insufficient emulsification of the penetrant, the part should be dried and then reprocessed by a new application of penetrant.

4.5.2 Solvent-removable penetrants are better removed in two steps : first, as much penetrant as possible may be removed by wiping with a clean, dry, asborbent lint-free cloth, then the remaining surface film of penetrant may be removed by spraying or washing the surface with the suitable solvent and wiping it promptly with a clean cloth or by wiping the surface with cloth that has been saturated with remover.

Other methods of removal are not precluded but in any case care has to be taken not to use too much solvent in order to minimize the possibility of removing penetrants from defects.

Vapour degreasing shall not be used to remove an excess of penetrants. Cleaning shall be continued until no visible evidence of coloured dye remains on the surface; for fluorescent penetrants this should be checked under a black light.

4.6 Drying

After excess penetrant removal and before applying the developer, generally the piece shall again be dried by means of clean, dry, lint-free cloth, by normal evaporation at ambient temperature or by blowing dry and clean compressed air on it having a temperature not exceeding 50 °C (125 °F) and a sufficiently low pressure.

Drying should be carried out with particular care when dry or non-aqueous wet developers are used. The approach of the required degree of dryness is indicated when the surface wetness begins to disappear. Excessive drying time or excessive temperature shall be avoided so as to prevent evaporation or drying of the penetrant in the flaws.

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

4.7 Application of the developer

4.7.1 *Dry developer*

A developer compatible with the penetrant shall be uniformly applied to the test surface, immediately after the surface has been dried. Application shall be such that no agglomerated masses of powder remain adhering to the surface, which shall present a uniform dusty appearance.

4.7.2 *Liquid-support developer*

A developer compatible with the penetrant shall be used.

The liquid-support developer is best applied by spraying, but applications by dipping, flow-on or, in particular cases, with a soft brush, if carefully done, are also suitable provided that the liquid-support developer is carefully mixed and its concentration is kept to a level suitable for a proper application. Immediately before use, the liquid-support developer shall be agitated to ensure uniform dispersal of solid particles in the carrier fluid.

The developer shall be uniformly applied on the test surface within a period not exceeding 15 min after removal of the penetrants or drying. Thick coatings and pools of liquid-support developer may result in masking of indications and shall be avoided.

When the developer dries, either a smooth and uniform coating in the case of paints or a film of powder is left at the surface. The liquid in which the developer is suspended often has good penetration properties and it can remove the penetrant from a flaw (particularly in the case of wide flaws) before the developer has stabilized itself on the surface. The result is that the penetrant spreads over the surface and produces vague indications. To prevent this happening, it is advisable, in such cases, 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 spray distance or by working at the upper temperatures recommended.

4.7.3 *Developing 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 (developing time) for any indications to develop. This time will depend on the testing media being used, the material examined and the nature of the defects which have to be detected; however, in general it is of the order of magnitude of from one-half the penetration time (see 4.3) to the full penetration time or more for fine flaws. Excessively long developing time may cause the penetrant in large, deep discontinuities to bleed back, making a broad, smudgy indication.

5 OBSERVATIONS OF INDICATIONS

5.1 Dye penetrants

When using dye penetrant, the area under test shall be adequately illuminated by daylight or artificial light to enable a proper evaluation to be made of the indications revealed on the test surface. In any case the viewing conditions shall be such that glare is avoided.

Because the size and type of flaws are difficult to appraise if the dye diffuses excessively in the developer, it is good practice to conduct the examination at intervals during the developing time.

5.2 Fluorescent penetrants

When using fluorescent penetrants, the room or area where the inspection is to be made shall be darkened, and inspection of the test surface shall be carried out under black light.[1)]

The black-light lamp shall be allowed to achieve full brilliance prior to inspection. To protect the operator and to concentrate the beam of light onto the area under examination, it is advisable to provide the lamp with a reflector.

The intensity of the black-light lamp shall be adequate for the area to be examined.

Prior to viewing, at least 5 min shall be allowed for the eyes to become accustomed to the reduced ambient lighting. The operator should avoid looking directly into the black light or in areas which act as mirrors for the black light. Furthermore, care should be taken that in no case do unfiltered radiations of the black-light lamp reach the eyes directly.

Also in this case it is good practice to conduct the examination at intervals during the developing time.

5.3 Interpretation of results

Laminations and cracks appear as broadening lines; the deeper and wider the flaw the wider the lines. Narrow fissures or partially welded laps may appear as broken lines or as a row of small dots. Porosity can appear as either scattered small dots or just a haze of colour. Any questionable or doubtful indications shall be retested to verify whether or not actual defects are present.

Visual examination, possibly under magnification, of the surface of the piece, after removal of the developer, may help in assessing the nature of the flaw.

1) Ultra-violet radiation of wavelength ranging from 320 nm to 400 nm and a peak 365 nm. This is intended to describe the kind of ultra-violet light desired and should not be taken to mean that the wavelength of the ultra-violet radiation must be measured. In this range, ultra-violet radiation is harmless to the human skin and eyes, but eyes should be protected by goggles of U.V.-absorbing glass, in order to avoid a temporary reduction in the observation capacity of the operator.