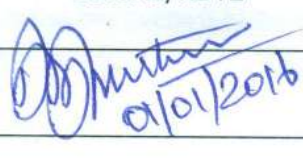
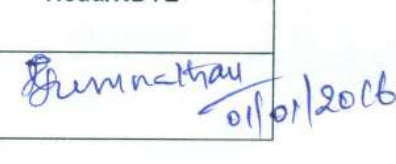


PROCEDURE FOR MAGNETIC PARTICLE EXAMINATION OF WELDS
 IN BOILER COMPONENTS, PRESSURE VESSELS AND HEAT EXCHANGERS

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RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
05	01-01-1993	Revised to include the requirements of ASME Section VIII, Div 1 Testing by Longitudinal Magnetization method included. Clause 2.0, 3.2, 3.3, 4.5, 5.6 and 10.5 included.
06	28-03-1994	Revised to include ASME Section VIII, Div 2.
07	01-08-1996	Revised in entirety.
08	27-07-1998	Fluorescent Examination method and requirements of Structural as per AWS D 1.1 included. Clauses 2.0, 4.5, 6.1.2.1 and 14.0 modified. 17.3 and 17.4 renumbered as 18.2 and 18.3 respectively. Annexure I added
09	20-03-2000	Clause 14.0 added and rest of the clauses renumbered. 15.1 modified. A4 added.
10	28-12-2002	15.1.1 Revised. 19.4.4 Added. Annexure A incorporated in main text, revised and renumbered
11	21-01-2004	14.0 Deleted
12	27-12-2007	Clause 2.0 , 9.2.2, 18.3, 18.4.2, 18.4.3 Revised Clause 26.1 Modified
13	02-05-2009	Clause 2.0, 4.1, 7.1, 13.1.2, 14.1.1 and 14.2.1 revised
14	30-12-2010	Clause 2.0, 16.0, 19.0 revised Table 1 and 2 added.
15	15-12-2011	Clause 2.0 revised Fig 5.0 added
16	08-03-2014	Clauses 7.2 and 7.3 added
17	30-01-2015	Clauses 12.0, 23.4, 23.5 and 23.6 modified. Figure 6 added.
18	01-01-2016	Clause- 2.0, 14.1.1 revised. SI.7, column 4 of Table- 2 revised.

1.0 SCOPE

- 1.1. This procedure describes the method, techniques and acceptance standards for Magnetic Particle Examination of Butt welds, fillet welds, partial penetration welds, Full penetration butt and corner welds , Nozzles, branch and piping connections attached to full penetration butt weld joints for Boiler components, pressure vessels, heat exchangers and power piping. This procedure shall be used for Prod (HWDC)-Visible dry particle examination on ferritic steel products.
- 1.2. Extent of examination: All the external, accessible internal weld surfaces and adjacent base material at least 15 mm on each side of the weld shall be subjected to 100% surface examinations.

2.0 REFERENCE

- a) ASME SECTION V / I / VIII (Division 1 & 2) / 2015
- b) ASME B 31.1 / 2014
- c) AWS D 1.1 / D1.1M:2010

3.0 EQUIPMENT

- 3.1. Equipment generating half wave rectified direct current employing prods at the end of magnetizing cables shall be used for examination.

4.0 EXAMINATION MEDIUM

- 4.1. The finely divided ferromagnetic dry visible (non-fluorescent pigments) particles shall be used as examination medium. The particle size used for dry shall be average 100 microns (specified by the supplier of the particles).
- 4.2. Dry magnetic particles Brick red in color (Table 1) shall be used as the examination medium for examination of welds and other product forms to provide adequate contrast with the surface being examined. The surface temperature of the part examined with dry particles shall be within the range of 17°C to 345°C (within maximum temperature specified by the supplier of the particles).

5.0 SURFACE CONDITIONING

- 5.1. Preparation
 - 5.1.1 As welded, as ground, as rolled, as cast or as forged surface is generally acceptable provided the surface irregularities will not mask the indications due to discontinuities. Otherwise surface preparation by grinding or machining may be necessary. Undercuts, overlaps or abrupt ridges and valleys in the welds and openings shall be smoothly merged with the parent metal.
 - 5.1.2 Prior to magnetic particle examination, the surface to be examined and adjacent area within at least 25 mm of the area of interest shall be dry and free of any dirt, grease, lint, scale, welding flux, spatter, oil or other extraneous matter that would interfere with the examination.
 - 5.1.3 Cleaning may be accomplished by detergents, organic solvents cleaner methods.
 - 5.1.4 Non-Magnetic coating shall not be present/permitted on the surface to be examined.

- 5.1.5 The color of the magnetic particle selected shall be sufficiently different than the color of the examination surface to give a good contrast for evaluation. Non-magnetic surface contrasts may be applied by the examiner to uncoated surfaces, only in amounts sufficient to enhance particle contrast. When nonmagnetic surface contrast enhancement is used, it shall be demonstrated that indications can be detected through the enhancement. Thickness measurement of this nonmagnetic surface contrast enhancement is not required.

6.0 METHOD OF EXAMINATION

- 6.1. Examination shall be made by continuous method.
- 6.2. Dry continuous magnetization method
- 6.2.1 The magnetizing current remains on while the examination medium (Brick red Dry particle) is being applied and while the excess of the examination medium is being removed.

7.0 TECHNIQUES

- 7.1. Prod Technique shall be used as magnetization technique.
- 7.2. Magnetizing Procedure: Magnetization is accomplished by portable prod type electrical contacts pressed against the surface in the area to be examined. To avoid arcing, a remote control switch, which is built into the prod handles, shall be used to permit the current to be applied after the prods have been properly positioned.
- 7.3. For inspection of components of Gr 91 material including Gr C12A, prod technique shall not be used. This shall be inspected by Yoke technique using Dry method based on suitable approved procedure.

8.0 TYPE OF CURRENT FOR MAGNETISATION

- 8.1. Single phase half-wave rectified Direct Current shall be employed for testing with prod techniques.
- 8.2. The amperage required with single-phase Half-wave rectified direct current shall be verified by measuring the average current during the conducting half cycle only.

9.0 CALIBRATION

- 9.1. Ammeter of magnetizing equipment shall be calibrated at least once in a year, or whenever the equipment has been subjected to major electrical repair, periodic overhaul or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use. The ammeter shall be calibrated through Instrumentation section of Maintenance and Services Department.

10.0 EXAMINATION

- 10.1. Direction of Magnetization
- 10.1.1 At least two separate examination shall be performed on each area. During the second examination the prods are spaced so that the lines of magnetic flux are approximately perpendicular to those used during the first examination. Examination shall be made by continuous method.
- 10.2. Examination Coverage

10.2.1 Examination shall be made with sufficient field overlap to assure 100% coverage of testing.

11.0 PROD TECHNIQUE: (Fig.1, 2 &3)

11.1. Magnetizing Procedure

11.1.1 The prod electrodes are pressed firmly against the surface in the area to be examined. In order to avoid arcing a remote control switch shall be built into the prod handles, to permit the current to be turned on after the prods have been properly positioned and to be turned off before they are removed.

11.2. Magnetizing Current

11.2.1 The current shall be 4 (minimum) amperes /mm to 5 (maximum) amperes/mm of prod spacing for sections 19 mm thick or greater.

11.2.2 For sections less than 19 mm thick, the current shall be 3.6 (minimum) amperes /mm to 4.4 (maximum) amperes/mm of prod spacing.

11.3. Prod Spacing

11.3.1 Prod spacing shall not be less than 85 mm nor exceed a maximum of 190 mm.

11.3.2 The prod tips shall be kept clean and dressed and the contact areas of the test surface shall be free from dirt, scale, oil etc. to minimize electrical arcing. If the open circuit voltage of the magnetizing current is greater than 25 Volts, Lead, Steel or Aluminum rather than copper tipped prods shall be preferred to avoid copper deposits on the part being examined.

12.0 YOKE TECHNIQUE

12.1. This technique is primarily intended to cover the region between the poles. The pole spacing shall be between 100 mm to 150 mm. In order to ensure that the region of interest gets 100 % coverage, every region (or segment of the test area, divided according to the pole spacing), shall be tested twice such that the pole space displacements are mutually perpendicular in the former and later cases. For example, in the case of the weld, the pole space orientation can be 45 Deg. and 135 Deg. Respectively with respect to the weld center line orientation, in the first and second attempts.

12.2. A Pie shaped magnetic particle field indicator shown in Figure 5 shall be used to check the adequacy as well as direction of the field. It shall be positioned on the surface to be examined, such that the copper-plated side is away from the inspected surface. A suitable field strength is indicated when a clearly defined line (or lines) of magnetic particles form(s) across the copper face of the indicator when the magnetic particles are applied simultaneously with the magnetizing force. When a clearly defined line of particles is not formed, the magnetizing technique shall be changed as needed.

13.0 APPLICATION OF MPI PARTICLES

13.1. DRY PARTICLES

The dry particles shall be applied in such a manner that a light uniform dust-like coating settles on the surface of the area being examined. The application technique shall be such that the particles are suspended

in air and reaches the examination surface in a uniform cloud with a minimum force, using hand powder applicators (squeeze bulb) or specially designed mechanical blower or by a spray nozzle.

13.1.1 Dry particles shall not be applied to a wet surface nor when there is excessive wind. The particles shall not be applied by pouring, throwing, or spreading with fingers.

13.1.2 Any excess powder shall be removed while the magnetization current is on and shall be with a gentle air stream by a blower or squeeze bulb without removing or disturbing particles attracted by a leakage field that may prove to be a relevant indication.

13.2. WET PARTICLES

13.2.1 The application of wet particles involves the bathing of the area to be examined, by spraying or flowing during the application of magnetizing current.

13.2.2 Two or more shots shall be applied, but the last shot shall be applied while the bath still remains on the area to be examined and after the particle flow has been stopped. Care shall be taken to cut off the bath application before removing the magnetic field, to prevent high-velocity particle flow that may wash away or remove fine or weakly held indications.

14.0 LIGHTING

14.1. Visible Light Intensity

14.1.1 A minimum light intensity of 100 foot candle (1000 lux) is required to ensure adequate sensitivity during the examination and *evaluation* of indications. "A Hand lamp with 240 Volts, 09 Watt LED Electric bulb white light is held at 300 mm distance normal to the test surface within a circle of 280mm diameter" is considered adequate to provide above level of illumination. The supplemental white light source, technique used, and light level verification shall be demonstrated one time, documented, and maintained on file.

14.1.2 Lux meter shall be calibrated at least once a year or whenever the meter has been repaired. If meter has not been used for one year it shall be calibrated before use.

15.0 SYSTEM PERFORMANCE CHECK (Fig.4 & 4a)

15.1. For prod magnetization with HWDC, performance sensitivity shall be checked at least once in a shift before start of the examination on a test plate that contains machined grooves to different depths. The indication of a groove at 3 mm depth from the surface of the test plate will indicate adequate sensitivity.

16.0 DEMAGNETISATION

16.1. When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

17.0 EVALUATION OF INDICATION

17.1. Mechanical discontinuity at the surface would be indicated by the retention of the powder or medium.

17.1.1 All the indications are not necessarily defects, however, since certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant.

- Relevant indications are those which result from unacceptable mechanical discontinuities.
- 17.2. Relevant indications are indications which result from imperfections. Relevant indications are caused by a condition or type of discontinuities that requires evaluation.
- 17.2.1 Linear indications are those indications in which the length is greater than three times the width.
- 17.2.2 Rounded indications are circular or elliptical with the length equal to or less than three times the width.
- 18.0 ACCEPTANCE STANDARDS AS PER ASME (Sec. I, VIII Div. 1 & 2)**
- 18.1. Welds and Materials
- 18.2. An indication of an imperfection may be larger than the imperfection that causes it. However, the size of the indication is the basis for acceptance for evaluation.
- 18.3. Only indications which have dimensions greater than 1.5 mm shall be considered relevant.
- 18.4. All surfaces to be examined shall be free of
- 18.4.1 Relevant linear indications.
- 18.4.2 Relevant rounded indications greater than 5.0 mm
- 18.4.3 Four or more relevant rounded indications in a line separated by 1.5 mm or less edge to edge.
- 18.4.4 In welds joining nipples to drums, spheres or headers, all slag or porosity indications shall be investigated to assure that no leak-path exists.
- 18.4.5 In attachment welds of non-load carrying class, indications from cracks or due to material separation are unacceptable.
- 19.0 For Power Piping (as per ASME B 31.1 Power Piping)**
- 19.1. Indications whose major dimensions are greater than 2.0 mm shall be considered relevant.
- 19.2. The following relevant indications are unacceptable:
- a) Any cracks or linear indications.
 - b) Rounded indications with dimensions greater than 5.0 mm.
 - c) Four or more rounded indications in a line separated by 2.0 mm or less edge to edge.
 - d) Ten or more rounded indications in any 3870 mm² of surface with the major dimension of this area not to exceed 150 mm with the area taken in the most unfavourable location relative to the indications being evaluated.
- 20.0 ACCEPTANCE STANDARD FOR STRUCTURAL COMPONENTS AS PER AWS**

- 20.1. The magnetic Particle acceptance criteria is based on the size of the actual discontinuity and not the size of the discontinuity as indicated by the magnetic particle inspection medium. Where discontinuity cannot be visually seen (with magnification if required), after removal of the indicating medium, evaluation shall be based on size and nature of the magnetic particle indication.

21.0 Statically loaded Non-tubular connections

- 21.1. Cracks, Lack of Fusion, and Incomplete Penetration are not acceptable.
- 21.2. Undercut - for material with thickness less than 25 mm, undercut shall not exceed 1.0 mm, except that a maximum 2.0 mm is permitted for an accumulated length of 50 mm in any 300 mm. For material equal to or greater than 25.0 mm thick, undercut shall not exceed 2.0 mm for any length of weld.
- 21.3. Porosity - a complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1.0 mm or greater in diameter shall not exceed 10.0 mm in any linear 25.0 mm of weld and shall not exceed 20mm in any 300 mm length of weld.

22.0 Cyclically Loaded Non-tubular Connections

- 22.1. Undercut - In primary members, undercut shall be no more than 0.25 mm deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall not be more than 1.0 mm deep for all other cases.
- 22.2. Porosity - The frequency of piping porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.5 mm. Exception: for fillet connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 10mm in any linear 25mm of weld and shall not exceed 20 mm in 300 mm length of weld.
- 22.3. Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have NO Piping Porosity.
- 22.4. PIPING POROSITY - (General) is elongated porosity whose major dimension lies in a direction approximately normal to the weld surface. Frequently referred to as pin holes when the porosity extends to the weld surface.

23.0 EDGE DISCONTINUITIES IN CUT MATERIALS

- 23.1. No crack is acceptable.
- 23.2. Mill induced discontinuity
- 23.3. Length 25 mm and less - acceptable.
- 23.4. Length over 25 mm and depth up to 3 mm – acceptable. Here the depth shall be explored for 10 % of the discontinuities on the cut surface by grinding.
- 23.5. Length over 25 mm and depth between 3 mm and 6 mm - indications shall be removed, but filling up of this region by welding is not required.

 235-029	BHARAT HEAVY ELECTRICALS LIMITED DEPT.235 – TIRUCHIRAPALLI – 620 014 Non-Destructive Testing	BHE:NDT:PB:MT-01 Revision 18 Page 9 of 15
23.6. 23.6.1 23.6.2 23.6.3 23.6.4	Length over 25 mm and depth greater than 6 mm and less than 25 mm- indications shall be removed and re-welded. The method explained in 23.6(1) through (4) shall be followed for disposition. Where discontinuities such as W, X or Y in figure 6 are observed prior to completing the joint, the size and shape of the discontinuity shall be determined by UT. The area of the discontinuity shall be determined by the area of total loss of back wall reflection. When tested in conformance with ASTM A 435. For acceptance of W,X or Y discontinuities, the area of discontinuity(or aggregate area of multiple discontinuities) shall not exceed 4% of the cut material area(length times width) with the following exception: if the length of the discontinuity of aggregate width of discontinuities on any transvers section , as measured perpendicular to the cut material length, exceeds 20% of the cut material width, the 4% cut material area shall be reduced by the % amount of the width exceeding 20%. (For example, if a discontinuity is 30% of the cut material width, the area of discontinuity cannot exceed 3.6% of the cut material area). The discontinuity of the cut surface of the cut material shall be removed to a depth of 25 mm beyond its intersection with the surface by chipping, gouging or grinding, and blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers. Repair shall not be required if a discontinuity Z, not exceeding the allowable area in 23.6(2), is discovered after the joint has been completed and is determined to be 25 mm or more away from the face of the weld, as measured on the cut base-metal surface. If the discontinuity is less than 25 mm away from the face of the weld, it shall be removed to a distance of 25 mm from the fusion zone of the weld by chipping, gouging or grinding. It shall then be blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers. If the area of discontinuity W,X,Y or Z exceeds the allowable in 23.6(2), the cut material and the subcomponent shall be rejected and replaced.	
24.0	REPAIR AND RE-EXAMINATION	
24.1. 24.2. 24.3. 24.4.	Whenever an imperfection is repaired by chipping or grinding or and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. After a defect is thought to have been removed and prior to making weld repairs, the area will be examined by suitable methods to ensure that the defect has been removed or reduced to an acceptable size of an imperfection. Where welding is required after repair of an imperfection the area shall be cleaned and repair carried out. After repairs have been made the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. After repairs have been made, the repaired area shall be re-examined by methods of examination that were originally required for the affected area.	
25.0	PERSONNEL QUALIFICATIONS	
25.1.	All personnel carrying out the examination and evaluation shall be qualified to as per BHE: NDT: G: CRT. The testing shall be done by minimum Level-I and Evaluation by Level II / III Personnel.	

26.0 POST EXAMINATION CLEANING

- 26.1. When the inspection is concluded, the magnetic particles shall be removed from the surface by using dry white cloth/cotton waste or any suitable means without adversely affect the part, leaving the product in a dry and clean condition.

27.0 REPORTING AND RETENTION PERIOD

- 27.1. The report shall include as a minimum, the data as specified in T-190(a) of Article-1, T 792 & T-793 of ASME Section V Article 7. Then report shall be reviewed and signed by NDT Level II / III and issued. All the reports will be retained for a period of 1 year or Final Inspection clearance whichever is later and reports for ASME Coded works for a period of 5 years.

Table 1
MAGNETIC PARTICLES USED

Manufacturer	Brand	Method	Color
Pradeep NDT Products-Pune	Automag RD-7	Dry	Brick Red

Table 2
DEMONSTRATION RECORD FOR ESSENTIAL AND NON-ESSENTIAL VARIABLES

Sl. No	Requirement	Type of variable	Covered in the procedure as
01	Magnetizing technique	Essential	Clause 7.1-Prod- Dry particle method
02	Magnetizing current type or as previously qualified	Essential	Clause 8.1-Single phase HWDC
03	Surface preparation	Essential	Clause 5.1-As welded, as ground surface -Free from oil, grease etc.
04	Magnetic particle(Fluorescent/ visible, Color, size, wet / dry)	Essential	Clause 4.2 -Visible Dry-Brick Red
05	Method of particle application	Essential	Clause 12.1:Hand Powder applicators- Squeeze bulb
06	Method of excess particle removal	Essential	Clause 12.1.2-Gentle air stream while the current is on.
07	Minimum light intensity	Essential	Clause 13.1.1-1000 lux Source: A hand lamp with <u>240 V/ 09 W LED</u> bulb <u>white light</u> kept at a maximum distance of <u>300 mm</u> .
08	Coating thickness greater than qualified	Essential	Not used
09	Non-magnetic surface contrast enhancement when utilized	Essential	Not used
10	Performance demonstration, if required	Essential	Clause 20.0: A change of requirement in Table-3 identified as essential variable from the specified value, or range of values, Procedure shall be re-qualified by satisfactory demonstration to the AI.
11	Part Surface temp. outside of the temp range recommended by the supplier of the powder or as previously qualified	Essential	Clause 4.2-Maximum 345°C for Dry method (within recommended range by M/s Pradeep NDT Products, Pune)
12	Shape / size of object	Non-Essential	Clause 1.1:Butt and fillet welds in Steam Generator, piping, pumps, valves, Pressure Vessel and Heat Exchanger components used for Nuclear applications

13	Equipment of same type	Non-Essential	Clause 3.0- Prod type
14	Temperature (within those specified by manufacturer or as previously qualified)	Non-Essential	Clause 4.2: 17° C to 345° C for Dry method (within recommended range by M/s. Pradeep NDT Products, Pune)
15	Demagnetizing technique	Non-Essential	Clause 15.1- No demagnetization unless otherwise specified
16	Post examination cleaning technique	Non-Essential	Clause 20.0
17	Personnel qualification requirement	Non-Essential	Clause 19.0

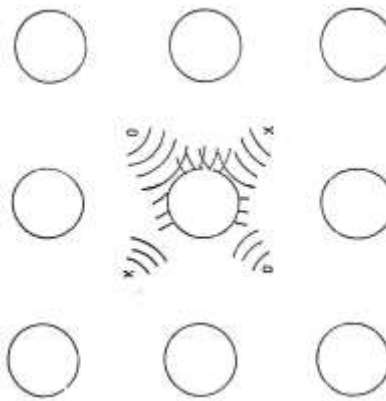
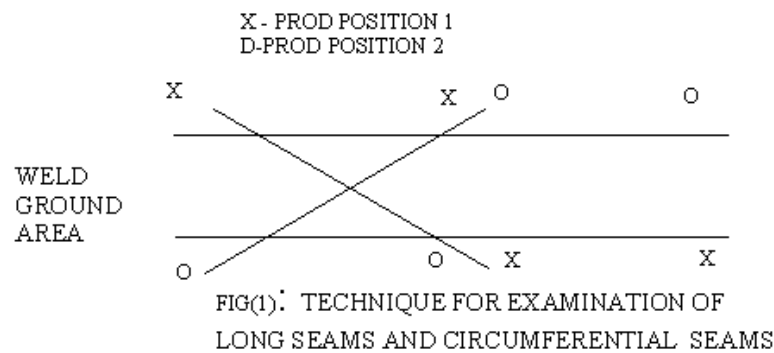


FIG (2): TECHNIQUES FOR EXAMINATION OF FILLET WELDS

O – POSITION 1 X – POSITION 2 ARC BREAK LOCATION

NOTE:

- 1) Prods must be placed on Drum / Header perpendicular to plate Surface.
- 2) Inspection will be 100% of weld for each shot.

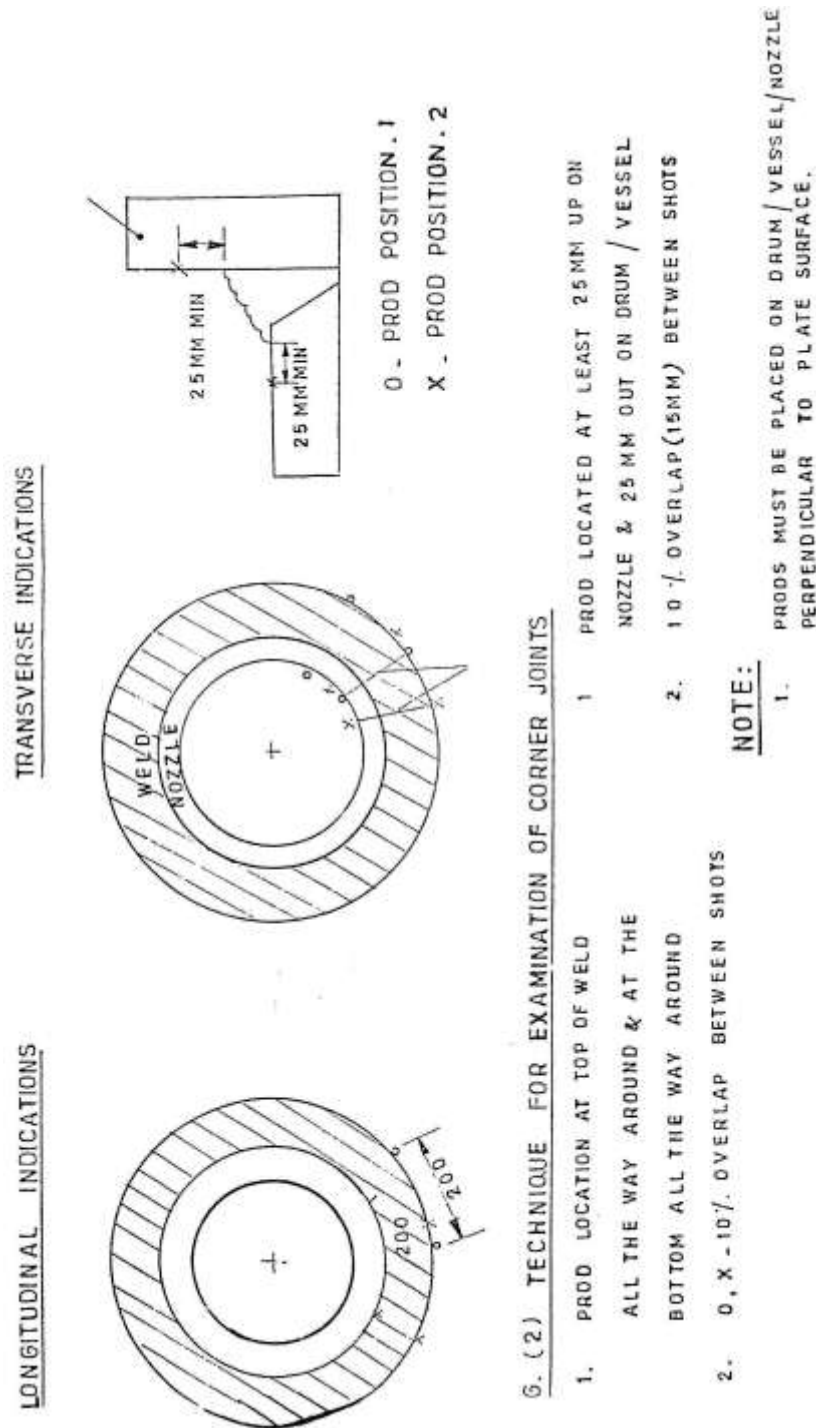


Fig (3) Technique for examination of Corner Joint

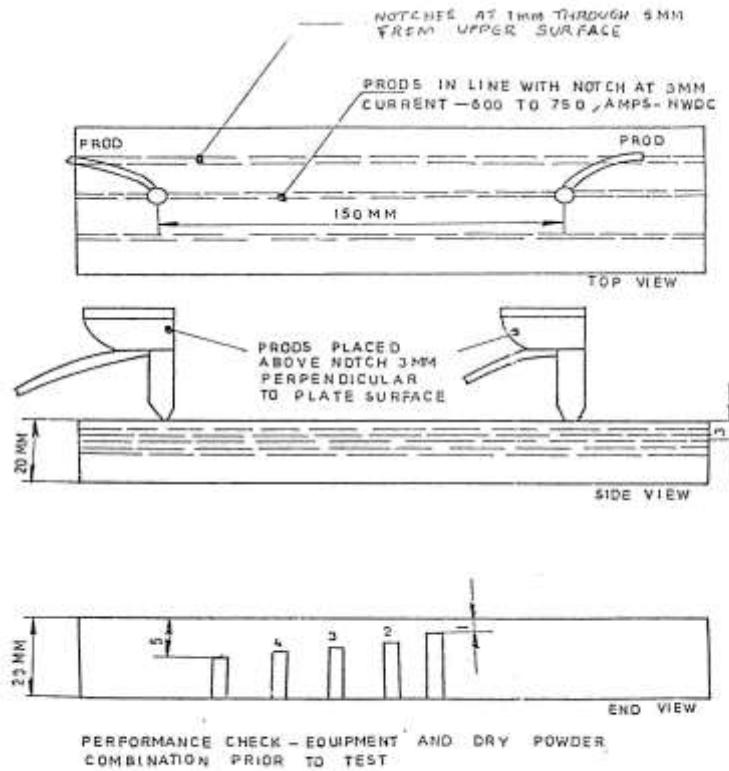


FIG (4) VERIFICATION OF SYSTEM
 PERFORMANCE FOR PROD TECHNIQUE

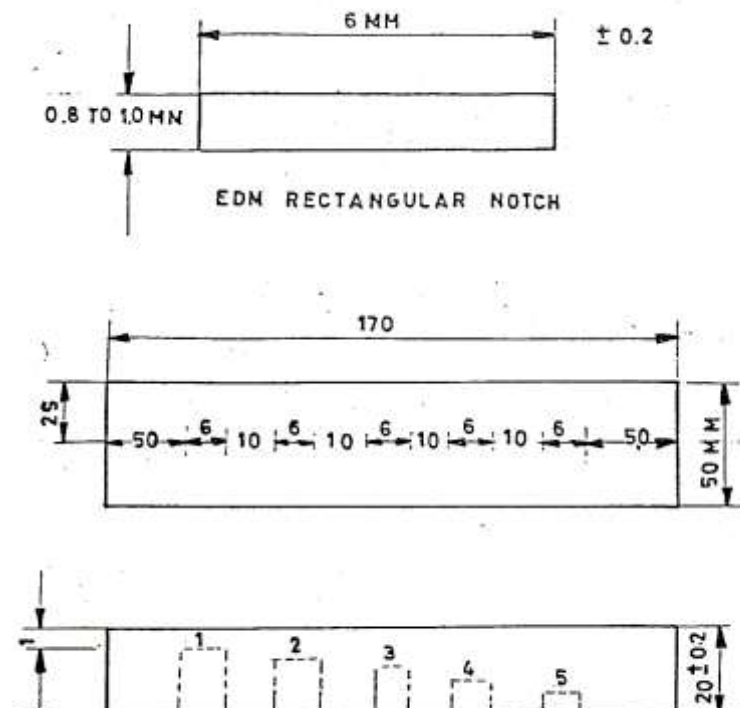


Fig 4a. SENSITIVITY BLOCK WITH EDM NOTCH

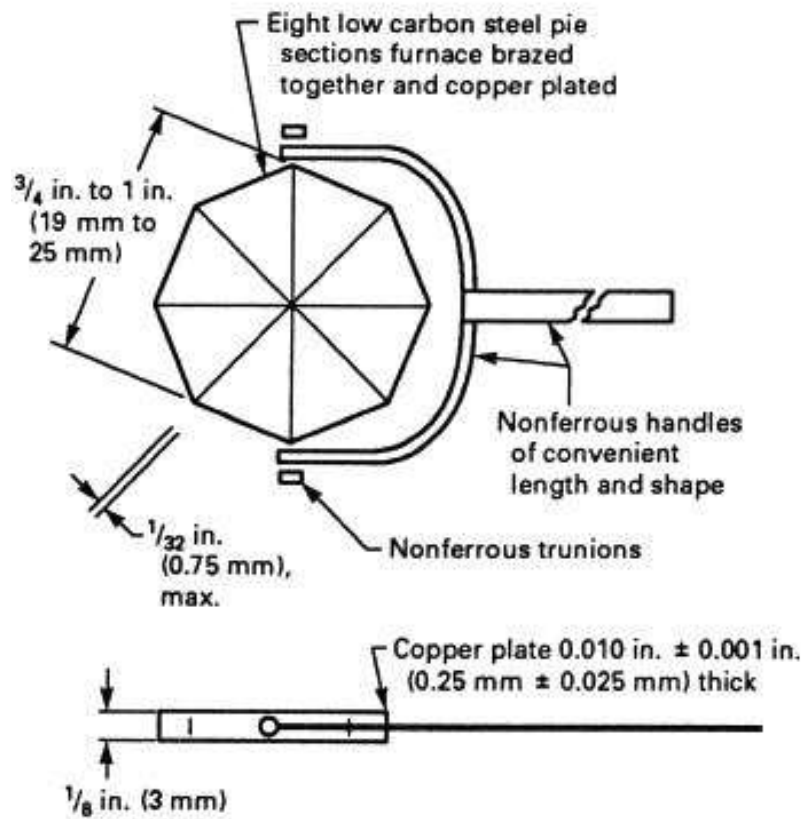


Fig (5): Pie shaped Magnetic Field Indicator

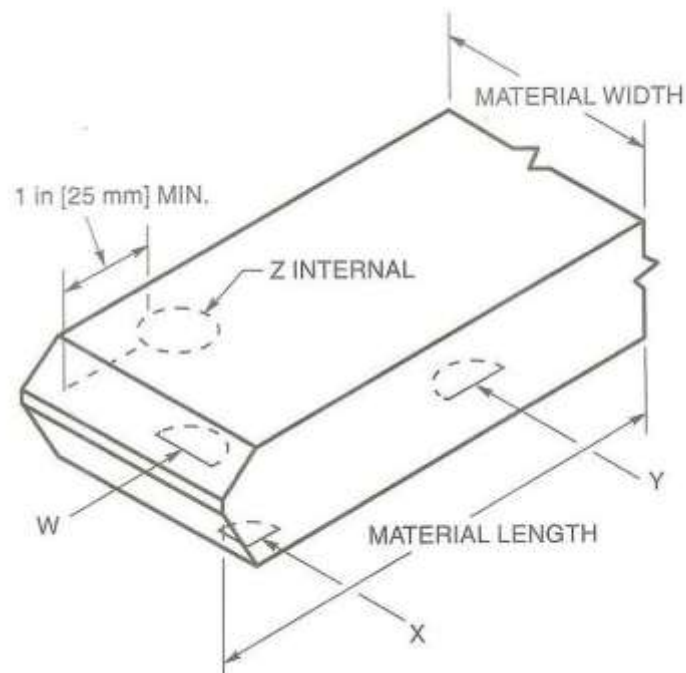


Fig (6) Edge discontinuities in cut material (See sec. 23.6)

