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Indian Standard
CODE OF PROCEDURE FOR INSPECTION OF WELDS

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

CODE OF PROCEDURE FOR INSPECTION OF WELDS

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Indian Standard
CODE OF PROCEDURE FOR INSPECTION OF WELDS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 22 December 1970, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard has been prepared to serve as a guide to inspection of welds. It covers the various stages of inspection and the methods which may be adopted.

0.3 During inspection of welds reference may have to be made to other Indian Standards. A list of such standards is given in Appendix A.

0.4 This standard keeps in view the practice being followed in the country in this field. Assistance has also been derived from the following:

Weld quality control and inspection. Canadian Welding Bureau, Toronto.

Welding inspection, 1968. American Welding Society, New York.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the recommended procedures for the inspection of welds.

1.1.1 This code is not limited to any specific process, method of manufacture or type of fabrication, but is intended to be a general guide, from where the provisions should be selected for individual applications.

*Rules for rounding off numerical values (*revised*).

1.2 This standard does not stipulate any acceptance standards. These shall be subject to mutual agreement and would depend upon the nature and end use of the weldment.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 812-1957* shall apply.

2.2 Terms relating to methods of mechanical testing of metals shall be as defined in IS : 5069-1969†.

3. SYMBOLS

3.1 Symbols for welding used as working drawings shall be as given in IS : 813-1956‡. If other symbols are used, a complete explanation of their meaning shall be given.

4. STAGES OF INSPECTION

4.1 Inspection for welding shall be carried in three stages :

a) Preliminary stage	Before commencing fabrication by welding
b) In process stage	During fabrication by welding
c) Final stage	After welding

5. INSPECTION BEFORE COMMENCING FABRICATION BY WELDING

5.0 Inspection before the commencement of the job should cover all aspects of the job with a view to eliminating all potential sources of defects.

5.1 Drawings and Specifications

5.1.1 The contract specifications should be studied to ascertain the standard of quality required, and the end use of the products.

5.1.2 The standard specifications prescribed for the contract, and the general standard specifications applicable to the class of work should be examined carefully.

5.1.3 All the relevant drawings should be studied in respect of weld details, dimensional tolerances, process specifications, and any special requirements specified.

*Glossary of terms relating to welding and cutting of metals.

†Glossary of terms relating to methods of mechanical testing of metals.

‡Scheme of symbols for welding. (Since revised).

5.1.4 Where the contract specification does not indicate all the standard specifications applicable, or where it has been left partly or wholly to the discretion of the inspector, the standard specifications to be applied on the job shall be decided in consultation with the customer. The fabricator should be informed about such decisions and the standards of inspection and acceptance should be clearly laid down at the preliminary stage.

5.2 Selection of Welding Process

5.2.1 The process of welding proposed to be adopted by the fabricator shall be in accordance with the job specification and, where necessary, should be proved capable of producing welds of the required quality.

5.3 Material Specifications

5.3.1 The materials to be used shall be in accordance with the job specification or approved drawings and any deviation shall be duly approved.

5.3.2 Only tested materials shall in general be used for welded work. Where the job permits the use of untested material, separate tests should be carried out to ensure that satisfactory welds can be produced consistently with the material used.

5.4 Inspection of Material

5.4.1 The material shall be examined and compared with the manufacturer's test certificates, in respect of cast numbers, ISI Certification Marks, where applicable, inspection stamps, etc.

5.4.2 The material shall be examined for surface defects, rust and corrosion products, presence of contaminants, and any other factor which may hamper the production of a satisfactory weld.

5.4.3 Since laminations are deleterious in welding, it is essential that the cut edges and weld preparations be examined for their presence. It is an advantage to use some non-destructive method such as liduid penetrant or magnetic particle flaw detection on the edges or to subject to ultrasonic flaw detection.

5.5 Selection of Consumables

5.5.1 The welding electrodes, welding wire, flux, gases, or other consumables proposed to be used for the job shall conform to the requirements of the relevant Indian Standard specifications or to the job specifications.

5.5.2 Conformity with the standard may not however be adequate, since a wide range of products may be covered by a standard. It is, therefore, necessary to ensure that the specific selection made gives welds of the necessary quality. In particular this applies to jobs where the welds are completely or partially free from inclusions and porosity (commonly known as radiographic quality welds) are demanded, since only some types of electrodes covered by the standard may give the required quality.

5.6 Inspection of Consumables

5.6.1 The consumables to be used on the job shall be examined to ensure that they have not deteriorated, and are stored as recommended by the manufacturer with a view to preclude potential damage.

5.6.2 Manufacturer's labels should be examined to ensure that the consumables conform to the latest specifications.

5.6.3 For important jobs it is advisable to get a test certificate for each batch of consumables supplied to the user; and to verify that these tests show conformity with the required standards.

5.7 Welding Procedures

5.7.1 Complete welding procedure should be laid down by the fabricator unless the procedure to be adopted corresponds to the relevant Indian Standard code of procedure.

5.7.2 The procedure selected by the fabricator shall conform to all the relevant drawings and specifications and it shall be capable of producing welds of the required quality consistently under actual working conditions. The procedure shall lay down only such preparations and tolerances that may be achieved during production work.

5.7.3 Welding procedures which are specially laid down should be qualified (that is, proved acceptable) by a qualification test carried out by operators of requisite skill using the approved consumables and materials under conditions closely approximating to those during fabrication. These test pieces shall be subjected to all the tests which will apply to the actual weld and to any other tests which may be required to demonstrate the quality of the weld.

5.7.4 Procedures conforming to the relevant Indian Standards do not normally require procedure qualification tests. But these may be carried out, if desired by the inspector, especially when the standard provides a wide latitude of choice.

5.8 Welding Equipment

5.8.1 The welding equipment to be used on the job shall be in satisfactory operating condition and appropriate for the job in question.

5.8.2 It is advisable to ensure that all welding equipment and accessories used by the fabricator conform to the relevant Indian Standard specificati

5.8 ne functioning of the welding plant shall be examined, and wher, necessary, tests shall be carried out to ensure that the plant is capable of consistently producing welds of the required quality.

5.9 Welders and Operators

5.9.1 *Welders* — All welders employed shall be trained, tested and certified according to the appropriate Indian Standards applicable for the job.

5.9.2 *Operators* — Operators employed for mechanized welding shall be trained and tested to execute the required job.

5.9.3 Such qualifying tests shall be made using the consumables and equipment approved for the job under conditions closely approximating to those during production.

5.9.3.1 The validity of the certificate of welder or operator shall lapse if for any reason he has not worked as a welder or operator for a period of six months.

5.9.4 A record shall be maintained of the welders and operators who are qualified by certificates or tests for the respective categories of work on the job. This record shall be made available to all concerned so that it can be ensured that all welding is done by duly qualified welders.

5.10 Testing Facilities

5.10.1 The fabricator should have facilities for performing all the tests required on the job, or shall be able to call upon the facilities of an outside agency or testing establishment.

5.10.2 Testing equipment should be in good condition and shall be calibrated and certified as required.

5.10.3 The testing equipment shall be operated by staff conversant with the testing techniques and able to operate the equipment properly and reliably.

5.11 Ancillary Equipment and Facilities

5.11.1 The fabricator should have adequate and suitable equipment for cutting, straightening, rolling, planing and other methods of preparation required for different classes of welded fabrication.

5.11.2 The fabricator should possess jigs, fixtures, clamping devices, manipulators, handling equipment, etc, to suit the class of work.

5.11.3 There should be adequate facilities for storage of materials and consumables.

5.11.4 There should be adequate facilities for drying the welding consumables.

5.11.5 Where preheating or other heat treatment is required, the fabricator shall possess adequate equipment for the operations and for indicating and controlling the temperature.

6. INSPECTION DURING FABRICATION BY WELDING

6.0 Inspection during fabrication by welding is done from the following points of view:

a) Ensuring that the procedures, consumables, operators, etc, on the job have been previously approved.

b) Examining assemblies, weld preparations, etc, prior to welding to ensure that they are in conformity with the approved procedures and conducive to good welding.

c) Visual inspection during welding to ensure that the work in process produces a good finished weld, and that defects in initial stages are removed prior to further work.

d) Testing of welds which may become inaccessible or more difficult to inspect at a later stage.

e) Permitting modifications, additions or permissible alternatives to procedures, consumables and welders previously approved.

6.1 Inspection of Prepared Materials

6.1.1 The materials previously inspected and approved should be re-examined just before welding is commenced with special emphasis on the weld zone. The weld and the adjacent area shall be free of dirt, rust, oil or other foreign material which may affect the quality of the welding.

6.1.2 The edge preparation for the weld and the weld zone should be checked for conformity with the requirements of the approved welding procedure, and shall be within acceptable tolerances.

6.1.3 The cut faces shall be examined for nick marks, cracks, scale, burrs, etc, and these shall be rectified prior to welding. Where the material is gas cut and by virtue of its thickness and composition; is susceptible to cracking during cutting, particular attention should be paid to crack detection on the cut surface, preferably using some method of non-destructive testing. This would apply even if subsequent machining has been carried out, since cracks may not have been removed completely by machining.

6.2 Assemblies

6.2.1 The method and sequence of assembly and the jigs and fixtures shall correspond to those previously approved, and shall permit welding according to the approved procedure.

6.2.2 The fit-up, gaps, orientation and welding position should correspond to those on the approved welding procedure.

6.2.3 Due precautions to minimise distortion and ensure dimensional accuracy of the finished fabrication shall have been taken without imposing undue stresses on the welds.

6.2.4 Tack welds shall be of adequate size, length and pitch and carried out using the correct welding procedures and by qualified welders (*see* ISI Handbook on Manual Metal Arc Welding for Welders).

6.2.5 Temporary fittings, clamps, fixtures, stiffeners, etc, where used, shall not interfere with the welding, and shall conform to accepted practices for the particular class of work.

6.3 Welding Consumables

6.3.1 Electrodes and other welding consumables shall be of types previously approved, and shall be in good condition. In particular it shall be ensured that these are clean, and have been dried according to the manufacturers' recommendations.

6.3.2 If during fabrication it is found necessary or desirable to alter, amend or make additions to the list of consumables previously approved, the new consumables proposed shall be duly approved. Whereas strict equivalents or identical types of alternative brands may be approved without further tests, change of type or category of consumable will in general require further tests to ensure that these will produce acceptable results when used wish the approved procedures.

6.3.3 If during fabrication there is an incidence of defects which may be attributed to the consumables, the defective consumables should be replaced by another batch of consumables or by another brand of identical type, subject to the approval of the inspector.

6.4 Operators and Welders

6.4.1 All operators and welders used on the job shall be persons who have been previously approved by virtue of certificates or qualification tests.

6.4.2 If any addition to the list of approved operators and welders for various categories is to be made, such additions shall be approved on the same basis as for initial approval. This will apply to inclusion of more operators and welders for a given class of work, to transfers from one class to another and to the approval of welders for class in addition to those for which they have been previously approved.

6.4.3 If at any time during the job there is any reason to question the capability of an operator or welder, for example, due to the incidence of defects in welds made by him, the inspector may, at his discretion, withdraw approval previously granted to him and demand tests for re-approval. Such operators shall not be used on the job until they are requalified.

6.5 Welding Procedure

6.5.1 The welding procedures followed shall conform to these laid down and duly approved in respect of all the relevant details.

6.5.2 Where it becomes desirable or necessary to amend, alter or deviate from the approved procedures, the revised procedures shall be fully laid down and approved on the same basis as for initial approval. Where the changes are of such a nature that they are not likely to affect the quality adversely, the tests for qualification may be waived provided that it is demonstrated that welds of satisfactory quality can be produced after incorporating the changes.

6.5.3 If it is found that despite conformity to approved welding procedures, welds of acceptable quality are not produced, such approval may be withdrawn. The same procedure may be submitted for re-approval, however, if it could be demonstrated that the procedure was not responsible for the defective weld.

6.5.4 Particular attention shall be paid to the observance of special requirements such as sequence of welding, preheating, peening, heat treatment, etc.

6.5.5 It shall be ensured that test coupons, extension pieces, etc, are provided as required by the job or as specified in the relevant Indian Standard. Additional test coupons shall be provided if demanded by the inspector.

6.6 Inspection during Welding

6.6.1 Besides ensuring that the approved welding procedures are being followed, it should be seen that the techniques conform to good welding practice. For example, the thorough removal of slag from an arc weld, or the dressing of spot welding electrodes, although implied in the procedure will fall in the category of good practice.

6.6.2 Welds which would become inaccessible or more difficult to inspect at a later stage shall be inspected completely at this stage.

6.6.3 For important welds, inspection during the welding process, and in between runs, is essential. With careful inspection during welding it is possible to identify potential sources of defects and eliminate them at the early stage.

6.7 Deviations

6.7.1 If any deviations from approved procedures or from approved lists of consumables, processes or operators are detected, the welding shall be stopped pending an appraisal of the consequences of such deviations.

6.7.2 It is essential that the fabricator be made to understand the importance of approvals and the dangers of unauthorised deviation.

6.7.3 If such deviations are detected after completion of a part or the whole of a job, suitable rectifications should be made or remedial measures are taken at the discretion of the inspector.

6.7.4 Where such deviations have produced welds of doubtful quality, the fabrication would not be deemed as acceptable unless adequate tests show that the quality achieved is satisfactory, or unless necessary rectifications are carried out subsequently to achieve this quality.

7. INSPECTION AFTER WELDING

7.0 Inspection after welding is done with a view to assessing:

a) the quality of the weld by tests on extension pieces or the actual fabricated component ; and

b) the correctness of the whole weldment (that is, the fabricated component) by visual and dimensional inspection, by leak and load tests on the actual fabricated component.

7.1 Visual Inspection

7.1.1 The completed weld and the welded fabrication as a whole should be examined visually, preferably with the assistance of a magnifying lens or a magnifying torch.

7.1.2 Visual inspection should cover all the visible aspects of the weld and the weldment.

7.1.3 The following types of weld defects may be detected during visual examinations:

a) Weld defects occurring at the surface such as blowholes, pipes, exposed porosity, exposed inclusions, unfilled crate, unfused welds, etc;

b) Surface cracks in the weld metal or in the parent metal adjacent to it;

c) Damages to the parent metal such as undercut, burning, over-heating, etc;

d) Profile defects such as excessive convexity or concavity, overlap, unequal leg lengths, excessive reinforcement, incompletely filled grooves, excessive penetration bead, root grooves, shrinkage grooves, etc; and

e) Incorrect finish, for example ripple marks, weaving faults, chipping and peening marks, spatter, under-flushing (excessive grinding), excessive indentation of spot welds, uneven welds etc.

7.1.4 The following types of faults on the weldment may also be detected by visual examination:

a) Distortion due to welding, that is, local shrinkage, camber, bowing, twisting, rotation, buckling, waviness, etc;

b) Linear, eccentric, angular and rotational misalignment of parts;

c) Incorrect location of components; and

d) Visible dimensional errors.

7.2 Inspection of Weld Dimensions

7.2.1 Inspection for the correct dimensions shall be carried out in the case of fillet welds, spot welds, seam welds, etc, where the size is specified. They shall be inspected using suitable gauges and taking into consideration the permissible tolerances.

7.2.2 Dimensional inspection of the completed weldment shall be carried out using tools and measuring instruments appropriate to the type of fabrication and the dimensional accuracy required.

7.3 Mechanical Testing

7.3.0 Mechanical tests (often described as destructive tests because their application will destroy the weldment) can be performed on:

a) prototype or sample welds, and

b) extension pieces or test coupons.

7.3.0.1 Mechanical tests may comprise of all or some of the following:

a) Tests for determining strength and ductility — Tensile test, bend test, impact test, load test, etc;

b) Tests for determining continuity, fusion and soundness — Bend test, slug test for spot welds, etc;

c) Tests for determining penetration and internal weld configuration — Macrosection, etching, etc; and

d) Tests for determining metallurgical properties and local variations in the weld and the heat affected zone — Microscopic examination, hardness surveys, chemical analysis of borings from the cross sections, etc.

7.3.1 *Prototypes*

7.3.1.1 For small weldments a prototype is welded and tested to destruction. This test may comprise an overload of the type of load to which the weldment is subjected in service or some form of fatigue test.

7.3.1.2 For larger weldments in repetitive work a prototype is welded and sectioned at various places. Such sections would be subjected to the required mechanical tests.

7.3.2 *Sample Welds*

7.3.2.1 Sample welds are normally required only for establishing the correct welding procedure and would be part of the inspection before fabrication.

7.3.2.2 In certain types of welds additional sample welds are made on test pieces using the same machine settings, operators and other conditions that would be obtained on the job. These test pieces are subjected to various tests, and may be deemed to be equivalent to testing the actual weldment.

7.3.3 *Extension Pieces and Test Coupons*

7.3.3.1 Many specifications specify extension pieces or test coupons which would be welded as part of the main weld and subsequently detached for testing. In fusion welds such extension pieces would serve the additional function of run-on and run-off pieces required to ensure the soundness of the full length of the weld.

7.3.3.2 Extension pieces and coupons should be of the same composition and with the same weld preparation as the parent material of the main weld. It would be ideal if they are off-cuts from the parent material and attached so that the direction of rolling is the same as that on the parent material.

7.3.3.3 Extension pieces are subjected to mechanical tests and the results of such tests shall be deemed to indicate the properties of the main weld.

7.3.4 *Tests for Determining Strength and Ductility*

7.3.4.1 *Tensile tests* :

a) Transverse tensile test,
b) Reduced section transverse tensile test (with a reduced section at the weld to cause tensile failure in the weld),
c) Longitudinal tensile test,
d) All weld metal tensile test,
e) Tensile (shear) test for spot welds,
f) Cruciform tensile test for fillet welds, and
g) Tensile tests on lap welds (shear on longitudinal and transverse fillet welds).

7.3.4.2 *Bend tests*:

a) Free transverse bend test,
b) Guided transverse bend test,
c) Longitudinal bend test,
d) Side bend test, and
e) Fillet weld bend test.

7.3.4.3 *Impact tests :*

a) Charpy V-notch impact test, and
b) Explosive impact test.

7.3.4.4 *Load tests*—Loads may be applied on the weldment by jacks, weights, pulley blocks, or universal testing machines until failure takes place.

7.3.5 *Tests for Determining Continuity, Fusion and Soundness of Welds*

7.3.5.1 *Bend tests*

a) Free transverse bend test,
b) Guided transverse bend test,
c) Longitudinal bend test,
d) Side bend test, and
e) Fillet weld bend test.

7.3.5.2 Nick break tests for butt and fillet welds.

7.3.5.3 Slug tests for spot welds.

7.3.6 *Tests for Determining Penetration and Internal Weld Configuration*

7.3.6.1 Macro-examination.

7.3.6.2 Etching of macrosection with proper etching solution.

7.3.7 *Tests for Determining Metallurgical Properties and Local Variations in the weld and Heat Affected Zone*

7.3.7.1 *Microscopic examination*:

a) Examination of microstructure,

b) Number and size of inclusions, and

c) Grain size measurements.

7.3.7.2 *Hardness surveys*:

a) Hardness survey of weld and heat affected zone on macrosection, and

b) Measurement of micro-hardness.

7.3.7.3 *Chemical analysis*:

a) Chemical analysis of borings taken from the macrosection or the surface of the weld, and

b) Chemical analysis by spectrographic method.

7.4 Non-destructive Testing

7.4.1 *General* — Non-destructive testing covers the examination of welds by all the processes which do not require destruction of weldment by sectioning or cause damage to it or render it unusable. While this includes methods such as visual and dimensional inspection non-destructive testing will normally cover the use of the following methods:

a) Radiographic examination,

b) Ultrasonic testing,

c) Magnetic particle flaw detection,

d) Liquid penetrant flaw detection, and

e) Eddy current testing.

The general application of the methods, their advantages and limitations are given in Table 1.

7.4.1.1 Before selecting the method of non-destructive testing, it is necessary to consider the following factors:

a) Portions of the weldment to be inspected;

b) End use of the weldment and the functional significance of discontinuities or flaws in the weld;

c) Material, thickness, shape and surface condition of the weld;

d) possible or expected defects, their type, size and location; and

e) Acceptable standards.

7.4.1.2 All the methods of non-destructive examination are comparatively expensive and would increase the cost of inspection. Their use should, therefore, be limited to the extent actually required in order to assess with reasonable confidence the absence of unacceptable flaws.

7.4.1.3 Used judiciously, non-destructive methods given in **7.4.1** are the most significant and useful among the various methods of inspection available.

7.4.2 *Radiographic Inspection* — In radiography the ability of short wavelength radiations, such as X-rays and gamma rays, to penetrate objects opaque to ordinary light is utilised to produce a shadow of any internal defect on the image. The defects are recorded on a film sensitive to the radiation or may be viewed on a fluorescent screen.

7.4.2.1 Radiography may be performed using X-rays generated from X-ray tubes, gamma rays emitted by radioactive isotopes or electron beams emitted by betatrons and linear accelerators.

7.4.2.2 Radiography may be employed for the inspection of welds of all types and thickness ranging from minute welds in electronic components to welds upto half metre thick employed in heavy fabrications. The maximum thickness of material (in terms of steel thickness) which can be inspected with various industrial X-ray generators are given in Table 2. In Table 3 are given the optimum range of thickness which may be tested with commonly used radioactive isotopes.

7.4.2.3 For material other than steel, the limits of thickness may be obtained by dividing those shown in Tables 2 and 3 by the radiographic equivalent factors given in Table 4.

7.4.2.4 Thickness above the range given in Tables 2 and 3 may be penetrated by electron beams emitted by betatron (25 Mev) upto 500 mm and by the electron beams emitted by Linear accelerator (12 Mev) upto 650 mm.

7.4.3 *Selection of Source* — Selection of source for radiography depends upon :

a) availability of sources,

b) thickness range to be examined,

c) shape of weldment and its accessibility,

d) availability of power supply, and

e) use of panoramic exposures.

TABLE 1 GUIDELINES FOR USE OF DIFFERENT METHODS OF NON-DESTRUCTIVE EXAMINATION OF WELDS

(*Clause* 7.4.1)

Sl No.	Method	Applications	Types of Faults Indicated	Advantages	Limitations
i)	Radiography				
	a) X-rays	Aircraft structures, structural steel work, ship building, pressure vessels and boilers, penstocks, electronic parts, etc	All types of internal flaws such as cracks, piping, porosity, inclusions, lack of fusion, incomplete penetration	a) Provides permanent record on film, b) Techniques standardised, c) Reference standards for defects available, d) Adjustable energy level gives high sensitivity, and e) Fluoroscopy techniques available.	a) Trained technicians needed, b) Radiation hazards, c) High cost of equipment, and d) Power source needed.
	b) Gamma rays	Pipework, penstocks, pressure vessels and boilers, structural steelwork, ship building, etc	All types of internal flaws such as cracks, piping, porosity, inclusions, lack of fusion, incomplete penetration	a) Provides permanent record on film, b) Techniques standardised, c) Reference standards for defects available, d) Low initial cost, e) Portable and independent of power supply (for site work), and f) Makes panoramic exposures (ideal for jobs like pipework).	a) Trained technicians needed, b) Radiation hazards, c) Fixed energy levels per source, d) Source loses strength continuously, and e) Generally lower sensitivity and defintion than X-rays.
ii)	Ultrasonics	All types of welded work in metallic and non-metallic materials	Internal defects such as cracks, porosity, inclusions, lack of fusion, incomplete penetration	a) Safe to use. No radiation hazards, b) Fast, results available immediately, c) Sensitive, d) Indicates presence of laminations and other planner defects missed by radiography, and e) Indicates depth of flaw also.	a) Entirely dependent on the interpretation skill of operator who requires much experience and training, b) Unsuited to the examination of weldments of complex shape or configuration (e.g. backing rings), c) Requires surface contact or immersion, and d) Surface must be ground smooth and clean.
iii)	Magnetic-particle	Welds (particularly fillet welds) in all ferro-magnetic materials	Cracks, porosity, inclusions and discontinuities at or close to the surface	a) Simple to use and interpret, b) Relatively inexpensive, and c) Portable.	a) Material must be ferro-magnetic, b) Demagnetisation may be needed, and c) Power source required.
iv)	Liquid-penetrant	All welds in ferrous and non-ferrous materials and in non-metallic materials	Surface defects only, such as surface cracks and blowholes	a) Simple to use and interpret, b) Relatively inexpensive, c) Portable, and requires no elaborate equipment, and d) Will work on all materials.	a) Will only detect surface defects on the accessible surface, b) Surfaces must be clean and dry, and c) Rust or paint will mask defects.
v)	Eddy-current	Welds in materials with good electrical conductivity.	Defects at or very close to the surface such as cracks, linear discontinuities.	a) Does not require contact with the surface.	a) Difficult to set and interpret, and b) Limited to materials with good electrical conductivity.

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TABLE 2 TYPE OF CONVENTIONAL INDUSTRIAL X-RAY GENERATORS AND THEIR APPLICATIONS

(*Clause* 7.4.2.2)

Peak Kilovoltage	Type of Screens	Maximum Thickness of Material that can be Inspected (Approx)
(1)	(2)	(3)
kV (Peak)		mm
50	—	Micro radiography, wood and plastics
100	—	50 (aluminium), 75 (magnesium)
150	None or lead foil	25 (steel or equivalent)
	Fluorescent	40 (steel or equivalent)
200	Lead foil	40 (steel or equivalent)
	Fluorescent	60 (steel or equivalent)
250	Lead foil	50 (steel or equivalent)
	Fluorescent	75 (steel or equivalent)
300	Lead foil	65 (steel or equivalent)
	Fluorescent	90 (steel or equivalent)
400	Lead foil	75 (steel or equivalent)
	Fluorescent	100 (steel or equivalent)
1 000	Lead foil	125 (steel or equivalent)
	Fluorescent	175 (steel or equivalent)
2 000	Lead foil	225 (steel or equivalent)

TABLE 3 APPLICATION OF ARTIFICIAL GAMMA RAY SOURCES

(*Clause* 7.4.2.2)

Sl No.	Element	Isotope	Half-Life	Energy of Main Gamma Ray Line	Optimum Thickness of Steel
(1)	(2)	(3)	(4)	(5)	(6)
				MeV	mm
i)	Thalium	Tm 170	130 days	0·084, 0·052	5-15
ii)	Iridium	Ir 192	75 days	0·31, 0·47, 0·60	5-20
iii)	Caesium	Cs 137	33 years	0·66	20-60
iv)	Cobalt	Co 60	5·3 years	1·33, 1·17	30-150
v)	Cerium	Ce 144	140 days	1·3	30-150

TABLE 4 APPROXIMATE RADIOGRAPHIC EQUIVALENCE FACTORS OF SEVERAL METALS

(*Clause* 7.4.2.3)

SL No.	METAL OR ALLOY	150 kVP	200 kVP	1 000 kVP	GAMMA RAYS
(1)	(2)	(3)	(4)	(5)	(6)
i)	Aluminium	0·12	0·13	—	—
ii)	Magnesium	—	—	—	—
iii)	24 ST Alloy	0·13	0·14	—	—
iv)	Steel	1·0	1·0	1·0	1·0
v)	18-8 Stainless Steel	1·0	1·0	—	—
vi)	Copper	1·5	1·4	—	—
vii)	Zinc	1·4	1·3	—	—
viii)	Brass*	1·4*	1·3*	1·2*	1·1*
ix)	Lead	14·0	12·0	5·0	2·3

*Tin or lead in the brass will increase these factors.

7.4.3.1 In general, X-ray sources will give more sensitive radiographs of higher contrast and better definition in a shorter time. Isotopes (gamma ray sources) are more advantageous for work at site, for pipework and where heavy thicknesses are to be inspected. Their initial cost is also lower.

7.4.3.2 The source selected for the radiography of a particular weld on the basis of the factors mentioned above shall be able to produce radiographs of the requisite quality (density and sensitivity).

7.4.4 *Indication of Defects on a Radiograph* — The indication of defects on the radiographs depends upon their nature and orientation with respect to the beam of radiation. Table 5 shows the types of faults in fusion welds and their radiographic images (*see* Part VI of IS : 812-1957*).

7.4.5 *Interpretation of Radiographs and Assessment of Defects* — Radiographs should be interpreted by viewing with adequate illumination in a darkened room. Before interpretation it should be ensured that the radiograph has adequate density and sensitivity as indicated by a suitable image quality indicator.

*Glossary of terms relating to welding and cutting of metals.

TABLE 5 RADIOGRAPHIC IMAGES OF DEFECTS IN FUSION WELDS

(*Clause* 7.5.3)

DEFECT	DESCRIPTION	IMAGE
Porosity	Gas pockets or voids	Rounded shadows of various sizes and densities, occurring singly, in clusters or scattered
Slag inclusions	Slag entrapped during welding	Elongated or irregularly shaped shadows
Lack of fusion	Lack of side fusion, root-fusion or inter-run fusion	A dark shadow usually elongated
Incomplete penetration	Unpenetrated cavities at the root or between runs	A linear indication straight, dark and usually at the centre of the weld
Cracks	Narrow discontinuity produced by tearing of the metal when in a plastic or cold condition	Fine dark line, straight or wandering
Capillary pipe	A fine pipe at the fusion face usually caused due to laminations in the parent material	A straight dark but rather diffuse shadow
Pipe (wormhole)	Elongated or tubular gas pocket	Elongated or very dark round shadow (*depending upon* the orientation of the pipe)

7.4.5.1 Correct interpretation of radiographs requires experience and should be done only by those inspectors who are properly trained and who possess adequate experience.

7.4.5.2 In the interpretation of radiograph and deciding the degree of faults, guidance may be derived from the reference radiographs published by International Institute of Welding. But these radiographs should not be used as acceptance standards.

7.4.6 *Ultrasonic Testing* — In ultrasonic testing a high frequency sound wave is propagated into the metal under test. Any discontinuity in the metal will result in the reflection of the wave thus indicating the presence of faults.

The initial signal and the reflected signals are usually indicated on a cathode-ray tube and appear as vertical indications (commonly called 'pips'). The equipment uses an electronic pulse generator to generate an electrical wave which is converted into a sound wave by using piezo-electric crystals mounted in the 'probes', which also pick up the reflected sound waves and convert it into electrical waves to be fed back into the cathode-ray tube.

Ultrasonic testing may be done with straight probes which generate a longitudinal wave perpendicular to the surface of contact, angle probes which give out shear waves at the specified angle or special surface wave probes.

Testing may be done using a single probe as transmitter and receiver or by a double-probe method with one probe functioning as the transmitter and the other receiving the echoes.

The method can be used successfully on welds in steel from about 10 mm in thickness to over 5 metres.

7.4.6.1 *Salient features of ultrasonic testing*:

a) *Indications* — In most of the equipment now in use, the wavy line on the screen has to be interpreted for the presence of echoes indicating discontinuities. It is necessary to scan the weld in different directions before the size and the location can be interpreted. Although new types of equipment are being developed to indicate the size of flaws, such refinements are in the development stage and at present the operator has to assess the indications in the form of 'pips' to determine the fault.

b) *Sensitivity* — Minute faults if oriented normal to the ultrasonic beam will give distinct 'pips' which could be mistaken for echoes from gross faults. Even a slight increase in the cross-section of the part under examination will register on the screen. Normal discontinuities such as grain boundaries or microporosity may generate such a degree of background 'noise' that a signal from a flaw is indistinct. This extreme sensitivity of the ultrasonic method to variations in the acoustic impedance is the chief cause of misinterpretation of readings.

c) *Operators* — In view of the difficulties in interpreting the indications on the screen and identifying the type and size of discontinuity, ultrasonic testing can only be done by experienced and highly skilled operators.

   The success of the method depends almost entirely upon the skill of the operator in making the correct settings, eliminating sources of spurious indications and in correctly interpreting the indications.

d) *Recording* — Usual types of ultrasonic testers do not have any methods of recording the results of the tests apart from photographing the screen, but such photographs only indicate the screen image at a particular setting but not the results of scanning. Other types of recording equipment are being developed, but most of these can only be used on fully automatic set-ups.

e) *Spurious Indications* — These may arise out of variations in acoustic impedance, grain boundaries, couplant, surface condition or electronic faults in the equipment. Use of test blocks can identify some of them, but it is dependent on the skill of the operator to detect and eliminate spurious indications.

7.4.6.2 *Interpretation and assessment* — In view of the features of the process enumerated in **7.4.6.1**, the interpretation and assessment of type, size of flaw and location should be left to the operator.

The Inspector will only be expected to assess the functional acceptability of the weldment based on the flaw detection report of the ultrasonic operator.

In case the indications of discontinuity by the ultrasonic testing method are doubted, it is preferable to corroborate this by using radiography. Where such an alternative is not possible, the area which is suspected to contain the defect should be again scanned at other positions and with other probes to confirm the presence of the defect.

7.4.7 *Magnetic Particle Flaw Detection* — Magnetic particle flaw detection is based on the principle that if a ferro-magnetic object is magnetised, the discontinuities in the material such as cracks and inclusions, lying at an angle to the magnetic lines of force, cause an abrupt change in the path of the magnetic flux flowing through the object. This results in local flux leakage at the surface over the discontinuity. If at this stage, fine particles of ferro-magnetic material, either dry or suspended in a liquid, are applied over the surface some of these particles will be attracted towards the leakage field and pile up and bridge the discontinuity setting up a magnetic pattern outlining the discontinuity.

7.4.7.1 *Methods* — The following methods of magnetization are available:

a) *Magnetic flow method* — The job (part to be tested) is placed between the poles of a permanent magnet or an electromagnet.

b) *Current flow method* — Longitudinal magnetization : Where the passage of electric current through a coil of several turns around the part to be tested produces a longitudinal magnetic field within it.

c) *Current flow method — circular magnetization* — Where the passage of electric current through the part or through a straight conductor enclosed by the part creates a circular magnetic field around it. Current is passed through the part by placing it between the machine contact plates of a current flow type testing machine, or by using prod type contacts to produce local circular magnetization.

7.4.7.2 The magnetic particles may be applied while the current is flowing (continuous method) or after the current has ceased to flow (residual method). The use of the latter depends upon the strength of the magnetising force and the capacity of the material to retain the magnetization.

The magnetic particles may either be applied in the form of dry powder (dry method) or as a suspension in a suitable liquid medium (wet method). The magnetic particles may be red or black to provide adequate contrast and should be visible under normal white light. For increased visibility when working with the wet method, the magnetic particles which are coated with a fluorescent dye are rendered visible by 'black light' (near ultraviolet light).

7.4.7.3 The following are the salient features of magnetic particle flaw detection:

a) *Indications* — Discontinuities are indicated by the pattern in which the magnetic powder is collected around the leakage fields. Fine elongated discontinuities which are parallel to the field are not indicated, and should be detected by using a field at right angles to them. Deep discontinuities are indicated by the 'piling up' of the magnetic powder at the lines of the flaws.

   Subsurface discontinuities show fuzzy or indistinct patterns which may easily remain undetected. Change of magnetic permeability, abrupt change of section and over magnetized welds may lead to false indications.

b) *Application* — The method may be applied only if both the weld metal and the parent metal are ferromagnetic. For satisfactory results, the surface should be clean, dry and reasonably smooth.

c) *Demagnetization* — For some applications it is necessary to demagnetize the weldment before the test. This may be done either by some form of heat treatment or by using an alternating current reducing the magnitude of the current gradually to zero.

d) *Recording of indications* — Defects may either be recorded by photography or by lifting off the pattern with transparent adhesive tape or a piece of adhesive coated tracing cloth.

7.4.7.4 *Interpretation and assessment* — Defects in the fusion welds generally indicated by magnetic particle flaw detection method, and the powder patterns formed are as follows:

Defects	*Powder Pattern*
Surface cracks	Sharp piled-up patterns
Subsurface cracks	Diffused powder patterns

Incomplete penetration	Diffused indication similar to that for subsurface cracks
Subsurface porosity and slag inclusions	Diffused indications
Incomplete fusion	Pronounced accumulation of powder along the edges of the weld

7.4.8 *Liquid Penetrant Flaw Detection* — In this method of testing a suitable liquid penetrant is applied to the surface of the portion under examination and remains there for a sufficient time to allow the liquid to penetrate into any defects open at the surface. After the penetrant time, the excess penetrant which remains on the surface is removed. Then a light coloured powder absorbent called the developer is applied to the surface. This developer acting as a blotter draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out, it diffuses into the coating of the developer, forming indication of the surface discontinuities of flaws (*see also* IS : 3658-1966*).

7.4.8.1 The following types of penetrants are used:

a) Thin oil when chalk powder is used as the developer;

b) Dye penetrants which form indications visible in the normal light; and

c) Fluorescent penetrants which make the defects visible in ultraviolet light.

7.4.8.2 The components under test may be dipped into the penetrant or, where only a local area of a component is to be tested, the penetrant may be applied by brush. It is necessary that the component to be tested is clean, free from all contaminants and dry.

7.4.8.3 After necessary penetration time, the surface film of the penetrant on the component is removed by appropriate means. Where the penetrant contains an emulsifier or where the penetrant is treated with an emulsifier after penetration, a water spray is used to remove the excess penetrant. Great care should be excercised to ensure that while the surface is clean, the penetrant from the defect is not removed.

7.4.8.4 On applying the developers the defects appear as amber coloured lines when the oil and chalk process is used, and as red (or the colour of the dye) when dye penetrant has been used. Where fluorescent penetrant is used the components should be inspected in a dark room under black light. Defects appear as bright green outlines against a dark purple background.

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*Code of practice for liquid penetrant flaw detection.

7.4.8.5 *Interpretation and assessment* — The indications generally take the shape of the discontinuity and its definition depends upon the depth and size of the defect.

Because of the inherent human factors involved in applying and removing penetrants, faulty indication, and when the cracks are choked with corrosion products, liquid penetrant method of flaw detection should be used with some caution.

7.4.9 *Eddy Current Testing* — This process depends upon eddy currents set up in the material under test when a suitable probe is brought close to the material.

The process is difficult to use and interpret, and is seldom used for weld testing. It has however the advantage of being able to detect fine cracks without touching the weldment. New types of this equipment are being developed to eliminate some of the difficulties in adjusting the equipment and reducing the spurious indications.

7.5 Leak Tests — For certain types of enclosed weldments such as in vessels, tanks, pipe lines, penstocks, etc, it is essential that the weld is leak-free under the working pressure. Leak tests are usually carried out at a pressure higher than the working pressure using some suitable liquid or gas.

7.5.1 While selecting the fluid for leak test, the end use of the component and the substance it has to store or carry should be kept in view. For example, use of a highly sensitive liquid of low viscosity may be more stringent than needed for containers of viscous liquids.

7.5.1.1 Water is very commonly used for leak tests because of its cheapness and moderate viscosity. But if the vessel or pipe has to carry a fluid of lower viscosity, the absence of leak at a certain test pressure with water does not indicate the absence of leak at the same pressure with the less viscous fluid. Leak tests with water are therefore normally carried out at pressures higher than the working pressures.

7.5.1.2 The oils which are to be contained in the vessel or pipe may themselves be used at an increased pressure. Leaks may be detected by coating the welds in the suspected zones with chalk or the developer used in liquid penetrant tests.

7.5.1.3 Liquid penetrants may also be used to detect leaks with or without the application of pressure. The liquid penetrant coated on one side of the weld may be examined for leakage by applying the developer on the other side of the weld.

7.5.1.4 Compressed air or other gases at pressure are sometimes used for leak tests. Leakage may be detected by the hissing noise of the escaping air or gas or by the drop in the pressure. Use of air or gas is not recommended since failure of the vessel or pipe may be disastrous.

7.5.1.5 Certain gases like ammonia and sulphur hexafluoride (stable gas) may be used even at normal working pressures since their presence even to the extent of a few parts per million can be detected using concentrated hydrochloric acids which forms white fumes with the gas.

7.5.2 *Assessment of Test* — In the majority of the cases any leakage would normally be treated as a rejection and would need the rectification (*see* **7.5.1**). It is advisable to tap with a light hammer approximately 1·5 kg in the vicinity of the weld during leak test, to dislodge the particles which may be blocking the path of leakage.

7.5.2.1 Before attempting the repair of a leakage it is necessary to examine the whole region of the leak to determine the cause for the leakage. Serious faults on the inside of welds are often detected by small leakages through a crevice of an otherwise sound outside weld.

7.5.2.2 Any weldment which is to be subjected to a leak test and on which a leak has been detected and repaired should always be retested to ensure that the repair has eliminated the leak and has not initiated other leakage paths.

7.5.2.3 Leak tests should always be done after the welding is complete, and should not be followed by other welding or repair work unless this is to be subsequently followed by a similar leak test.

7.6 Load Test, Proof Test and Overload Test

7.6.0 In view of the complexity of the stress pattern in welded components especially when residual stresses are locked in these tests give a practical and concrete appraisal of the correctness of design calculations. Proof stress causes local yielding to a certain extent and thus results in a degree of stress relief.

7.6.1 Proof tests, load tests and overload tests are carried out on weldments by applying a load greater than or equal to the design load, but not great enough to cause damage to acceptable products.

Load may be applied by pressure, weights, jacks, ropes, chains, filling with liquids, or in testing machines.

During testing, it may be adequate to inspect for local damage of the weldment and for permanent set or yielding, or it may be necessary to use strain gauges.

7.6.2 The overload and proof tests are usually carried out at 50 percent overload, that is, at pressures or loads 50 percent higher than that encountered in service. Alternatively these are done at 50 percent higher than the design load or minimum allowable pressure.

7.6.3 The following types of overload tests are performed:

a) Pressure tests for vessels, tanks and pipe lines;

b) Static overload tests for welded structural members and components;

c) Impact, knocking and hammer tests for completed weldments such as rolling stock;

d) Proof tests for welded chains, ropes, etc; and

e) Load and overload tests of small weldments on universal tensile testing machines or special purpose machines.

7.6.4 *Assessment* — During and after load, overload or proof tests some of the following would be determined:

a) Strain at important locations;

b) Local deformation or deflection under load;

c) Permanent set, yielding, etc, after the load is released;

d) Cracking or rupture of the welds;

e) Leakage (if leak tests are combined with these tests); and

f) Evidence of cold working, hardening or embrittlement of the weld zones.

The nature and permissible limits of the above factors would depend upon the requirements of the specifications applicable to the class of weldment and its end use.

8. EVALUATION OF WELD QUALITY

8.0 The purpose of inspection before, during and after fabrication by welding is to assess the quality and to exercise control over it. The weld and the weldment shall conform to the required standards of quality. The inspector should therefore be able to evaluate the quality of the welding and determine with a reasonable degree of certainty whether the weld or the weldment contains any faults which would render it unacceptable.

8.0.1 The process of evaluation of weld quality consists of the following steps:

a) Determining the standard of quality, the range of permissible defects, the finish and the dimensional tolerances required in the weld and the weldment.

b) Laying down specifications, where needed, for the procedures to be adopted to achieve the necessary quality.

c) Specifying the methods and the extent of testing required to assess the quality actually achieved in terms of the required quality.

d) Ensuring that adequate precautions have been observed in the process and sufficient tests have actually been carried out.

e) Interpreting the results of the tests and the inspection carried out and inferring from these results whether the required level of quality has been achieved in the welds and the weldment.

8.1 Required Quality

8.1.1 The requisite quality standards should be specified in the contract specifications either by reference to the provisions of one or more standard specifications or by mutual agreement between the' purchaser and the supplier.

8.1.2 The requisite quality is dependent upon the end use of the weldment. In assessing the required quality the following factors affecting the service condition of the weldment should be taken into account:

a) *Stress* — Maximum stress, nature of the stress whether static, dynamic, repeated or alternating.

b) *Pressure and temperature in service* — High pressure or vacuum, high temperature and creep-resistant applications or low temperature and cryogenic applications, fluctuations in pressure and temperature, non-uniformity of temperature distribution, etc.

c) *Effect of failure of a weld in service* — Risk to human life and property, possibility of explosive or catastrophic failure, possible loss of prestige and goodwill, probable financial compensation, other hazards such as radioactivity.

d) *Special properties required* — Ductility, resistance to corrosion, impermeability, electrical or magnetic properties, etc.

e) *Surface finish and appearance* — Smoothness, straightness, conformity to true geometric shape, significance of deviations from the appearance in terms of function and in relation to aesthetic values, etc.

f) *Expected life* — Useful life, permanence, obsollasence, expendiability etc.

g) *Customer satisfaction* — Goodwill, prestige, saleability, dependability, export worthiness, competitiveness, etc.

8.1.3 The required quality should be realistic in terms of the quality that can be achieved at reasonable expense. The specification of the best possible standard or a 'nil-defect' standard may be idealistic and commercially impractical for most applications. It may only be justifiable in exceptional applications where it is necessary to achieve defect free welds due to the disproportionate cost of other components whose satisfactory performance may be impaired by the presence of even minor defects in the weldment.

8.2 Quality Control

8.2.1 In order to ensure that the required quality will be achieved it is necessary to ensure that the welding technique adopted is capable of achieving the required quality consistently. The facilities, equipment, processes, consumables, operators, welding procedure should all be such that welds of the required quality are produced.

8.2.2 It is equally necessary to ascertain that due care has been taken during the process to ensure that the techniques and equipment have been used to the best advantage and that the procedures and precautions specified have been followed. No factor which might affect the quality adversely should be overlooked.

8.2.3 Carrying out adequate tests to detect faults after they occur is no substitute for taking steps to prevent faults. With good quality control before and during a process, a lesser, and therefore less expensive, degree of testing is required.

8.3 Testing

8.3.1 The list of tests normally applicable to the inspection of welds and weldments is given in **7**. For a particular application, the choice of the tests and the degree of assessment should be ascertained after a realistic appraisal of requirement, based on the following factors :

a) Required quality (*see* **8.1**) and the provisions in regard to testing in the contract specifications or other applicable standard specifications;
b) Extent of quality control (*see* **8.2**);
c) Types and degrees of defects that can be expected to occur, their probable frequency and location;
d) Significance of defects in relation to location and service conditions;
e) Facilities available for testing, and the ability of the available methods to detect the significant defects that can occur;
f) Degree of confidence required in the evaluation of the quality actually achieved; and
g) Cost of such testing.

8.3.2 The methods and extent of testing shall be chosen judiciously, and should normally be laid down clearly prior to the commencement of fabrication. This has the advantage of exerting a cautionary influence on the manufacturer and his operators and will result in better quality being aimed at and achieved. Excessive testing will however have a negative effect since quality control measures may be neglected owing to the misplaced confidence that any defects would be detected during subsequent testing and would not pass unnoticed.

8.3.3 Visual inspection being a vital part of the testing, and should be first to be carried out and the results be given due weightage.

8.3.4 It shall be ensured that the required tests are being carried out correctly and honestly and that their results are being recorded clearly and comprehensively.

8.4 Interpretation of Tests and Evaluation of Weld Quality

8.4.1 *Compilation of Test Records* — The records of the various test results and inspection procedures adopted on the weldment should be collected and arranged so that they may be correlated and related to the specific portions of the weldment.

8.4.2 *Interpretation of Test Results* — Indications shown by the various test methods should be interpreted in terms of weld defects, their sizes and extents. Due attention should be paid to the particular features of each method of testing, especially in regard to its sensitivity or insensitivity in detecting specific types of defects.

8.4.3 *Evaluation of Weld Quality* — The evaluation of the quality of the weld depends upon the interpretation of the results of the various tests carried out, and upon the skill of the inspector in assessing the results of the interpretation.

8.4.3.1 Weld quality achieved should always be related to the required quality (*see* **8.1**) and shall be evaluated as superior to the requirement if the weld is to be accepted. Where defects occur they should be assessed either as acceptable or unacceptable.

8.5 Repairs

8.5.1 Wherever the weld defects are evaluated to be beyond the acceptability limits for the particular weld, it is necessary either to repair the defective portion or to reject the weld, according to the nature of the defects and the weldment.

8.5.2 Where repairs are to be carried out, the proposed method of rectification shall be approved prior to commencement of the repair. For critical applications it may be necessary to perform a test on a separate test piece to demonstrate that the proposed rectification procedure is capable of giving acceptable results.

8.5.3 It is essential that the area to be repaired is inspected after the defect has been cut out or otherwise removed. In order to ensure that the defect has been completely removed, and the weld preparation thus formed is conducive to a defect-free repair.

8.5.4 All repairs shall be carried out by qualified welders. They should normally be done by adopting same process and using the same consumables as for the original weld. A deviation may be permitted if the adequate quality is ensured.

8.5.5 The repaired weld should be subjected to adequate tests to evaluate its quality. The repaired portion should be subjected to as many of the tests made on the original welds as considered reasonable. In general, all the non-destructive tests carried out on the original weld should be repeated on the repaired weld.

8.5.6 After evaluation of the quality of the repaired portion, the overall quality of the weldment should be assessed and used as the basis of acceptance of the weldment.

9. ACCEPTANCE

9.1 Acceptance of the finished weldment will be the culmination of the entire process of inspection before, during and after fabrication and of the evaluation of the quality of the weldment in terms of the required quality.

9.2 Such acceptance should be final and unambiguous and should imply that the weldment is of the required quality as far as it was possible to assess on the basis of the inspection carried out.

9.3 Acceptance should in general be documented by the issue of a suitable certificate of acceptance. Where necessary suitable permanent markings such as the inspector's personal hardstamp may be used to indicate acceptance of the specific weldment. Similar steps would be required also in the event of the weldment being totally rejected, where in addition to a document indicating rejection and the reasons for rejection, permanent identification of rejected weldments should be made.

9.4 Whereas the inspection report would contain full details of the inspection carried out, and the findings at each stage of inspection, acceptance certificates will generally not contain such details, but will be confined to certifying that after carrying out the inspection in all respects, the weldment has been found to be of acceptable quality.

APPENDIX A

(*Clause* 0.3)

LIST OF INDIAN STANDARD SPECIFICATIONS AND CODES OF PRACTICE RELEVANT TO THE INSPECTION OF WELDING

A-1. Standards listed below pertain to or may require to be consulted in connection with the inspection of welding. This list is only indicative and does not cover very unusual applications.

a) Materials

1) *Rolled Steel*

IS : 226-1969 Structural steel (standard quality) (*fourth revision*)

IS : 808-1964 Rolled steel beam, channel and angle sections (*revised*)

IS : 961-1962 Structural steel (high tensile) (*revised*)

IS : 1079-1968 Hot rolled carbon steel sheet and strip (*second revision*)

IS : 1173-1967 Hot rolled and slit steel, tee bars (*first revision*)

IS : 1252-1958 Rolled steel sections bulb angles

IS : 1730-1961 Dimensions for steel plate, sheet and strip for structural and general engineering purposes

*IS : 1731-1961 Dimensions for steel flats and for structural and general engineering purposes

*IS : 1732-1961 Dimension for round and square steel bars for structural and general engineering purposes

IS : 1762-1961 Code for designation of steel

IS : 1852-1967 Rolling and cutting tolerances for hot-rolled steel products

IS : 1863-1961 Dimensions for rolled steel bulb plates

IS : 1977-1969 Structural steel (ordinary quality)

IS : 2002-1962 Steel plates for boilers

IS : 2049-1963 Colour code for the identification of wrought steels for general engineering purposes

IS : 2062-1969 Structural steel (fusion welding quality) (*first revision*)

IS : 3039-1965 Structural steel (shipbuilding quality)

IS : 3503-1966 Steel for marine boilers, pressure vessels and welded machinery structures

IS : 3747-1966 Steel for flanging and pressing

*Since revised.

2) *Steel Castings*

IS : 2856-1964 Carbon steel castings suitable for high temperature service (fusion welding quality)

3) *Other Metals*

IS : 737-1965 Wrought aluminium and aluminium alloys, sheet and strip (for general engineering purposes) (*revised*)

IS : 1550-1967 Copper sheet and strip for the manufacture of utensils and for the general purposes (*first revision*)

4) *Tubes*

IS : 1161-1968 Steel tubes for structural purpose (*second revision*)

IS : 1239 (Part I)-1968 Mild steel tubes, tubulars and other wrought steel fittings: Part I Mild steel tubes (*second revision*)

IS : 1914-1961 Carbon steel boiler tubes and superheater tubes

IS : 3589-1966 Electrically welded steel pipes for water, gas and sewage (200 to 2 000 mm nominal diameters)

IS : 3601-1966 Steel tubes for mechanical and general engineering purposes

IS : 4310-1967 Weldable steel pipe fittings for marine purposes

IS : 4922-1968 Seamless, steel tubes (suitable for weldings) for aircraft purposes

b) Electrodes and Consumables

1) *Welding Rods and Electrodes*

IS : 814-1970 Covered electrodes for metal arc welding of structural steel (*third revision*)

IS : 815-1966 Classification and coding of covered electrodes for metal arc welding of mild steel and low alloy high tensile steel (*revised*)

IS : 1278-1967 Filler rods and wires for gas welding (*first revision*)

IS : 1395-1964 Molybdenum and chromium molybdenum low alloy steel electrodes for metal-arc welding (*revised*)

IS : 2680-1964 Filler rods and wires for inert gas tungsten arc welding

IS : 2879-1967 Mild steel for metal arc welding electrode core wire (*first revision*)

IS : 4972-1968 Resistance spot-welding electrodes

IS : 5206-1969 Corrosion-resisting chromium and chromium-nickel steel covered electrodes for manual metal arc welding

IS : 5511-1969 Covered electrodes for manual metal arc welding of cast iron

2) *Automatic Arc Welding Wire and Flux*

IS : 3613-1966 Acceptance tests for wire flux combination for submerged arc welding

3) *Gas Welding*

IS : 5760-1969 Compressed argon

c) Welding Equipment and Accessories

1) *Arc Welding*

IS : 1851-1966 Single operator type arc welding transformers (*first revision*)

IS : 2635-1966 dc electric welding generators (*revised*)

IS : 2641-1964 Electrical welding accessories

IS : 4559-1968 Single operator rectifier type dc arc welder

2) *Resistance Welding*

IS : 4804 (Part I)-1968 Resistance welding equipment: Part I Single-phase transformers

IS : 4804 (Part II)-1968 Resistance welding equipment: Part II Single-phase rocker arm spot welding machines

IS : 4804 (Part III)-1969 Resistance welding equipment: Part III Single-phase spot and projection welding machines

d) Terminology and Symbols

1) *Terminology*

IS : 812-1957 Glossary of terms relating to welding and cutting of metals

IS : 813-1961 Scheme of symbols for welding (*amended*)

e) Training and Testing of Welders

1) IS : 817-1966 Code of practice for training and testing of metal arc welders (*revised*)

2) IS : 1181-1967 Qualifying test for metal-arc welders (engaged in welding structures other than pipes) (*first revision*)

f) Codes of Procedure

IS : 819-1957 Code of practice for resistance spot welding for light assemblies in mild steel

IS : 823-1964 Code of procedure for manual metal arc welding of mild steel

IS : 2811-1964 Recommendations for manual tungsten inert-gas arc-welding of stainless steel

IS : 4944-1968 Code of procedure for welding at low ambient temperatures

g) Mechanical Testing

1) *Tensile Testing*

IS : 1521-1960 Method for tensile testing of steel wire

IS : 1608-1960 Method for tensile testing of steel products other than sheet, strip, wire and tube

IS : 1663 (Part I)-1960 Method for tensile testing of steel sheet and strip: Part I Steel sheet and strip of thickness 0·5 mm to 3 mm

IS : 1663 (Part II)-1962 Method for tensile testing of steel sheet and strip: Part II Steel sheet and strip of thickness above 3 mm

IS : 1894-1962 Method for tensile testing of steel tubes

2) *Impact Test*

IS : 1499-1959 Method for charpy impact test (U-notch) for steel

IS : 1598-1960 Method for izod impact test for steel

3) *Bend Test*

IS : 1403-1959 Method for reverse bend test for steel sheet and strip less than 3 mm thick

IS : 1599-1960 Method for bend test for steel products other than sheet, strip, wire and tube

IS : 2329-1963 Method for bend test on steel tubes

4) *Hardness Test*

*IS : 1500-1959 Method for Brinell hardness test for steel

*IS : 1501-1959 Method for Vickers hardness test for steel

*IS : 1586-1960 Methods for Rockwell hardness test (B and scales) for steel

*Since revised.

IS : 5072-1969 Method for Rockwell superficial hardness test (N and T scale) for steel

h) Non-Destructive Testing

1) *Radiography*

IS : 1182-1967 Recommended practice for radiographic examination of fusion welded butt joints to steel plates (*first revision*)

IS : 2478-1963 Glossary of terms relating to industrial radiology

IS : 2595-1963 Code of practice for radiographic testing

IS : 2598-1966 Safety code for industrial radiographic practice

IS : 3657-1966 Radiographic image quality indicators

2) *Ultrasonics*

IS : 2417-1963 Glossary of terms relating to ultrasonic testing

IS : 3664-1966 Code of practice for ultrasonic testing by pulse echo method (direct contact)

IS : 4225-1967 Recommended practice for ultrasonic testing of steel plates

IS : 4260-1967 Recommended practice for ultrasonic testing of welds in ferritic steel

3) *Magnetic Particle Flaw Detection*

IS : 3415-1966 Glossary of terms used in magnetic particle flaw detection

IS : 3703-1966 Code of practice for magnetic particle flaw detection

IS : 3658-1966 Code of practice for liquid penetrant flaw detection

4) *Testing of Welds*

IS : 3600-1966 Code of procedure for testing of fusion welded joints and weld metal in steel

j) Applications: Use and Design

1) *Structural Steel Work*

IS : 800-1962 Code of practice for use of structural steel in general building construction (*revised*)

IS : 803-1962 Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks

IS : 805-1968 Code of practice for use of steel in gravity water tanks

IS : 1024-1968 Code of practice for use of welding in bridges and structures subject to dynamic loading

IS : 2751-1966 Code of practice for welding of mild steel bars used for reinforced concrete construction

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