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**CLASSIFICATION NOTES:
GUIDELINES FOR
NON-DESTRUCTIVE TESTING
OF HULL AND MACHINERY
STEEL FORGINGS**

REVISION 1

SEPTEMBER 2021

CLASSIFICATION NOTES

Guidelines for Non-Destructive Testing of Hull and Machinery Steel Forgings

Revision 1, September 2021

TABLE 1 – AMENDMENTS INCORPORATED IN THIS VERSION

These amendments will come into force on 1 January 2022

Clause	Subject/ Amendments
Section 1 : General	
1.1.1 to 1.1.6	More clarity is provided on the scope of the Classification Note. .
1.1.7 to 1.1.12 (all new)	Reference to advanced NDT Methods is made and acceptable personnel qualification requirements are indicated.
Section 2 : Surface Inspections	
2.1.1	It is specified that personnel engaged in visual examination are to have sufficient knowledge and experience, however, may be exempted from formal qualification requirements.
2.1.3 (new)	Supplementary methods of surface inspection like eddy current testing are indicated.
2.2.1	It is specified that all accessible surfaces of steel forgings are to be subjected to 100% visual examination.
2.2.2 to 2.2.4 (all new)	Clarity is provided on acceptability of other standards for products or components not covered by this Classification Note.
2.2.5	Better clarity is provided on the type of steel forgings amenable to surface inspections.
2.3, 2.5, 2.6.1, 2.6.2.3, Table 1, Table 2	Editorial changes are made for better clarity.
2.6.2.1	Definitions for various indications are amended.
2.6.2.3	The scope of Table 1 & 2 is extended to include austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings.
2.6.3.1, 2.6.3.1 a)	Greater clarity is provided on rectification of shallow indications.
2.6.3.1 e)	It is additionally clarified that repair welding is not permitted on rotating items subjected to torsional fatigue such as propeller shafts.
2.7	Some additional requirements to reporting criteria are incorporated.
Section 3 : Volumetric Inspection	
3.1.1	Reference to advanced NDT Methods is made.
3.1.2, 3.1.3 to 3.1.5 (new)	Clarity on the use of angle beam probes is provided. General UT requirements are updated, and details provided regarding the setting up of, and using DAC sensitivity.
3.2.1	Better clarity is provided on the type of steel forgings amenable to volumetric inspections.
3.2.2 to 3.2.4 (all new)	Clarity is provided on acceptability of other standards for products or components not covered by this Classification Note.
3.3 & 3.4	Editorial changes are made for better clarity.
3.6	Some additional requirements to reporting criteria are incorporated.
Tables 3, 4 (new), 5 & 6 (new)	Acceptance criteria of volumetric inspection by ultrasonic testing for different products/ components are amended/ introduced.

CLASSIFICATION NOTES

Guidelines for Non-Destructive Testing of Hull and Machinery Steel Forgings

Revision 1, September 2021

Contents

Sections

1. General

1.1 Scope and Qualification of Personnel involved in NDT

2. Surface Inspections

2.1 General

2.2 Products

2.3 Zones for Surface Inspections

2.4 Surface Condition

2.5 Surface Inspection

2.6 Acceptance Criteria and Rectification of Defects

2.7 Reporting

3. Volumetric Inspection

3.1 General

3.2 Products

3.3 Zones for Volumetric Inspection

3.4 Surface Condition

3.5 Acceptance Criteria

3.6 Reporting

Section 1

General

1.1 Scope and Qualification of Personnel involved in NDT

- 1.1.1 This Classification Note complements the requirements for hull and machinery steel forgings given in IRS Rules Pt.2, Ch.5 “Steel Forgings” and Table 3.2.2 (b) of IRS Classification Note: *Approval of I.C. Engines*, which specifies the engine components. This document also contains general guidance for the non-destructive testing (NDT) methods, the extent of testing and the minimum recommended quality levels to be complied with unless otherwise approved or specified. The requirements contained herein may also be applied to the testing of austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings.
- 1.1.2 This document contains guidance on “Surface Inspections” (Section 2) by visual examination, magnetic particle testing and penetrant testing and volumetric Inspection” (Section 3) by ultrasonic testing.
- 1.1.3 For steel forgings (e.g. components for couplings, gears, boilers and pressure vessels) other than those specified in these guidelines, the requirements in this Classification Note may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.
- 1.1.4 Forgings are to be examined in the final delivery condition. For specific requirements see paragraphs 2.5.2 and 3.4.2.
- 1.1.5 Where intermediate inspections have been performed the manufacturer is to provide reports of the results upon the request of the Surveyor.
- 1.1.6 Where a forging is supplied in semi-finished condition, the manufacturer is to take into consideration the quality level of final finished machined components.
- 1.1.7 In general, where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, reference is made to IRS Classification Note: *Advanced NDT Methods*, for adopting and application of these advanced methods. Acceptance levels regarding accept/ reject criteria are to be as per the applicable Section in this Classification Note.
- 1.1.8 Personnel carrying out NDT are to be certified to a recognised national or international certification scheme, e.g. ISO 9712:2012. Where employer based qualification schemes (such as SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016) are applied, personnel qualification to

these schemes may be accepted if the written practice is reviewed and found acceptable by IRS. The written practice is to align with the main requirements with those of ISO 9712 (apart from the impartiality requirements of a certification body).

- 1.1.9 The NDT personnel's certificates and competence are to comprise all industrial sectors and techniques being applied by the manufacturer or its subcontractors.
- 1.1.10 Certificates are to be made available to IRS for verification, when requested.
- 1.1.11 Procedures are to be approved by Level III personnel for the appropriate NDT method.
- 1.1.12 The operator carrying out the NDT and interpreting indications, is to as a minimum, be qualified and certified to Level II in the NDT method(s) concerned. However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at Level I. The operator is to have adequate knowledge of materials, weld, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

Section 2

Surface Inspections

2.1 General

- 2.1.1 Surface inspections are to be carried out by visual examination and magnetic particle testing or penetrant testing, for the purpose of detecting relevant indications and assessing them against accept/reject criteria stated herein. Personnel engaged in visual examination are to have sufficient knowledge and experience, however, may be exempted from formal qualification requirements in this Classification Note.
- 2.1.2 The testing procedures, apparatus and conditions of magnetic particle testing and penetrant testing are to comply with recognised national or international standards.
- 2.1.3 Other surface inspection methods e.g. eddy current testing, may be required by IRS as a supplementary method, e.g. for confirming the presence of indications, or for detecting the presence of undocumented weld repairs. This Classification Note does not include accept/reject criteria for this purpose and is mentioned here for information only.

2.2 Products

- 2.2.1 The steel forgings are to be subjected to a 100% visual examination of all accessible surfaces by the manufacturer and made available to the Surveyor. For mass produced forgings the extent of examination will be specially considered in each case.
- 2.2.2 In cases where a particular component or type is not included, either in Part 2 Chapter 5 of the Rules or this Classification Note, appropriate national/international standards may be applied, to determine the appropriate testing regime and defect acceptance criteria.
- 2.2.3 Austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings acceptance criteria details are included in the appropriate sections for surface and volumetric inspections, however, other acceptance criteria and national or international standards may be applied, upon agreement with IRS.
- 2.2.4 Where such standards are used or referenced as a basis for accept and reject criteria, the quality level should provide reasonable equivalence to the allowable criteria stated in the appropriate tables

within this Classification Note. The quality levels would normally be the highest or most stringent, to provide reasonable equivalence with this Classification Note.

2.2.5 Surface inspections by magnetic particle and/or penetrant methods generally apply to the following steel forgings manufactured at the approved works:

- 1) All crankshafts ;
- 2) Propeller shafts, intermediate shafts, thrust shafts, rudder stocks and rudder shafts with minimum diameter not less than 100 mm;
- 3) Cylinder heads, connecting rods, piston rods and crosshead as per the engine type and size requirements in IRS Classification Note : *Approval of I.C. Engines*;
- 4) Bolts with minimum diameter not less than 50 mm, which are subjected to dynamic stresses such as cylinder cover bolts, coupling bolts for crankshafts, tie rods, crankpin bolts, main bearing bolts, and other items as per the engine type and size requirements in IRS Classification Note: *Approval of I.C. Engines*;
- 5) Propeller blade fastening bolts which are subjected to dynamic stresses.

Note : 1) Any forgings supplied by the traders are to be subjected to UT regardless of their sizes.

2) Forgings of diameters greater than 250 [mm] or equivalent cross section are to be subjected to UT and either magnetic particle or penetrant test. For additional requirements for ultrasonic testing of forgings for specific items, refer to 3.2.1.

2.3 Zones for Surface Inspections

2.3.1 Magnetic particle or where permitted penetrant testing is to be carried out in the zones I ,II and III (as applicable) as indicated in Figures 1 to 4.

2.4 Surface Conditions

2.4.1 The surfaces of forgings to be examined are to be free from scale, dirt, grease or paint. If the testing performed in as-forged condition, only if it can be ensured to that the roughness / forge mark do not prevent transmission of ultrasound within the material.

2.5 Surface Inspection

2.5.1 Where indicated by Figures 1 to 4, magnetic particle inspection is to be carried out with the following exceptions, when penetrant testing would be permitted:

- austenitic and ferritic-austenitic (duplex) stainless steels;
- interpretation of open visual or magnetic particle indications;
- at the instruction of the Surveyor.

2.5.2 Unless otherwise detailed in the specification, the magnetic particle test is to be performed on a forging in the final machined surface condition and final thermally treated condition.

2.5.3 Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor. The surface inspection is to be carried out before the shrink fitting, where applicable.

2.5.4 For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods should not be permitted on finished machined items.

2.5.5 When indications are detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with clause 2.6.

2.6 Acceptance Criteria and Rectification of Defects

2.6.1 Acceptance Criteria Visual Inspection

.1 All forgings are to be free of cracks, crack-like indications, laps, seams, folds or other detrimental indications. At the request of the Surveyor, additional magnetic particle, penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

.2 The bores of hollow propeller shafts are to be visually examined for imperfections uncovered by the machining operation.

2.6.2 Acceptance Criteria Magnetic Particle Testing and Penetrant Testing

2.6.2.1 The following definitions relevant to indications apply:

Linear indication	an indication with a largest dimension three or more times its smallest dimension (i.e. $l \geq 3 w$).
Nonlinear indication	an indication with a largest dimension less than three times its smallest dimension (i.e. $l < 3w$).
Aligned indication	<p>a) Non-linear indications form an alignment when the distance between indications is less than 2mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.</p> <p>b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.</p>
Open indication	an indication visible after removal of the magnetic particles or that can be detected by the use of penetrant testing;
Non-open indication	an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of penetrant testing;
Relevant indication	an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm shall be considered relevant for the categorization of indications.

2.6.2.2 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 [cm²]. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

2.6.2.3 The allowable number and size of indications in the reference area is given in Table 1 for crankshaft forgings and in Table 2 for other forgings (including austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings), respectively. Cracks are not acceptable. Irrespective of the results of non-destructive examination, the Surveyor may reject the forging if the total number of indications is excessive.

Table 1 : Crankshaft forgings : Allowable number and size of surface indications in a reference area of 225 [cm²]				
Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension [mm]
I (critical fillet area)	0	Linear Nonlinear Aligned	0 0 0	- - -
II (important fillet area)	3	Linear Nonlinear Aligned	0 3 0	- 3.0 -
III (journal surfaces)	3	Linear Nonlinear Aligned	0 3 0	- 5.0 -

Table 2 : Steel forgings excluding crankshaft forgings : Allowable number and size of surface indications in a reference area of 225 [cm²]				
Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension [mm]
I	3	Linear Nonlinear Aligned	0 ¹⁾ 3 0 ¹⁾	- 3.0 -
II	10	Linear Nonlinear Aligned	3 ¹⁾ 7 3 ¹⁾	3.0 5.0 3.0
<p>Note:</p> <p>1) Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts, cylinder cover bolts.</p>				

2.6.3 Rectification of Defects

2.6.3.1 Defects and unacceptable indications that exceed the requirements of Table 1 and 2 are to be rectified as indicated below and detailed in 2.6.3.2 through 2.6.3.6.

- a) In general, shallow indications may be removed by light grinding to a depth of 1.5 [mm]. Defective parts of material may be removed by grinding or by chipping and grinding. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to the adjacent surface.
- b) To depress is to flatten or relieve the edges of a non-open indication with a fine pointed abrasive stone with the restriction that the depth beneath the original surface shall be 0.08 [mm] minimum to 0.25 [mm] maximum and that the depressions be blended into the bearing surface. A depressed area is not considered a groove and is made only to prevent galling of bearings.
- c) Non-open indications evaluated as segregation need not be rectified.
- d) Complete removal of the defect is to be proved by magnetic particle testing or penetrant testing, as appropriate.
- e) Repair welding is not permitted for crankshafts or rotating items subjected to torsional fatigue (such as propeller shafts). Repair welding of other forgings is subject to prior approval of IRS.

2.6.3.2 Zone I in crankshaft forgings

Neither indications nor repair are permitted in this zone.

2.6.3.3 Zone II in crankshaft forgings

Indications must be removed by grinding to a depth no greater than 1.5 [mm].

Indications detected in the journal bearing surfaces must be removed by grinding to a depth to greater than 3.0 [mm]. The total ground area shall be less than 1% of the total bearing surface area concerned.

Non-open indications, except those evaluated as segregation shall be depressed but need not be removed.

2.6.3.4 Zone I in other forgings

Indications must be removed by grinding to a depth no greater than 1.5 [mm]. However, grinding is not permitted in way of finished machined threads.

2.6.3.5 Zone II in other forgings

Indications must be removed by grinding to a depth no greater than 2% of the diameter or 4.0 [mm], whichever is smaller.

2.6.3.6 Zones other than I and II in forgings

Defects detected by visual inspection must be removed by grinding to a depth no greater than 5% of the diameter or 10 [mm], whichever is smaller. The total ground area shall be less than 2% of the forging surface area.

2.7 Reporting

2.7.1 Test results of surface inspections are to be recorded at least with the following items:

- 1) Date of testing;
- 2) Name(s), signature(s) and qualification level of inspection personnel;
- 3) Testing method and testing details, including procedure number;
 - for penetrant testing : the penetrant system used and viewing conditions (as appropriate to the penetrant technique and media used)
 - for magnetic particle testing : method of magnetizing, test media, magnetic field strength, magnetic flux indicators (where appropriate), and viewing conditions (as appropriate to the magnetizing technique and media used)
- 4) Type of product;
- 5) Product number and unique identification;
- 6) Grade of steel;
- 7) Heat treatment;
- 8) Stage of testing;
- 9) Position (zone) of testing;
- 10) Surface condition;
- 11) Test standards used, including reference to the appropriate tables for acceptance purposes;
- 12) Testing condition;
- 13) Results, including documentation regarding the repair and testing history (as appropriate);
- 14) Statement of acceptance / non-acceptance;
- 15) Details of weld repair including sketch (where applicable).

Section 3

Volumetric Inspection

3.1 General

- 3.1.1 Volumetric inspection in these guidelines is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique. Advanced UT methods (such as PAUT or TOFD) should meet the general requirements of IRS Classification Note: *Advanced NDT Methods*.
- 3.1.2 The testing procedures, apparatus and conditions of ultrasonic testing are to comply with recognized national or international standards. Generally, the methods of setting test sensitivity and testing evaluation utilize the DAC (distance amplitude correction) or the DGS (distance-gain-size) methods. The applied methodology is to use 2 to 4 MHz straight beam (or normal) probes and/or angle beam probes. For near surface testing (upto a depth of 25mm) twin crystal 0° probe should be used plus a 0° probe (usually single crystal beyond a depth of 25mm) for the remaining volume. The appropriate acceptance criteria tables should be used, depending on the sensitivity method selected.
- 3.1.3 Fillet radii should be examined using 45°, 60° or 70° probes, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.
- 3.1.4 For fabricated forgings and weld repairs, weld testing is to be carried out to the appropriate standard, and the acceptance tables contained herein are not to be used as a basis for acceptance criteria of welds.
- 3.1.5 Construction of DAC curves for normal probes are to be performed using reference blocks containing suitably sized Flat Bottom Holes (FBH) spaced over the inspection thickness. Reference blocks are to be manufactured from similar material, with similar surface condition to that being inspected. Where necessary, allowances are to be made for attenuation losses by performing a transfer correction and adjusting the DAC curve as required. The applied transfer correction (measured in decibels (dB)) should become the new reference sensitivity, to which indications are evaluated against, according to the appropriate table contained herein.

3.2 Products

3.2.1 Volumetric inspections by ultrasonic testing generally apply to the following steel forgings:

- 1) All crankshafts;
- 2) Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 [mm];
- 3) Cylinder heads, connecting rods, piston rods crosshead, coupling bolts and studs as per the engine type and size requirements in IRS Classification Note: *Approval of I.C. Engines*.

3.2.2 In cases where a particular component or type is not included, either in Part 2, Chapter 5 or this Classification Note, appropriate national/international standard may be applied, to determine the appropriate testing regime and defect acceptance criteria.

3.2.3 Where such standards are used or referenced as a basis for accept and reject criteria, the quality level should provide reasonable equivalence to the allowable criteria stated in the appropriate tables within this Classification Note. The quality levels would normally be the highest or most stringent, to provide reasonable equivalence with this Classification Note.

3.2.4 Ultrasonic acceptance criteria detailed in Tables 3 to 6 are intended for C, C-Mn, and alloy steel forgings, and do not apply to austenitic stainless steel or ferritic-austenitic (duplex) stainless steel forgings. Examples of standards for acceptance criteria for stainless steel or duplex stainless steel forgings are detailed below, and quality levels should be agreed with IRS. Other national or international standards may be used, as agreed with IRS.

- (i) ASTM A745 / A745M – 20
- (ii) EN 10228-4:2016

3.3 Zones for Volumetric Inspection

3.3.1 Ultrasonic testing is to be carried out in the zones I to III as indicated in Figures 5 to 8. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

3.4 Surface Condition

3.4.1 The surfaces of forgings to be examined are to be such that adequate coupling can be established between the probe and the forging and

that excessive wear of the probe can be avoided. The surfaces are to be free from scale, dirt, grease or paint.

3.4.2 The ultrasonic testing is to be carried out after the steel forgings have been machined to a condition suitable for this type of testing and after the final heat treatment, but prior to the drilling of the oil bores, prior to surface hardening and the machining of bolt threads. Black (or 'as forged') forgings are to be inspected after removal of the oxide scale by either flame descaling or shot blasting methods.

3.5 Acceptance Criteria

3.5.1 Acceptance criteria of volumetric inspection by ultrasonic testing are shown in Tables 3 to 6.

3.6 Reporting

3.6.1 Test results of volumetric inspection are to be recorded at least with the following items:

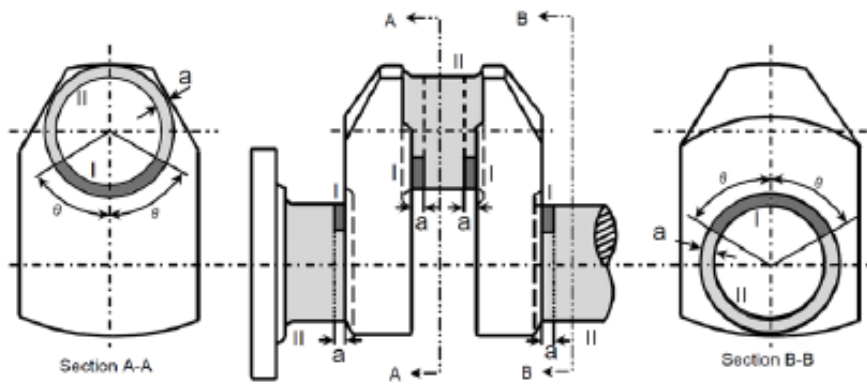
- 1) Date of testing;
- 2) Name(s), signature(s) and qualification level of inspection personnel;
- 3) Testing method including procedure number and details of the following items:
 - a. Equipment used (instrument, probes (and any adaptations to probes for curved surfaces), calibration and reference blocks)
 - b. Technique(s) used to set test sensitivity (including sensitivity method, specific reference blocks, reflector size, transfer correction)
 - c. Maximum scanning rate (mm/s)
 - d. Details of any testing restrictions
- 4) Type of product;
- 5) Product number and unique identification;
- 6) Grade of steel;
- 7) Heat treatment;
- 8) Stage of testing;
- 9) Position (zone) of testing;
- 10) Surface condition;
- 11) Test standards used including reference to the appropriate tables for acceptance purposes;
- 12) Testing condition;
- 13) Results including documentation regarding the repair and testing history (as appropriate);
- 14) Statement of acceptance / non-acceptance;
- 15) Details of weld repair including sketch (where applicable).

Table 3 : Ultrasonic Acceptance Criteria for Crankshafts: DGS Method – Normal Probes				
Type of Forging	Zone	Allowable disc shape according to DGS¹⁾	Allowable length of indication	Allowable distance between two indications²⁾
Crank shaft	I II III	d ≤ 1.0 mm d ≤ 2.0 mm d ≤ 4.0 mm	Not Applicable ≤ 10 mm ≤ 15 mm	Not Applicable ≥ 20 mm ≥ 20 mm
<p>Notes:</p> <p>1) DGS : distance-gain-size</p> <p>2) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighboring indications must be at least the length of the bigger indication. This also applies to the distance in axial direction as well as to the distance in depth. Isolated indications with less distances are to be determined as one single indication.</p> <p>3) For zone 1 testing, probe selection is to take into account the limits of probe beam-path length and depth of beam penetration and should normally be carried out with a minimum probe frequency of 4MHz.</p> <p>4) For zone 1, indications with an echo height greater than a 1.0mm disc shaped reflector are not acceptable. Indications with an echo height of less than 1.0mm are acceptable if they are deemed as point reflectors and have no measurable length.</p>				

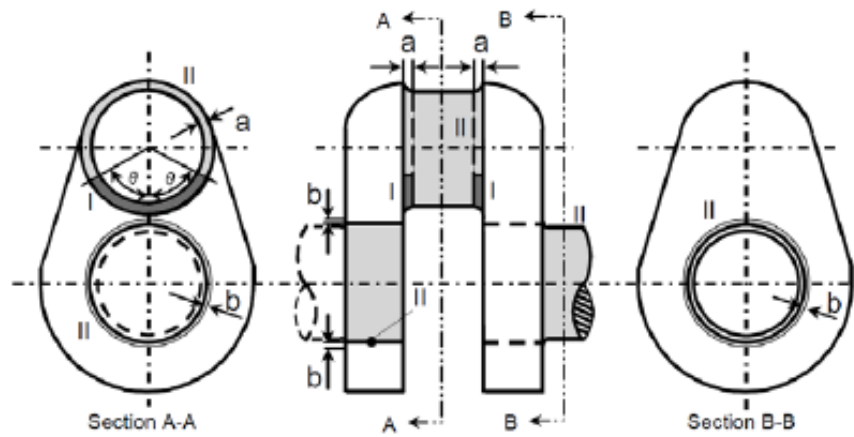
Table 4 : Ultrasonic Acceptance Criteria for Crankshafts: DAC Method – Normal Probes				
Type of Forging	Zone	DAC reference level, based on 3.0mm FBH^(1), 2), 3)	Allowable length of indication	Allowable distance between two indications ⁵⁾
Crank shaft	I	3.0 mm DAC minus 19 dB	Not Applicable ⁴⁾	Not Applicable
	II	3.0 mm DAC minus 7 dB	≤ 10. 0mm	≥ 20.0mm
	III	3.0 mm DAC + 5 dB	≤ 15. 0mm	≥ 20.0mm
<p>Notes:</p> <p>1) The requirement of a 3mm FBH is to standardize the DAC reference blocks for clarity and consistency. The dB value for the FBH/DAC setting is equivalent to the disc shaped reflector stated in Table 3, corresponding to the applicable zone.</p> <p>2) Other size FBH's may be used for the DAC method (and the dB value adjusted accordingly to provide equivalence with the stated FBH/disc shaped reflector). Where other size FBH's are used, the ultrasonic procedure should state the equivalence using an appropriate calculation formula.</p> <p>3) For zone 1 testing, probe selection should take into account the limits of probe beam-path length and depth of beam penetration and should normally be carried out with a minimum probe frequency of 4MHz.</p> <p>4) For zone 1, indications with an echo height greater than the DAC reference level are not acceptable. Indications with an echo height of less than the DAC reference level are acceptable if they are deemed as point reflectors and have no measurable length.</p> <p>5) In case of accumulations of two or more isolated indications which are subject to registration the minimum distance between two neighbouring indications be at least the length of the larger indication. This also applies to the distance in axial directions as well as to the distance in depth. Isolated indications with less distances should be determined as one single indication.</p>				

Table 5 : Ultrasonic Acceptance criteria for shafts and machinery components: DGS Method – Normal Probes				
Type of Forging	Zone	Allowable disc shape according to DGS ¹⁾²⁾	Allowable length of indication	Allowable distance between two indications ³⁾
Propeller shaft intermediate shaft	II	Outer : $d \leq 2$ mm Inner : $d \leq 4$ mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Thrust shaft Rudder stock	III	Outer : $d \leq 3$ mm Inner : $d \leq 6$ mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Connecting rod	II	$d \leq 2$ mm	≤ 10 mm	≥ 20 mm
Piston rod Crosshead	III	$d \leq 4$ mm	≤ 10 mm	≥ 20 mm
<p>Notes:</p> <p>1) DGS : distance-gain-size</p> <p>2) Outer part means the part beyond one third of the shaft radius from the center, the inner part means the remaining core area.</p> <p>3) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighbouring indications must be at least the length of the larger indication. This also applies to the distance in axial directions as well as to the distance in depth. Isolated indications with less distances should be determined as one single indication.</p>				

Table 6 : Ultrasonic Acceptance Criteria for Shafts and Machinery Components: DAC Method – Normal Probes				
Type of Forging	Zone	DAC reference level, based on 3.0mm FBH^{1), 2)}	Allowable length of indication	Allowable distance between two indications ³⁾
Propeller shaft Intermediate shaft	II	Outer : DAC minus 7 dB	≤ 10.0mm	≥ 20.0mm
		Inner : DAC + 5 dB	≤ 15.0mm	
	III	Outer : + 0 DAC	≤ 10.0mm	≥ 20.0mm
		Inner : DAC + 12 dB	≤ 15.0mm	
Thrust shaft Rudder stock	II	Outer : DAC minus 7 dB	≤ 10.0mm	≥ 20.0mm
		Inner : DAC + 5 dB	≤ 15.0mm	
	III	Outer : + 0 DAC	≤ 10.0mm	≥ 20.0mm
		Inner : DAC + 12 dB	≤ 15.0mm	
Connecting rod Piston rod Crosshead	II	DAC minus 7 dB	≤ 10.0mm	≥ 20.0mm
	III	DAC + 5 dB	≤ 10.0mm	≥ 20.0mm
<p>Notes:</p> <p>1) The requirement of a 3mm FBH is to standardize the DAC reference blocks for clarity and consistency. The dB value for the FBH/ DAC setting is equivalent to the disc shaped reflector stated in Table 3, corresponding to the applicable zone.</p> <p>2) Other size FBH's may be used for the DAC method (and the dB value adjusted accordingly to provide equivalence with the stated FBH/ disc shaped reflector). Where other size FBH's are used, the ultrasonic procedure is to state the equivalence using an appropriate calculation formula.</p> <p>3) In case of accumulations of two or more isolated indications which are subject to registration the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This also applies to the distance in axial directions as well as to the distance in depth. Isolated indications with less distances are to be determined as one single indication.</p>				



(a) Solid crankshaft



(b) Semi built-up crankshaft

Notes)

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I. (See the figure in the right.)

2. In the above figures, 'θ', 'a' and 'b' mean:

$\theta = 60^\circ$

$a = 1.5 r$

$b = 0.05 d$ (: circumferential surfaces of shrinkage fit)

where,

r : fillet radius

d : journal diameter

3. Identification of the Zones (Similar in Figs. 1 thru 4):

- : Zone I
- : Zone II
- : Zone III

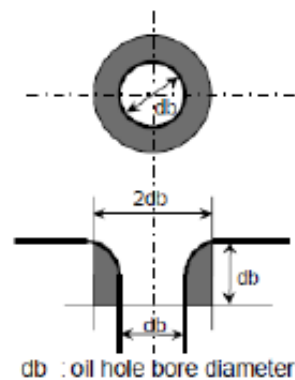
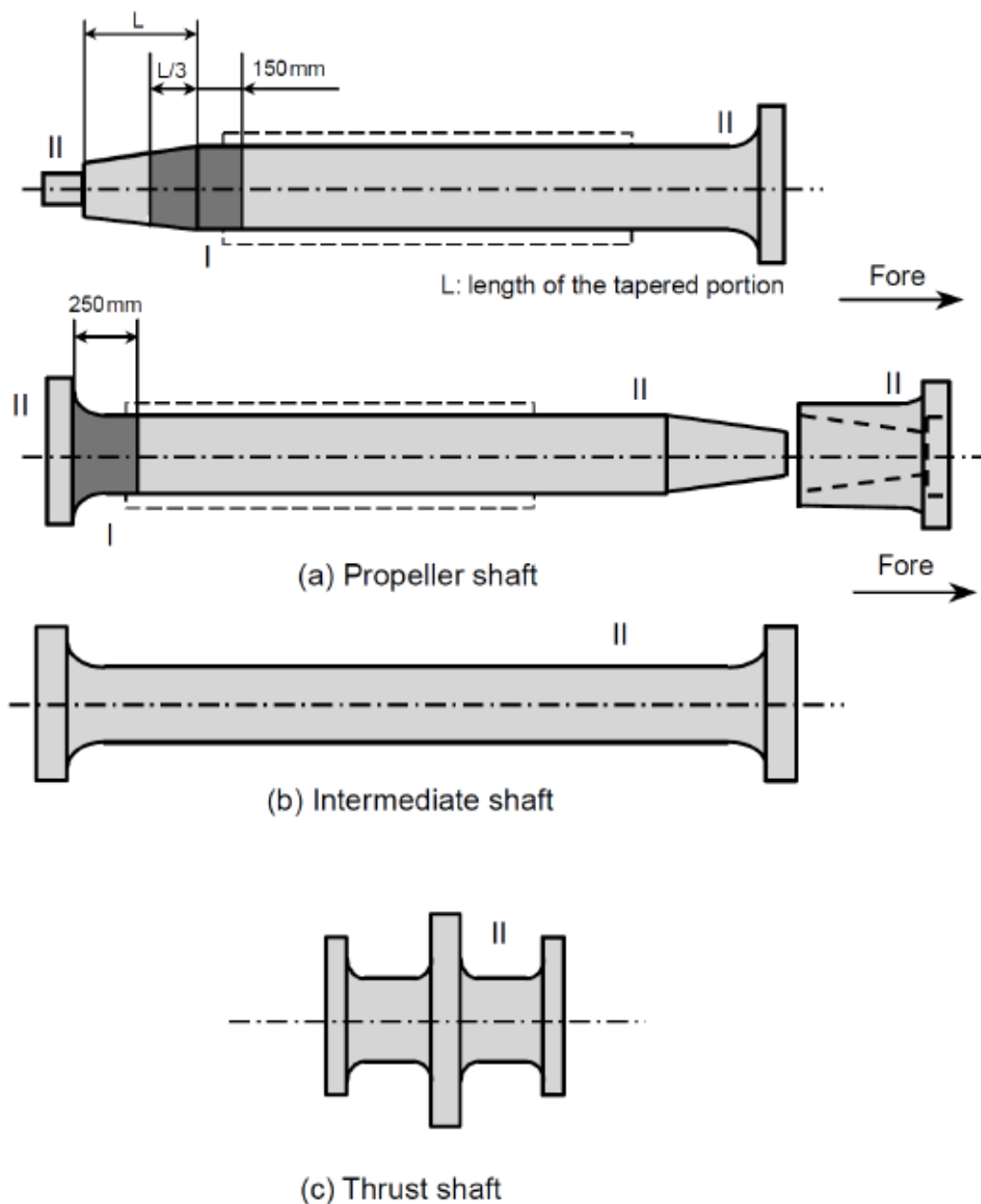


Fig.1 Zones for magnetic particle /liquid penetrant testing on crankshafts



Note) For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 2 Zones for magnetic particle / liquid penetrant testing on shafts

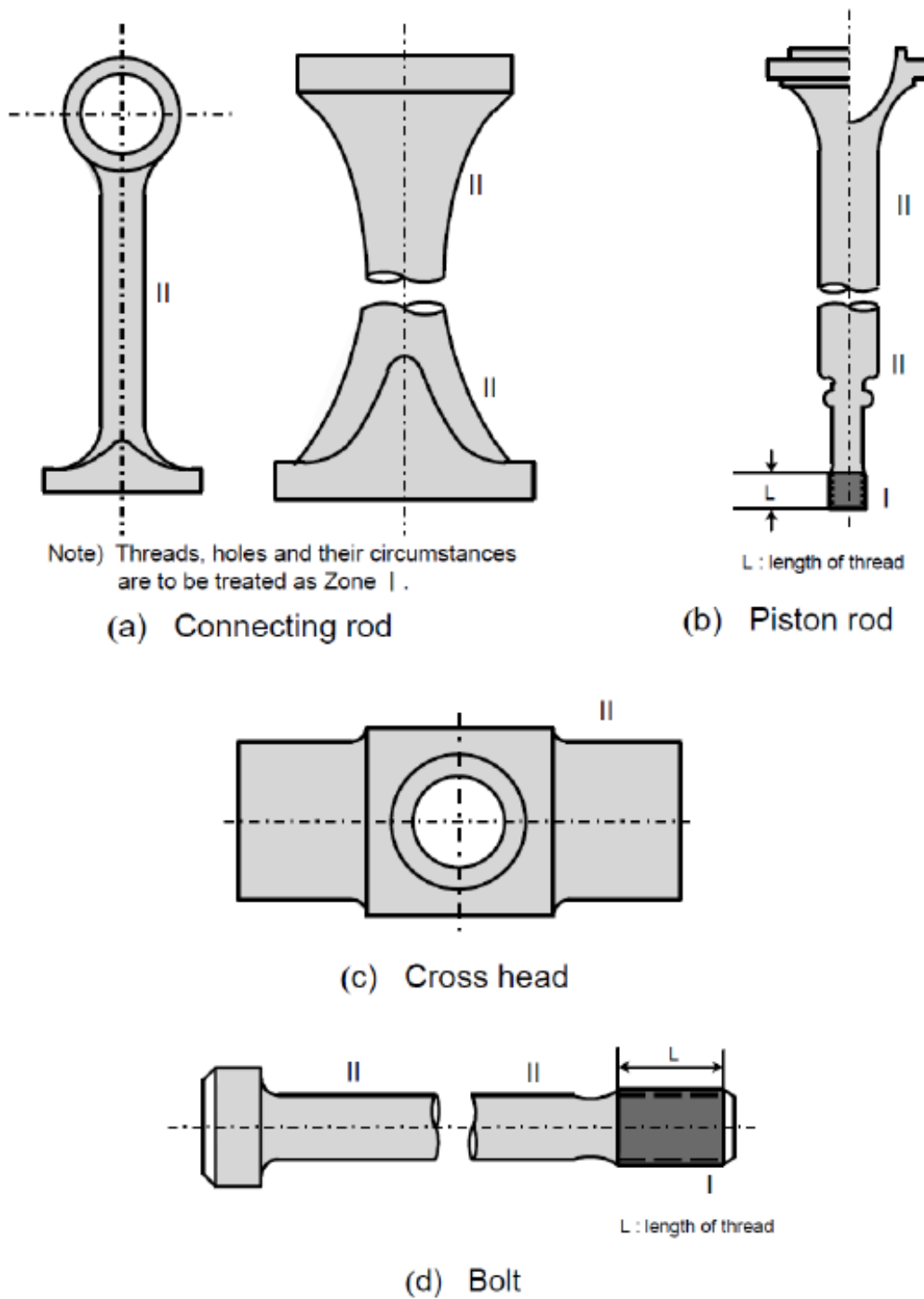
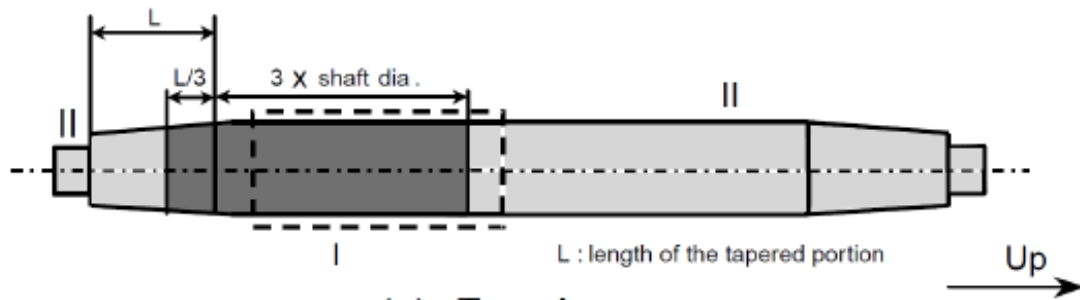
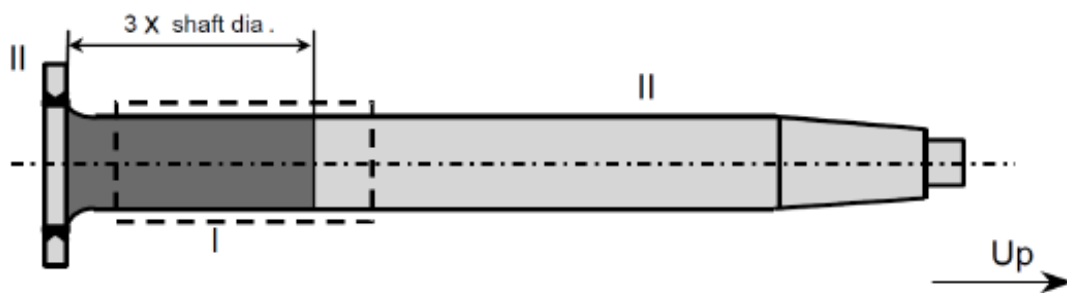


Fig.3 Zones for magnetic particle / liquid penetrant testing on machinery components

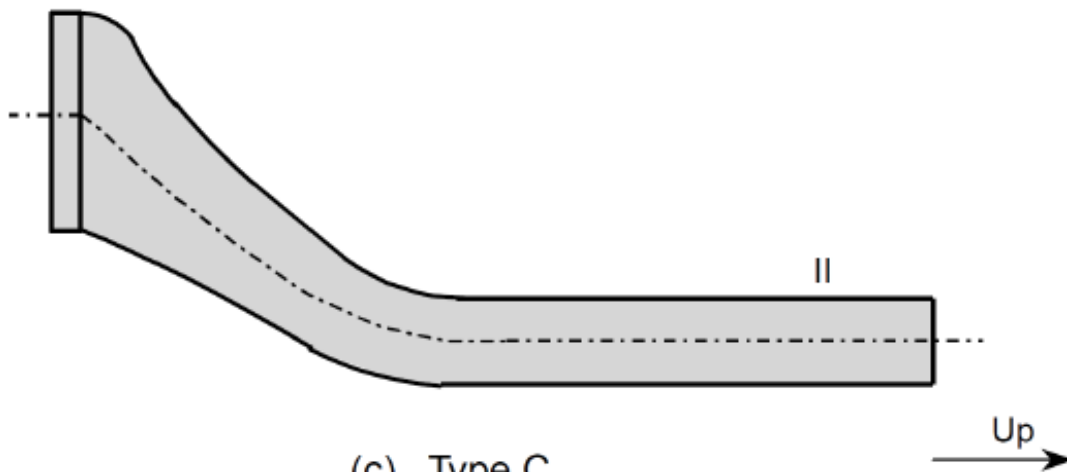


(a) Type A



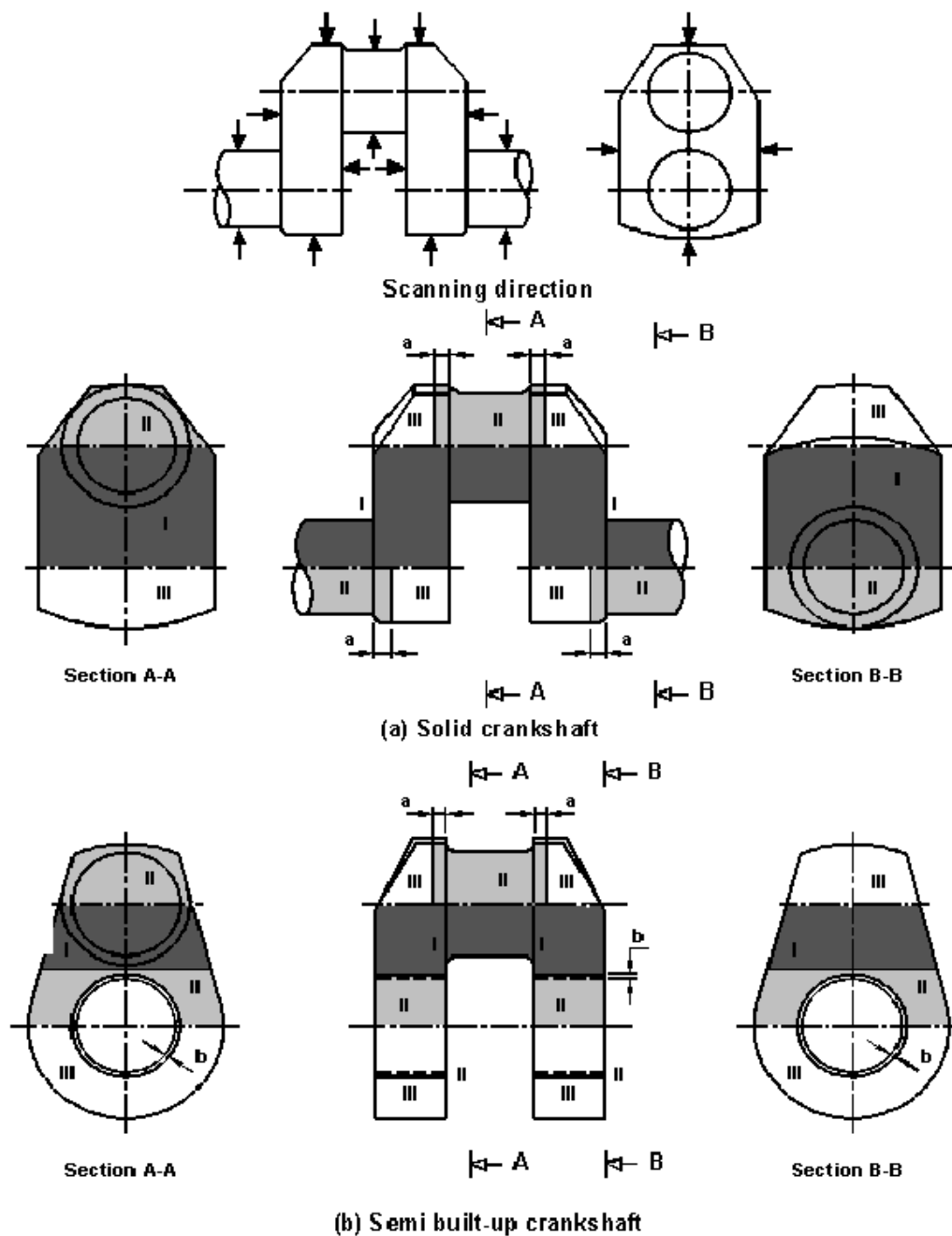
Note) Welded areas are to be treated as Zone I .

(b) Type B



(c) Type C

Fig.4 Zones for magnetic particle / liquid penetrant testing on rudder stocks



Notes :

1. In the above figure, 'a' and 'b' mean :
 - a = 0.1d or 25 mm, whichever greater
 - b = 0.05 d or 25 mm, whichever greater (: circumstanced of shrinkage fit)
 where,
 d = pin or journal diameter
2. Core areas of crank pins and/or journals within a radius of 0.25 d between the webs may generally be co-ordinated to Zone II.
3. Identification of the Zones (Similar in Figs. 5 thru 8) :

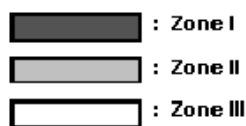
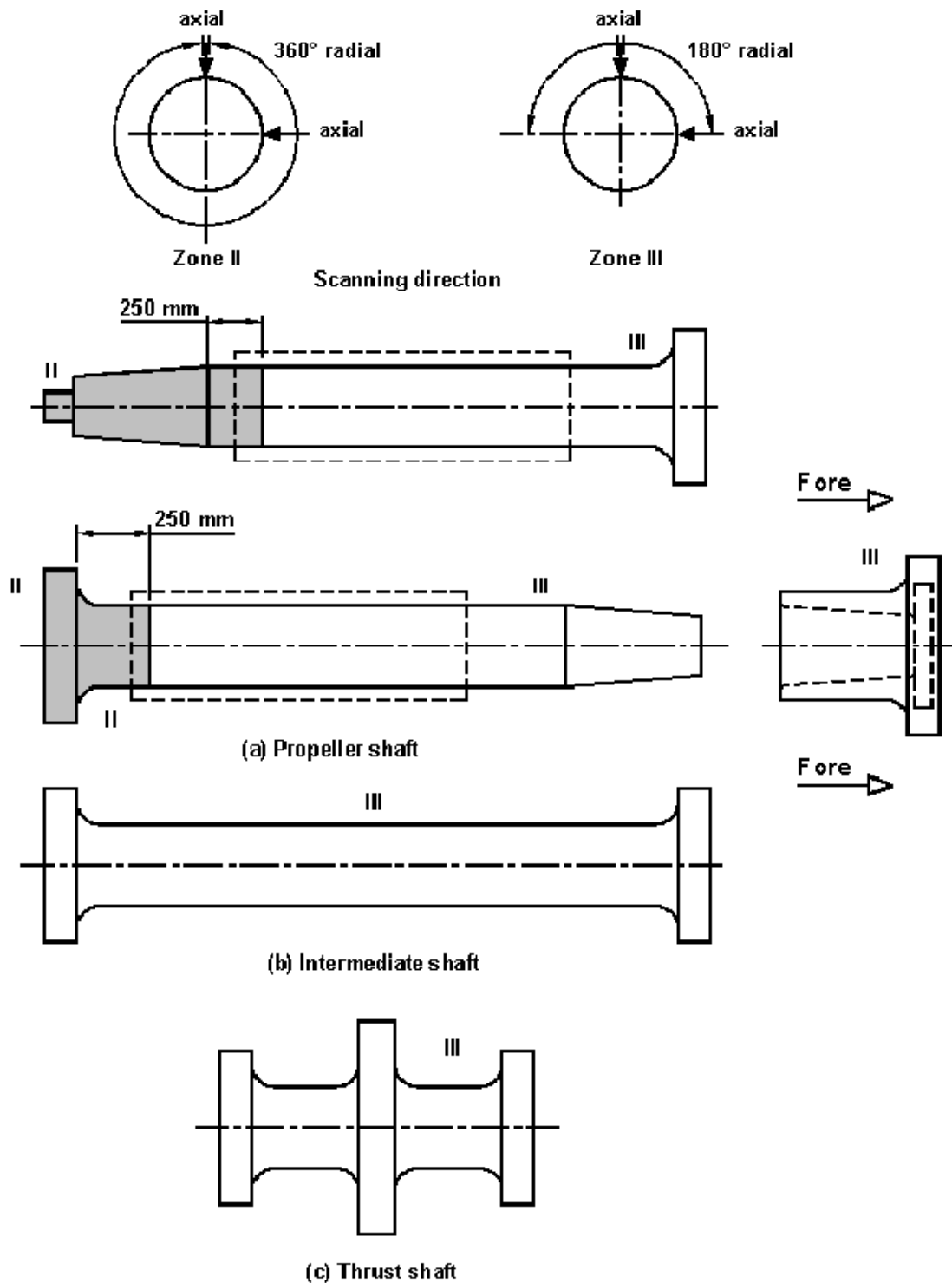


Fig. 5 : Zones for ultrasonic testing on crankshafts



- Notes :
1. For hollow shaft, 360° radius scanning applies to Zone III.
 2. Circumferences of the bolt holes in the flanges are to be treated as Zone II.

Fig. 6 : Zones for ultrasonic testing on shafts

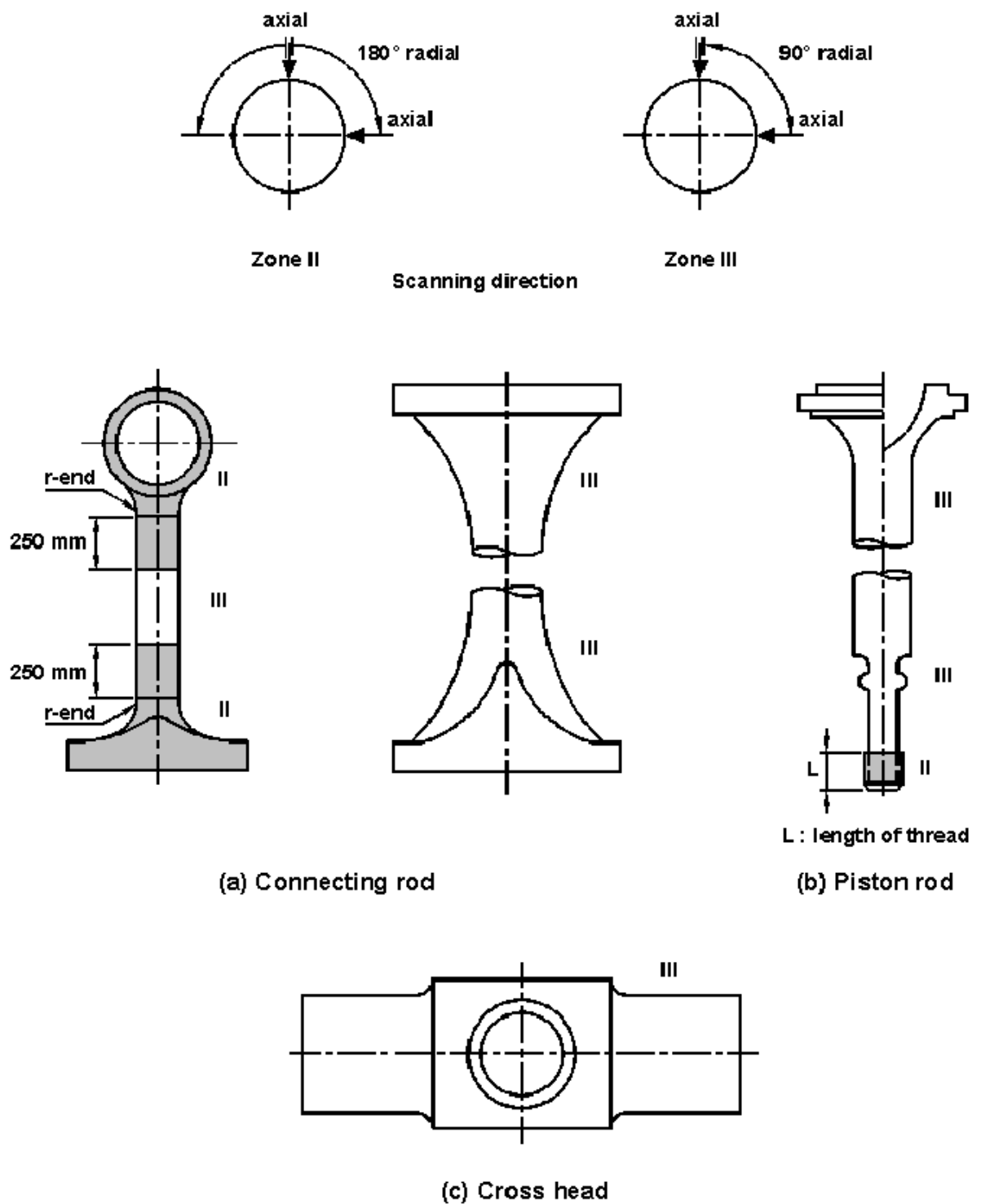


Fig. 7 : Zones for ultrasonic testing on machinery components

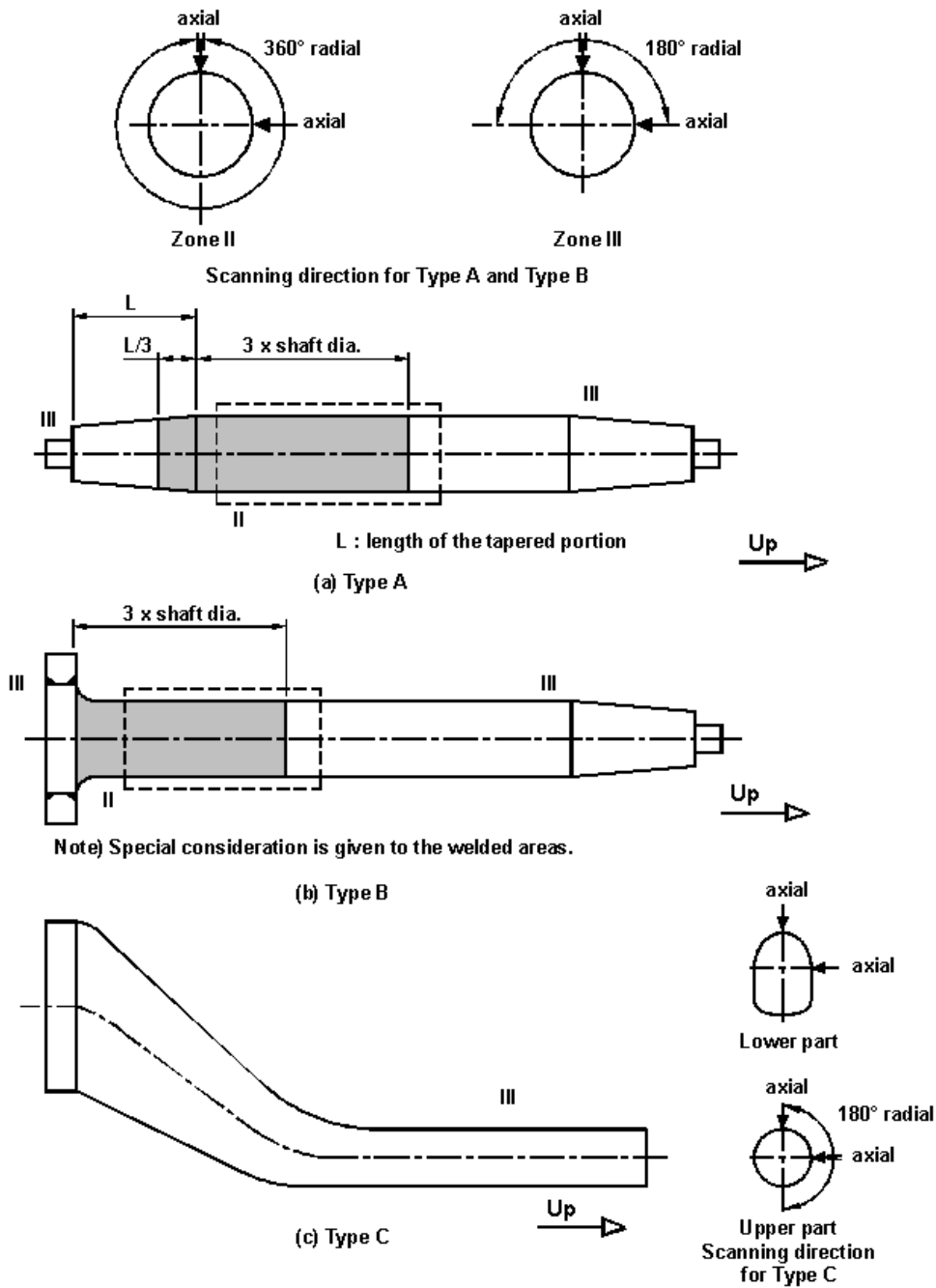


Fig. 8 : Zones for ultrasonic testing on rudder stocks

End of Classification Note