CARBON STEEL CASTINGS FOR STEAM TURBINES

GRADE: GP 240 GH

1.0 GENARAL :

This specification governs the quality requirements of carbon steel castings of material grade GP240 GH.

2.0 APPLICATION :

These castings are required for steam turbine casings, valve bodies, guide blade carriers, inserts etc.

3.0 CONDITION OF DELIVERY :

The castings shall be supplied in normalized or normalized & tempered, rough machined; stress relieved and shot blasted condition. Cleaning of internal surface shall be ensured. The surface condition of the casting shall be suitable for the applicable NDT. The castings shall not be painted.

4.0 COMPLIANCE WITH NATIONAL STANDARDS :

This specification complies, in general, with EN 10213, Gr.GP 240 GH.

5.0 DIMENSIONS AND TOLERANCES :

5.1 Dimensions:

The enclosed drawings are finish machined ones (unless otherwise specified). The castings shall be supplied in rough machined condition with an allowance of 4 to 6mm on the surfaces where machining symbols have been shown on the drawing. Small grooves, steps etc., up to 50 mm (width or size), need not be rough machined.

5.2 Tolerances:

If not specified in the purchasing documents, the general tolerances according to DIN 1683-1, Grade GTB 18 are applicable.

6.0 MANUFACTURE:

6.1 General requirements :

The steel shall be manufactured by an electric melting process or by any other process involving secondary refining. Surface finish of the machined surface shall be as per ordering drawing.

6.2 Welding: Welding shall be performed on heat treated castings only according to the successful welding procedure approval record (WPAR). Area to be welded shall be ground down to the flawless base metal & design welds shall be prepared accordingly. This shall be checked by surface crack inspection. In this case quality level S1 according to AA0850108 shall be achieved. In case of design welding, the weld ends have to fulfill severity level 1 as per AA0850107 over a length of 50 mm.

Before welding of all major defects, the supplier shall hand over to BHEL a documentation of the areas to be prepared for welding & the welding procedure specification (WPS).

Major defects are classified as:-

1. Excavations ready for welding with a length $\geq$ 150 mm.
2. Excavations with a depth $\geq$ 40% of the wall thickness or $\geq$ 25 mm.
3. Any build-up welding greater than 100 cm^2.
4. Unusual large production welding (e.g. weight of filler metal $\geq$ 3 % of the total casting weight) and/or welding situated in high stress of the casting.

These shall be documented by a sketch or photograph noting the appropriate positions and dimensions so that their traceability is assured.

Note: 1. A written permission from BHEL shall be obtained before starting weld repair of all major defects as classified above. All other defects can be repaired after review and permission by BHEL nominated inspection agency.
2. Production welds without post weld heat treatment are not acceptable.

6.3 Weld hardness shall be checked random wise and documented accordingly. The values of 320 HV maximum are allowed.

6.4 Welding filler material shall be covered electrodes E 425B42H5 according to EN 499 or E 7018-1 H4R according to AWS A 5.1-91. The use of other welding filler material is allowed only after written permission from BHEL.

7.0 HEAT TREATMENT :

According to EN 10213.
Normalizing: Heating in the range of 900-980°C, holding time corresponding to wall thickness. If required, tempering in the range of 600 - 700°C, followed by air cooling can be done, to achieve the desired properties.

Stress relieving: The casting shall be stress relieved after rough machining at supplier works. The stress relieving shall be carried out in the range of 600-650°C. However, the actual stress relieving temperature shall be 30 °C below the tempering temperature (incase tempering process is followed). The stress relieving after rough machining can be dropped, if production welding followed by stress relieving is carried out after rough machining of the casting.

The actual heat treatment cycles followed shall be reported in the test certificate.

8.0 FREEDOM FROM DEFECTS:

8.1 Supplier shall ensure that the casting is free of defects like porosity, shrinkage, cracks etc., in the areas which will be subsequently machined at BHEL.

8.2 In case where pressure tightness is called for (though the test may be conducted at BHEL) the required quality shall be ensured to guarantee the same.

8.3 As cast surfaces shall be free from harmful foundry defects like slag inclusions, sand spots, cold shuts, shrinkage, scabs etc.

8.4 Cracks are not permitted on any surface of the castings.

9.0 CHEMICAL COMPOSITION :

The heat analysis of steel shall conform to the following according to EN 10213 in weight %.

Element	Melt analysis	
	Minimum	Maximum
C	0.18	0.23
Si	-	0.60
Mn	0.50	1.20
S	-	0.020
P	-	0.030

The contents of tramp elements shall be as follows:

Element	Minimum	Maximum
Cr	-	0.30
Mo	-	0.12
Ni	-	0.40
V	-	0.03
Cu	-	0.30
Al	-	0.025
As	-	0.020
Sb	-	0.010
Sn	-	0.025

Note: 1) Cr+Mo+Ni+V+Cu ≤1.00%

10.0 MECHANICAL PROPERTIES :

10.1 **Test samples** – The mechanical properties shall be determined on one separately cast test coupon for each heat and heat treatment batch (if the casting weight is less than or equal to 500 kg) or on one integral test coupon (castings having weight more than 500 kg) for each casting. The size of the test coupon shall be selected as appropriate to the thickness of the actual castings and the extent of testing. After casting, the test coupons shall receive a stamp indicating the heat number. It is mandatory to keep the test coupon along with the castings from same heat during each subsequent heat treatment.

10.2 **Supply of keel blocks to BHEL** (only applicable for Outer casing, Inner casing and Steam chambers) – Another integral keel block similar to the size of the keel block already used for testing at suppliers works shall also be casted along with the casting. It shall be stamped with Heat No./P.O. No./HY19570 and also third party stamp and supplied to BHEL after detaching from the casting but tack welded at a suitable location where its removal is easy at BHEL. This test block will be utilized for any retests required at BHEL.

10.3 **Mechanical properties** – the following mechanical properties shall be achieved at room temperature.

0.2% yield strength N/mm^2. (min)	Tensile strength, N/mm^2 (min)	Elongation(l =5d)% (min)	Reduction in area %, (min)	Impact energy, J (See Note (1)) (min.)
240	420-600	22	40	27

Note (1) Average of 3 charpy (2mm V-notch) specimens, where the smallest value shall be at least 21 J.

10.4 **Hardness check –**

1. All welded zones shall be checked for hardness at random and the hardness shall be 320 HV maximum.

2. All castings (weighing less than or equal to 500 kg, for which separate keel block is casted for mechanical testing) shall be subjected to hardness check on three far off locations on the casting. The hardness values shall be within ± 20 BHN of the average of three hardness values tested on the keel block after heat treatment.

11.0 OUTER AND INNER QUALITY / NDE :

The following non-destructive examinations shall be conducted:

11.1 **Ultrasonic Examination:-** Unless otherwise specified in the drawing/order, 100% area of the casting shall be tested by ultrasonic examination . Acceptance norms shall be severity level 1 weld ends and 2 for all other areas, as per AA0850107. Wherever ultrasonic examination is not technically feasible, radiography examination shall be made. In case both are not possible, the same shall be referred to BHEL for clarification and approval.

11.2 **Magnetic Particle Examination:-** Unless otherwise specified in the drawing/order, 100% area of the castings (technically feasible) shall be tested by magnetic particle examination. Acceptance norms shall be severity level 1 for weld ends and 2 for all other surfaces as per AA0850108.

11.3 **Radiographic examination:** Unless otherwise specified in the order, all areas marked on the drawings, high defect level areas as indicated in ultrasonic examination and also the areas which are not feasible to be examined by UT shall be examined by radiographic examination. Acceptance norms shall be severity level 1 for weld ends and 2 for all other areas, as per EN 12681.

12.0 QUALITY PLAN :

12.1 The supplier shall follow the quality plan Ref. BHEL/QP/HY 19570 Rev.07 as per annexure A, unless the conditions stipulated in cl. 12.2 & 12.3 are applicable.

12.2 In case customer/project related additional requirements are applicable in the enquiry/tender, vendor may be asked to submit a separate QP including such requirements.

12.3 In case of new vendors or first time supplies according to drawings mentioned in BHEL enquiry, QP shall be submitted for approval by BHEL.

13.0 TEST CERTIFICATE:

Three sets of the original test certificates (in English) shall be furnished to BHEL with the following details.

(a) Heat no. and order no. on every page.
(b) Material specification HY 19570 Rev.07 and material grade GP 240 GH.
(c) Heat analysis and melting method.
(d) Information about the size of the separately cast sample or the attached sample.
(e) Mechanical test results for each casting or heat treatment load, as applicable.
(f) Hardness test results

(g) Heat treatment charts / cycles actually followed.
(h) Photos or sketches with all recordable areas prepared for welding.
(i) Weld report with the information of PQR, the welders and the used electrodes and copy of written approval for welding by BHEL (in case of major repairs).
(j) Confirmation of the quality ordered.
(k) Records / Reports for NDE.
(l) Dimensional inspection report.

Deviation: Any deviation from this delivery specification has to be reported to BHEL immediately. Any deviation is generally accepted only if this has been approved by BHEL in a written form.

14.0 MARKING:

For castings' the pattern and heat numbers shall be used as identification markings. The pattern number may be applied by casting or with numeral punches depending on the item size. The heat number shall be applied with numeral punches.

In addition to above following information shall also be provided on the castings.
(a) HY 19570 Rev. 07.
(b) Drawing Number and Purchase Order Number.
(c) BHEL appointed inspectors' stamp.

15.0 PACKING, PRESERVATION AND TRANSPORTATION :

The casting shall be suitably packed in a condition to withstand for indefinite time exposure to all climatic conditions without developing any external and internal defects.

The castings shall be properly protected from damage and corrosion during transport. The entire surface of the castings shall be applied with suitable non-greasy anticorrosive coating. Painting is not permitted on any surface. Supplier may use anticorrosive paint HE 1707 (produced by central insulation technology, BHEL, Bhopal) or petrolatum (produced by Bharat petroleum). The overseas supplier may use Tectyle 506 produced by Volvoline, Germany.

16.0 REJECTION AND REPLACEMENT :

The final decision regarding acceptance or rejection rests with BHEL, if the casting is not found as per this specification at any time during further operation on the casting.
The supplier shall replace the rejected casting at this own cost and the rejected castings shall be returned after all commercial terms and conditions are satisfied.

ANNEXURE A (as per clause 12.0)											HY19570REV.07 PAGE 7 OF 8
Vendor's Name & Address		Customer:			BHEL ENQ. NO.						QP No. BHEL/HY19570REV.07
		Project:			Date:						Page: 1 of 2
		Product:			BHEL Spec. HY19570REV.07						
Sl. No.	Characteristics	Type of Check	Quantum	Reference Document	Acceptance Norms	Format of records	Documents to be submitted to BHEL	AGENCY M	C	I	Remarks
1.	Chemical composition	Chemical	Every Melt	HY19570 Rev.07	HY19570 Rev.07	TC	TC	P		V	
2.	Heat treatment	HT cycles review	100%	-do-	-do-	H.T Records	HT Charts, TC	P		V	Final verification of documents.
3.	Keel block identification	Physical	Each casting	Each casting	HY19570 Rev.07	HY19570 Rev.07	Identification report	P		W	If casting weight is more than 500 kg. Refer Cl.10.1
4.(a)	Mech. properties	Mechanical tests	-do-	-do-	-do-	-do-	TC	P		W	Tests shall be conducted on samples selected / identified by BHEL nominated inspection agency.
4.(b)	Mech. properties	Hardness	Weld repaired areas & casting/test coupon	HY19570 Rev.07	HY19570 Rev.07	TC	TC	P		W	Refer clause 10.4
5.(a)	WPS/PQR for repair welding, if any (Based on internal NDT)	Record review	100%	-do- Cl. 6.2	-do-	Welding records. Defecto-gram	Inspection Report. Welder qualification Re-cords	P		V	Defectogram shall be submitted to BHEL for written permission for weld repair.
5.(b)	Welder qualification	Record view	100%	100%	HY19570 Rev.07	HY19570 Rev.07	Welding records	P		V	Review of welder qualification
6.	Stress relieving followed by shot blasting	Record view	100%	HY19570 Rev.07	HY19570 Rev.07	H.T Records	HT Charts, TC	P		V	Refer clause 7.0
7.	Dimensional Inspection	Visual	Each Casting	Spec. & Drg.	Spec. & Drg.		TC	P		W	
8.	Surface quality	MPI	100% technically feasible areas	-do-	-do-	-do-	TC	P		W	

Signature of the Manufacturer with Company Stamp

ANNEXURE A (as per clause 12.0)												HY19570REV.07PAGE 8 OF 8
Vendor's Name & Address		Customer:			BHEL ENQ. NO.							QP No. BHEL/HY19570REV.07
		Project:			Date:							Page: 2 of 2
		Product:			BHEL Spec. HY19570REV.07							
Sl. No.	Characteristics	Type of Check	Quantum	Reference Document	Acceptance Norms	Format of records	Documents to be submitted to BHEL	AGENCY M	AGENCY C	AGENCY I	Remarks
9.	Soundness of material	UT	-do-	-do-	-do-	-do-	TC	P		W	RT films to be reviewed.
		RT	At areas marked in Drg and any other area where UT & MPI are not possible	-do-	-do-	-do-	TC	P		V	
10.	Matching of upper & lower half of casting	Visual	100%	Drg	Drg	TC	Dimensional Inspection Report, TC	P		W	Casting shall be allowed to dispatch as a set only (if ordered as a set).
11.	Marking and punching	Markings	Each casting	Spec. & Drg.	Spec. & Drg.			P		W	
12.	Visual Inspection	Visual check 1) surface finish 2)cleaning of internal surfaces 3)Cleaning of holes, opening etc	Each Casting	Spec. & Drg.	Spec. & Drg.		TC	P		W	
13.	Preservation & Dispatch	Visual	Each casting	Spec. & Drg.	Spec. & Drg.	Records	Records	P		V	Both U/P & L/P castings shall be dispatched as a set only after machining (if ordered as a set).
14.	Documentation & certification		Each casting	Spec. & Drg.	Spec. & Drg.	TC	TC	P		V	TPIA shall certify all documents required as per specification & drawing.

LEGENDS: P PERFORM ;W WITNESS ;V VERIFICATION ; M:MANUFACTURE/SUB-SUPPLIER; C: CUSTOMER (BHEL); I: NOMINATED INSPECTION AGENCY

Signature of the Manufacturer with Company Stamp
(To be submitted along with the technical offer)

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Surface Crack Testing of Steel Castings and Nodular Iron Casting

List of Contents

Revisions: Cl. 33.1.0 of MOM of FC&F+HTM			APPROVED: INTERPLANT MATERIAL RATIONALISATION COMMITTEE-MRC (FCF+HTM)		
Rev. No. 00	Amd.No.	Reaffirmed:	Prepared	Issued	Dt. of 1st. Issue
Dt:	Dt :	Year :	HARIDWAR	Corp. R&D	FEB. 2008

1. Scope of Application

This instruction applies to the surface crack testing (MT, PT) of nodular iron components and steel casting components including production welding e.g. as barrel type casings, inner casings, outer casings, valves, guide blade (vane) carriers, etc. This specification also covers design welding between two cast components and between casting and forging components.

2. Referenced Documents

EN 473, SNT TC 1A, EN 571-1, EN 1289, EN 1290, EN 1291, EN 1369, EN 1370, EN 1371-1, pr EN 1956, EN ISO 3452-3

3. Inspection Purpose

Examination of surface discontinuities caused by manufacturing

4. Stage and Scope of Inspection

- **Steel Castings**

A **fluorescent** magnetic particle examination at
- all inside and outside surfaces after quality heat treatment
- all excavations after removing of unacceptable indications
- all inside and outside surfaces after the last heat treatment in delivery conditions

The quality department has to prepare detailed sketches with the applied clip technique adjusted to the casting to be checked when using stationary magnetic particle test equipment (magnetization of the complete casting or sections of it). These sketches shall be available for the inspection.

- **Nodular Iron Castings**

A **fluorescent** or **"black and white"** magnetic particle examination shall be performed in the double hatched areas (areas with higher requirements; severity level 3 and better) in delivery conditions i.e. in as cast condition or, if carried out, after ferritic heat treatment.

In case of excess material in the testing areas which will be machined off in the final shape, the surface crack testing can be omitted.

Remark for Steel Castings and Nodular Iron Castings

A liquid-penetration test according to EN 571-1 may be applied:
- in areas, which are not accessible for a magnetic particle test
- in areas, which cannot be magnetized sufficiently due to geometry or accessibility
- in case of not interpretable magnetic particle indications
- at non magnetic build-up welding e.g. stellited areas

A detailed description of the test procedure is shown under clause 11.

5. Testing Personnel

The testing shall be carried out with test personnel having certification according to EN 473, according to SNT-TC-1A, or according to any other equivalent international standard for the used method. Following certification levels are prescribed:

- Operator: minimum level 1 for the used method
- Supervisor: minimum level 2 for the used method

An actual list of the operators with the required certifications is to be sent to the customer and must be kept up to date.

6. Inspection Surfaces

The inspection surface must be free from dust, scaling, residual molding material and shot-blast material.

- **Steel Castings**

  Unless otherwise specified in the material specification, the surface condition in the tested areas must meet the minimum requirements 4S1 (for shot-blast areas) and 4S2 (for ground areas) of BNIF 359 according to EN 1370.

  In case of design welding, the root area and the final pass must be ground smoothly or must be machined.

- **Nodular Iron Castings**

  Unless otherwise specified in the material specification, the surface condition in the tested areas (severity level 3 and better) must meet the minimum requirements 4S1 (for shot-blast areas) and 4S2 (for ground areas) of BNIF 359 according to EN 1370.

7. Test Requirements

The testing shall be carried out with naked eye.

8. Test Media

- **Magnetic Particle Test**

  Water soluble fluorescent test suspension with rust protection (grain size < 5 µm)

- **Liquid Penetration Test**

  Colour liquid penetration medium, water or cleaner, wet developer. The test media must be compatible to each other.

9. Test Equipment and Control Equipment (Equivalents are also permitted)

- **Magnetic Particle Test**

  - magnetic particle equipment
  - MTU comparison piece
  - Castrol indicators, indicator A3 (ASTM E 709), or device for tangential field strength
  - UV-lamp

- **Liquid Penetration Test**

  - calibration block 2 according to EN ISO 3452-3 for checking the system power when using other means than spray cans.

10. Viewing Conditions

- **Magnetic Particle Test**

The UV-A radiation must be higher than 10 W/m^2 on the test surface of the casting. The lighting strength of the white light must be higher than 20 lx on the test surface of the casting. The foundries must ensure the above mentioned values in the testing areas. This can be done with darkening means, e.g. tents or black tent cloths.

- **Liquid Penetration Test**

The test is to be performed under natural or artificial illuminating conditions. The test area shall be illuminated steadily. Blinding must be avoided. The lighting strength of the white light on the test surface must be higher than 500 lx.

11. Test Procedure

The severity levels in the different casting areas are shown in the order drawings. All indications, which exceed the acceptability limits of clause 13 and 14 shall be excavated to a flawless base material. A severity level 1 shall be reached for a production welding. The production welding shall be performed according the instruction for the specification of a production welding on castings. Any production welding on nodular iron castings are only allowed with the approval of the customer.

11.1 Magnetic Particle Test

- check the test suspension before testing and when changing the test suspension
- check for sufficient magnetization with Castrol indicators, indicator A3 (ASTM E 709) or measurement of the tangential field strength (reference value 20 – 64 A/cm)
- check of residual magnetization (< 8 A/cm) at the end of the testing; a demagnetization shall be done for residual field strength > 8 A/cm

- **Steel Castings**

- Application of direct current or half wave rectified alternating current; the application of yokes shall be used exceptionally.

- magnetization of an area (about 25 cm x 25 cm) by magnetic flux linkage technique shall be done in two perpendicular directions when applying consumable electrodes or magnetization by magnetic flux linkage technique when applying stationary magnetic particle test equipment (magnetization of the complete casting or sections of it). In this case detailed sketches with the applied clip technique must be prepared for the pattern Nos.

- time of magnetization by wetting > 3 sec
  When applying stationary magnetic particle test equipment (magnetization of the complete casting or sections of it) the wetting must be ensured during the complete magnetization.

- subsequent time for magnetization > 3 sec

- **Nodular Iron Castings**

- application of alternating current
- magnetization of an area with yokes or consumable electrodes in two perpendicular directions
- time of magnetization by wetting > 3 sec
- subsequent time for magnetization > 5 sec

Remark for Steel Castings and Nodular Iron Castings

The checking of the surfaces with UV-lamp shall be done under simultaneous magnetization when using yokes or consumable electrodes. Therefore, if the casting is magnetized and checked in sections, indications with length > 3 mm or diffuse shining indications must be checked once more accurately. When using this procedure, care must be taken also for those areas, which have been already tested. They shall not be again flown over with test suspension.

Arc spots (not to mix up with contact points) shall not result on the casting when using consumable electrodes. Arc spots are not acceptable. They must be removed and rechecked.

11.2 Liquid Penetration Test

The procedure of the test sequence is fixed as follows:

- If necessary, the pre-cleaning shall be done with chemical cleaning media
- complete drying so that neither water nor solvent remains in the surface defects.
- The dye penetration medium can be applied by spray, brush or dip. It is to be assured that the test area will be kept wet during the complete penetration period.
  The casting temperature shall be 5° C – 50° C.
  The penetration time shall be 10 – 15 minutes.
- The excess material of the dye penetrant shall be removed by a suitable procedure.
  (spraying or wiping with a cloth which do not fluff)
- The drying of the test area must be done quickly after removal of the excess dye penetration material. Therefore cloth which is clean, dry and do not fluff or compressed air are suitable; compressed air must be free from water and oil
- The developer must be put on steadily by spraying, so that the test area is even humid and yield a thin steady film.
- The developing time shall be 10 – 15 minutes.
- The first inspection shall be done immediately after the application of the developer. The final inspection shall be done after the developing time.

Remark

If a new test is necessary, e.g. a definite evaluation of the indications was not possible, the entire process of the liquid penetration test must be performed again beginning with the pre-cleaning. The use of other dye penetration or of a similar one from another supplier is not at all allowed.

12. Definition of Indications

On BHEL ordering drawing, quality level of the casting is indicated as 1, 2 or 3. For example, quality level 3 for magnetic particle test means that acceptability limit shall meet the characteristics SM3, LM3 and AM3 according to tables 1 and 2.

- **Non Linear Indications (SM), (SP) or (CP)**

The indications are considered to be non-linear when the length L is smaller than three times the width W.

?

- **Linear Indications (LM), (LP)**

  The indications are considered to be linear when the length L is larger than or equal to 3W.

- **Aligned Indications (AM), (AP)**

  Indications are considered to be aligned in the following cases:
  - non-linear : the distance between indications is less than 2 mm and at least three indications are noted
  - linear : the distance between two indications is smaller than the length L of the longest discontinuity in the alignment

  Indications arranged such in a line are considered to be one common indication. Its length is equal to the overall length L of this alignment.

  Description of abbreviations

  SM: S for surface and M for magnetic particle ;
  SP: isolated indications at liquid penetration test
  CP: area of multiple indications; The distance between the indications cannot be measured (they seem to form only one indication)
  LM: L for linear and M for magnetic particle;
  LP: L for linear and P for liquid penetration test
  AM: A for aligned and M for magnetic particle;
  AP: A for aligned and P for liquid penetration test

13. Classification of the indications and interpretation of results

13.1 General

In order to classify a discontinuity indication, it is necessary to place a 105mmX148mm frame in the most unfavourable location, i.e. showing the greatest severity for discontinuities.

13.2 Non linear Indications

Only those indications with a length greater than L_1 shall be taken into account (see tables 1 and 4). The sum of the surface areas of these indications shall be calculated. The length of these indications shall be measured.

13.3 Linear and Aligned Indications

The length L of the isolated indications greater than the minimum length taken into account, defined by the required severity levels, shall be measured. The sum of the indications included in the 105mmX148mm frame shall be calculated.

14. Acceptability Limit for the Magnetic Particle Test

Table-1: Acceptability Limits for Non-Linear Indications(SM)

Characteristic		Severity Levels			
		SM 1	SM 2	SM 3	SM 4
Length L_1 of the smallest indication to be considered in mm		1.5	2	3	4
Non-linear indications (SM)	maximum total surface area allowed in mm^2	10	35	70	200
	maximum individual length L_2 allowed in mm	2[1)]	4[1)]	6[1)]	10[1)]
1) A maximum number of 2 indications of the designated maximum dimension are permitted.					

Table 2: Acceptability Limits for Linear Indications (LM) and Aligned Indications (AM)

Characteristic		Severity Levels							
		LM 1 AM 1		LM 2 AM 2		LM 3 AM 3		LM4 AM4	
Length L_1 of the smallest indication to be considered in mm		1.5		2		3		4	
Arrangement of indications [1)] isolated (I) or cumulative (C)		I	C	I	C	I	C	I	C
Maximum length L_2 of linear (LM) and aligned (AM) indications allowed depending on the section thickness t, in mm	Section thickness $t \leq 16$ mm	2	4	4	6	6	10	10	18
	Section thickness $16\ mm < t \leq 50$ mm	3	6	6	12	9	18	18	27
	Section thickness $t > 50$ mm	5	10	10	20	15	30	30	45
1) The linear and aligned indications shall be taken into consideration for the calculation of the cumulative length.									

Table 3: Acceptability Limits for Indications in Design Welding

Characteristic	
Linear indications *l* length of indications in mm	1.5
Non-linear indications *d* greatest diameter in mm	3

Groups of acceptable individual indications shall be considered unallowable when they exceed the following limits:

$\Sigma l \leq s$ for L = min. (12s; 150 mm)

In words this means:

Depending on which value is smaller, over a weld length of 150 mm or the length corresponding to twelve times the wall thickness, the cumulative length of several adjacent indications may not exceed the wall thickness. This however only applies to indications which are otherwise acceptable owing to their distance from each other and their individual lengths.

15. Acceptability Limits for the Liquid Penetration Test

Table 4: Acceptability Limits for Non Linear Indications, Isolated (SP) or Clustered (CP)

Characteristic	Severity Levels			
	SP 1 CP 1	SP 2 CP 2	SP 3 CP 3	SP 4 CP 4
Length L_1 of the smallest indication to be considered in mm	1.5	2	3	5
Maximum number of non-linear indications allowed	8	8	12	20
Maximum size of discontinuity indication allowed in mm - isolated indications (SP) - clustered indications (CP)	 3 10	 6 16	 9 25	 14 -

Table 5: Acceptability Limits for Linear Indications (LP) and Align Indications (AP)

Characteristic		Severity Levels							
		LP 1 AP 1		LP 2 AP 2		LP 3 AP 3		**LP4 AP4**	
Length L_1 of the smallest indication to be considered in mm		1.5		2		3		4	
Arrangement of indications [1] isolated (I) or cumulative (C)		I	C	I	C	I	C	I	C
Maximum length L_2 of linear (LP) and aligned (AP) indications allowed depending on the section thickness t, in mm	Section thickness $t \leq 16$ mm	2	4	4	6	6	10	10	18
	Section thickness $16 \text{ mm} < t \leq 50$ mm	3	6	6	12	9	18	18	27
	Section thickness $t > 50$ mm	5	10	10	20	15	30	30	45

1) The linear and aligned indications shall be taken into consideration for the calculation of the cumulative length.

Table 6: Acceptability Limits for Indications in Design Welding

Characteristic	
Linear indications l length of indications in mm	2
Non-linear indications d greatest diameter in mm	6

Groups of acceptable individual indications shall be considered unallowable when they exceed the following limits:

$\Sigma l \geq$ s for L = min. (12s; 150 mm)

In words this means:

Depending on which value is smaller, over a weld length of 150 mm or the length corresponding to twelve times the wall thickness, the cumulative length of several adjacent indications may not exceed the wall thickness. This however only applies to indications that are otherwise acceptable on the basis of their distance from each other and their individual lengths.

15. Documentation

The test report must contain the following information:

- supplier's name
- Identification of the component on every page
- Condition of casting at time of examination
- Material
- Surface conditions
- Place, date, signature of the operator
- Name, certification and signature of the supervisor

Magnetic Particle Test

- test method, designation of applied equipment
- mode of magnetization
  - Yoke magnetization (J)
  - magnetization by current flowed through conductor (L)
    magnetization by fixed coils (LS)
    magnetization by movable conductor (LK)
  - magnetic flux linkage technique (S)
    self magnetic flux linkage technique (SS)
    induction magnetic flux linkage technique (SI)
- test media

The magnetic particle inspection document shall be furnished according to **Annexure-1**.

Liquid Penetration Test

Description of the used liquid penetration system with manufacturer's trademark, product explanation and the batch-No. of the test media.

The liquid penetration inspection document shall be furnished according to **Annexure-2**.

CORPORATE STANDARD

Annexure-1

Model of a Magnetic Particle Inspection Document according to EN 1369

Company	**Magnetic Particle Inspection Document**		No.	
			Page	
			According to	
Customer	Order No.			
Specification	Material		Heat No.	
Identification	Quantity	Casting designation	Lot No.	Drawing No.

area examined 100% testing scheme cavity root	
Stage after heat treatment before stress relieving	
testing conditions	
apparatus	
magnetic particle reference	
surface condition shot blasted ground machined	
magnetization method	
testing material	
rod spacing magnetizing current	mm A
type of current alternating direct	
tangential field strength	A/mm
field indicator	
testing results	
according to	
non-conformable note	
continuation sheet	
inspection authority	
quality assurance section	
date/place	
signature of operators	
signature of QA manager	

If applicable, tick the relevant box.

Annexure-2

Model of a Liquid Penetration Inspection Document according to EN 1371-1

Company	**Liquid Penetration Inspection Document**		No.	
			Page	
			According to	
Customer	Order No.			
Specification	Material		Heat No.	
Identification	Quantity	Casting designation	Lot No.	Drawing No.

area examined
100%
testing scheme
cavity root

Stage
after heat treatment
before stress relieving

Dye penetrant Trade mark Batch no.	
Excess penetrant remover Trade Mark Batch no.	
Developer Trade mark Batch no.	

testing conditions

surface condition: shot blasted / ground / machined	
Casting Temperature : 58C to 148C / 158C to 358C / 368C to 558C	
Pre-cleaning	yes / no
Penetrant application: Penetration time	brush / spray / dip minutes
Penetration removal	cleaning with water / solvent
Drying time	minutes
Drying temperature	8C
developer application: developing time	brush / spray / wet / dry minutes
illumination:	Natural / artificial

testing results

according to	
non-conformable note	
continuation sheet	
inspection authority	
quality assurance section	
date/place	
signature of operator	
signature of QA manager	

if applicable, tick the relevant box.

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Ultrasonic Testing of Steel Castings

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Revisions : **Cl. 33.1.0 of MOM of FC&F+HTM**			**APPROVED :** INTERPLANT MATERIAL RATIONALISATION COMMITTEE-MRC (FCF+HTM)		
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Dt:	**Dt :**	**Year :**	**HARIDWAR**	**Corp. R&D**	**FEB. 2008**

CORPORATE STANDARD

1. Scope of Application

This instruction applies to the Ultrasonic testing of steel casting components including production welding, e.g. barrel type casings, inner casings, outer casings, valves, guide blade (vane) carriers, half rings, valve inserts, valve covers, etc. This specification applies also for design welding between two cast components and between casting and forging components.

2. Referenced Documents

EN 473, SNT TC 1A, EN 1370, EN 27963, EN 12223, pr EN12680-2, AVS D 58 A/000

3. Inspection Purpose

Examination of surface and volume discontinuities caused by manufacturing

4. Point of Time and Scope of Inspection

4.1 First Testing after Quality Heat Treatment

The castings shall be tested to 100 % after quality heat treatment. Detailed sketches with description of the applied casting technology (gatings, feedings, risers, chills) shall be made available upon request during acceptance inspection by the Quality Department. In case of non-availability of such documents the procedure corresponding to clause 13.1 is to be applied.

4.2 Testing after last Heat Treatment

Cross sections, radii, production welding and design welding are to be tested after last heat treatment. A detailed description of the test procedure is shown under clause 13.2.

5. Testing Personnel

Testing personnel with certification according to EN 473 (level 1 according to SNT TC 1A or an equivalent standard) can be employed, if there is any supervisory personnel with certification level 2 according to EN 473 (level 2 according to SNT TC 1A or an equivalent standard). The personnel must be able to apply DGS method.

An actual list of the operators with the required certification is to be sent to the customer and must be kept up to date.

6. Inspection Surfaces

The inspection surface must be free from dust, scaling, residual molding material and shot-blast material. The surface condition in the testing areas must meet the minimum requirements 3S1 (for shot-blast areas) and 3S2 (for ground areas) of BNIF 359 according to EN 1370. In case of design welding the root pass and the final pass must be ground evenly or must be machined. In any case, a satisfactory coupling of the transducer must be ensured.

7. Ultrasonic Test Equipment

USD15, USN52 (digital), USIP11, USM3-S, USL31 and other equivalent instruments.

8. Transducers

The transducers must be used according to the tables 3 and 4. Equivalent transducers are permitted.

To match the casting shape, fit the probe shoes always when applying shear wave probes, especially twin-crystal shear wave probes.

9. Coupling Medium

Paste, glycerin, oil or other equivalent couplent.

10. Calibration of Sound Path Distance

- **Straight Beam Probes**

A steel cast reference block is to be used for calibration of sound path distance (e.g. a stepped wedge) or the calibration can be done on the casting itself.

- **Angle Beam Probes**

The calibration block No. 1 with radius 100 mm according to EN 12223 or the calibration block No. 2 with radius 25 mm according to EN 27963 is to be used for calibration of sound path distance (see supporting data sheet).

11. Sensitivity Calibration

- **Straight beam probe**

The sensitivity calibration will be carried out by reflecting sound off the opposite face of the casting (parallel back-wall). An area without indications must be used for the calibration. The sensitivity for scanning must be calibrated in such a way that the amplitude of the flat-bottomed holes with diameters according to table 1 shall be at least about one fifth of the screen height at the end of the test range. Especially useful for scanning are DGS curves fed into the UT device or DGS scales attached to the screen. For the latter case the 6mm DGS-curve is to be used for the 3 mm DGS-reference line (gain surcharge of 12 dB).

Table 1: Requirements of ultrasonic testability (valid for 2 and 4 MHz)

wall thickness (mm)	flat-bottomed-hole (FBH) diameter to be detected (minimum detectability) (mm)
≤ 100	2
> 100 to ≤ 300	3
> 300 to ≤ 600	4
Areas with severity level 1 like weld preparation ends and sealing faces	1.5
design welding	1.5 (for radial direction of scanning)

If, in the search of discontinuities, an increased noise level, accumulation of indications or other observations imply that the reduction of back-wall echo exceeds the permissible level (see table 2), the testing shall be done locally with reduced sensitivity. In this case, the reduction of back-wall echo indications shall be measured quantitatively.

- **Angle beam probes**

The calibration block No. 1 with radius 100 mm according to EN 12223 or the calibration block No. 2 with radius 25 mm according to EN 27963 is to be used for the sensitivity calibration (see corresponding data sheet).

The sensitivity of the testing system must be adjusted such that the echo levels for general casting volumes and production welding gain about 5 % of screen height. However a testing sensitivity of 1.5mm disc reflector is to be aimed at.

- **Twin Crystal Angle Beam Probes**

The sensitivity and the testing system for twin-crystal angle beam probes are checked by watching the dynamic characteristic at an as cast rough surface standing perpendicular to the incident surface. For this method the echo height shall be about 80 % screen height at sound path distance of 20 mm.

When all surfaces of the casting are machined the sensitivity can be adjusted at a 1.5mm side drill hole. In this case the echo height shall adjust to 80 % screen height and give a gain surcharge of 8 dB.

- **Testing of Design Weldings**

For the testing of design weldings, one of the following methods shall be applied:

Method 1: The reference line is a distance amplitude correction curve (DAC) of a 0.75mm side drill hole (SDH). A 0.75 mm diameter side drill hole (SDH) can be represented by a 3mm diameter SDH, if the distance amplitude correction curve (DAC) of a 3mm diameter SDH is reduced by 50%.

Method 2: The reference line of 1.5mm disc reflector is to be produced on the screen for each probe for testing of design welding. A sound attenuation of 8 dB/m must be considered for the test frequency of 2 MHz and 20 dB/m for 4 MHz.

The applicable method shall be recorded in the test report

Remark

The notable amplification values in the various wall thickness areas shall be documented for straight beam and angle beam probes with reference to table 6.

If this minimum testing sensitivity is not possible to adjust, the smallest disc reflector (minimum detectable size) which can be detected is to be recorded in the test report. Additionally corrective measures shall be agreed with BHEL.

The minimum detectable flaw size has to be determined as follows:

a) Adjusting the back wall echo to 40 % screen height.

b) The amplification has to be increased until the noise level reaches in average 20 % screen height.

c) Determination of equivalent flaw size from the DGS diagram in consideration of the corresponding maximum sound path.

12. Evaluation and Recording of Indications

- **Straight Beam Probes**

All back-wall echo reductions or echo indications as shown in table 2 are to be evaluated if they are not dependent upon casting shape or coupling. They shall be documented according to table 7, if their recordable limits meet those in figures 3 and 4 (from draft of EN 12680-2).

Table 2: Ultrasonic Signals to be evaluated (Valid for a Frequency of 2 and 4 MHz)

section thickness in discontinuity area mm	reduction of back-wall echo dB	flat bottomed hole diameter mm
≤ 100	> 12	2
> 100 to ≤ 300	> 12	3
> 300 to ≤ 600	> 12	4
areas with severity level 1 like weld preparation ends and sealing faces	-	1.5 [1)]
design welding	-	2 [2)]
1.) Acceptability limits see table 5		
2.) Acceptability limits see figure 5		

- **Angle Beam Probes and Twin Crystal Angle Beam Probes**

In all casting areas (except design welding) all echo indications with an amplitude height of 6 dB above noise level are to be evaluated according to figure 2 (draft EN 12680-2), if they point at a length and/or depth extension.

Single indications must be evaluated only in quality class 1 areas (acceptability limits see table 5, pr EN 12680-2).

All indications in design welding which reach the reference line must be considered, if they point at a length and/or depth extension. They must be evaluated according to figure 5. Indications without measurable extension can be accepted with maximum 6 mm disc reflector (decision level; compare also clause 15 - tandem testing).

13. Test Procedure

13.1 First Testing after Quality Heat Treatment (Minimum Scope of Inspection)

Table 3: Selection of Transducer for First Testing

Testing areas	Transducer	Scope of Inspection
general casting areas section thickness up to 60 mm or at one-sided accessible areas **additionally**	B2S or MB4S	100 %
	twin crystal straight beam probe	100 %
severity level 1 – areas like weld preparation ends and sealing faces	TMAPF-60 *or TS-60* twin crystal straight beam probe	100 % in four directions 100 %
severity level 1 – areas section thickness > 60 mm and/ or with one-sided accessibility **additionally**	MWB45-4 transducer according to figure 1	100 % in four directions 100 % in two circum-ference directions
Accessible only from outside surface cylindrical areas	TMAPF-60 or TS-60 MWB45-4 transducer according to figure 1	100 % in four directions 100 % in two circum-ference directions
areas, which cause planar defects e.g. risers, iron chills, radii (concave and convex), cross sections	TMAPF-60 or TS-60 MWB45-4 or MWB60-4 at long sound path distance	100 % in four directions

Remark

If the testing personnel have not detailed description about the casting technology, the castings must be tested - as far as possible - to 100 per cent with the transducer TMAPF-60 or TS-60.

* TMAPF-60: Twin crystal 60 degree angle probe
* TS-60 : Single crystal 60 degree angle probe

13.2 Testing after last Heat Treatment (Minimum Scope in Delivery Condition)

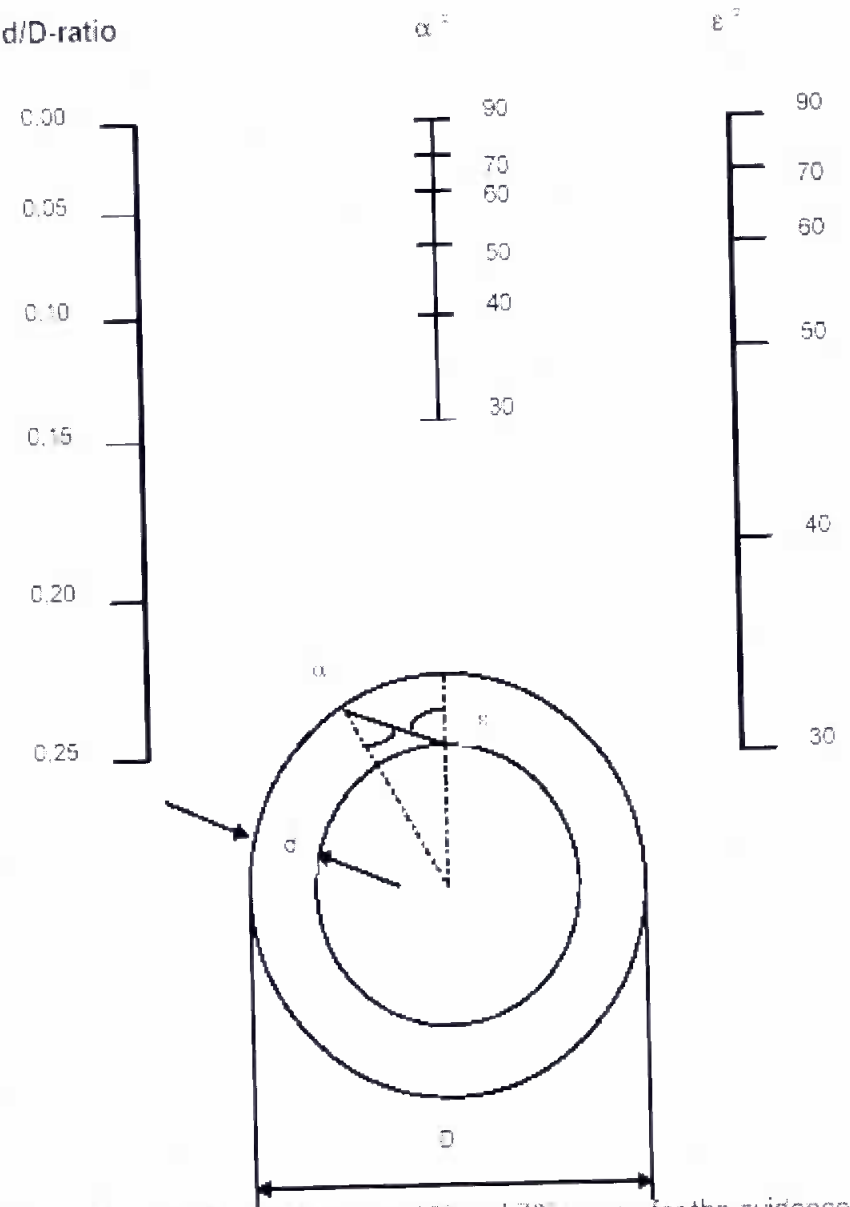
Table 4: Selection of Transducer after the last Heat Treatment

Testing areas	Transducer	Scope of Inspection	
accessible radii	TMAPF-60 */ TS-60 *	100 % in four directions	
production welding	twin crystal straight beam probe	100 %	
	TMAPF-60 or TS-60	100 % in four directions	
depth > 30 mm **additionally**	MWB45-4	100 % in four directions	
evaluation of recordable indications	according to first testing	100 %	
design welding [1]		accessible only from outside surface [2]	Accessible from inside and outside surface [3]
SECTION THICKNESS ≤ 30 MM	twin crystal straight beam probe	100 %	100 % from outside surface
	TMAPF-60 or TS-60	100 % in four directions	100 % from outside surface
section thickness > 30 mm	TMAPF-60 or TS-60	100 % in four directions	every surface 100 % in four directions
	MWB45-4 and/or WB45-2	100 % in four directions	100 % in four directions
	MWB60-4 and/or WB60-2	100 % in four directions	100 % in four directions
	transducer according figure 1	100 % in two circum-ference directions	-
	B2S or MB4S	100 %	100 % from one surface
section thickness ≥100 mm **additionally tandem testing** [4]	MWB45-2; MWB45-2 WB45-2 (10X20); WB45-2	100 % in one direction	100 % in one direction

1) For angle transducers all tests are always performed at half skip distance. If the design welding are only accessible from the outside surface the complete testing must be performed in skip distance.
2) Select probe for transverse testing eventually according to fig.1
3) If welding is accessible from inner and outer surface, test areas can be chosen in such a way that 60% of each of the cross section can be covered.
4) The root volume can be exceptionally radiographed after consultation with the customer. In this case the acceptance limits of **Annexure-1** table 2 are valid

* Equivalent transducers are permitted.

Figure 1: Diagram for Determination of Incidence Angle ε as Function of curvature Geometry for Evidence of Cracks at the Opposite Surface



Remark

The incidence angle ε shall range between 35° and 70°, resp., for the evidence of cracks. If this cannot be realized (e.g. thick walled castings), the beam angle of incidence can be chosen exceptionally such way that the centre beam of the sound fields meets the inner surface tangentially (touching entry).

13.3 Selection of Test Frequency

Transducers according to table 3 are to be applied. Transducers with a frequency of 2 MHz are to be used preferably for straight direction of scanning. Transducers with a frequency of 4 MHz are to be used preferably for scanning with angle beam probes and twin crystal angle beam probes.

13.4 Determination of the Sizes of Discontinuities

Further transducers can be used for the evaluation of discontinuities.

Discontinuity dimensions shall be determined with probes with the smallest possible sound beam diameter at the discontinuity location.

Reflectors have only a measured length or depth extension, if their dimension is bigger than the sound beam diameter at the reflector location.

The sound beam diameters of the single transducers depending on path length according to draft EN 12680-2 is shown in **Annexure-2**.

13.4.1 Determination of Discontinuities Sizes mainly parallel to the Surface

The boundaries of discontinuities which meet or exceed the limits according to table 2 are to be identified by moving transducer over the test surface to those positions where the echo height decreases to 6 dB below the last recordable maximum for the discontinuities. The determination of the depth extension is performed as far as possible from opposite sides.

13.4.2 Determination of the Sizes of Discontinuities Perpendicular to the Surface

The determination of depth extensions with twin crystal testing occurs by means of the so-called "tenth value method" (20 dB drop). The depth extension of discontinuities can be determined after examination of the indications normally under consideration of sound path distances by transducer movement where the echo heights reach 100 % and at both sides 10 % (20 dB-drop). This value gives the discontinuity dimension in through-wall direction. The path distances are to be cut in half when 60°-beam direction is applied. The discontinuity length is to be measured according to the half-value method (6 dB drop).

Remark

The measured dimensions in through-wall direction reflect the reality only largely, if there are planar defects, i.e. a "clear" finding can only occur out of two directions.

14. Acceptability Limits

Table 5: Acceptability Limits for Discontinuities without Measurable Dimensions for Example in Weld on Ends and Sealing Faces (Severity class 1) Detected with Normal and Angle Probes

Quality Class	Smallest comparison reflector size to be considered		Acceptability limits [4]	
	Flat-Bottomed-Hole mm	Side Drilled-Hole mm	Number max.	Distance mm min.
1 [1]	1.5	0.75 [2) 3)]	6	12

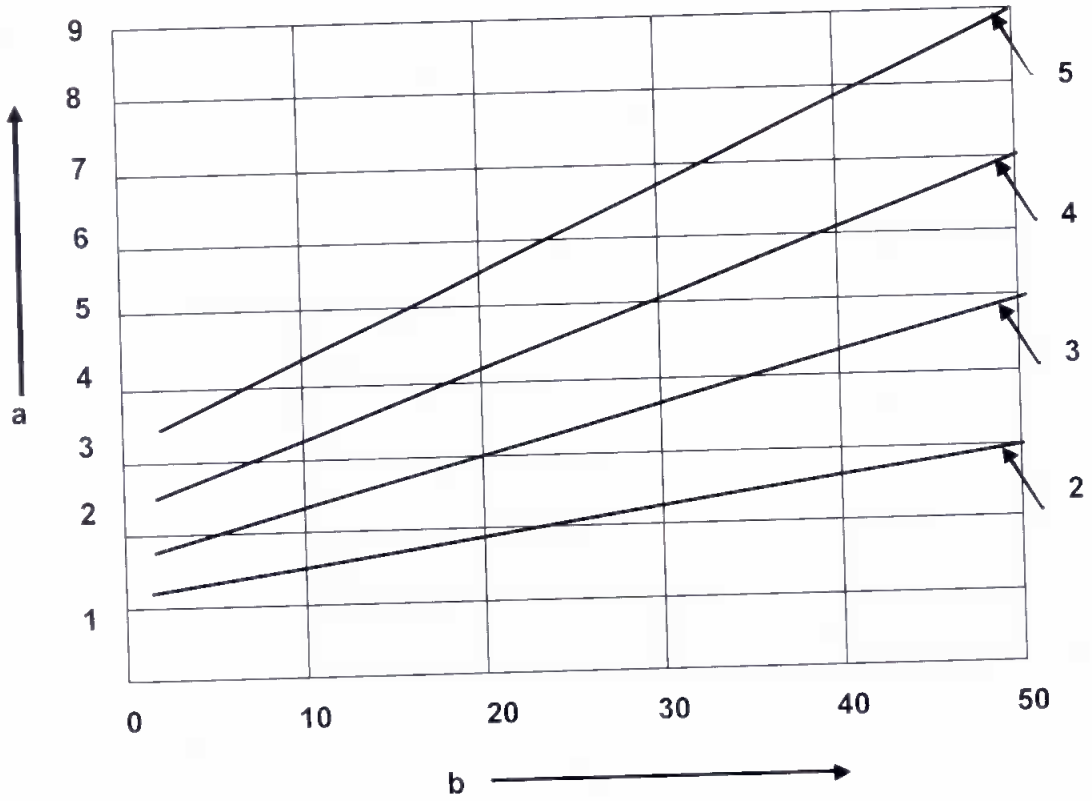
1) Severity level 1 applies to the complete wall thickness of weld on ends.
Indications with measurable dimensions are not permissible for severity level 1.

2) Applicable to angle probes with the frequency of 4 MHz

3) A 0.75 mm diameter side drill hole (SDH) can be represented by a 3 mm diameter SDH, if the distance amplitude correction curve (DAC) of a 3 mm diameter SDH is reduced by 50 %

4) Indications are acceptable irrespective of their number if they are more than 15 mm apart from each other.

Figure 2: Acceptance Limits for Planar Indications mainly Orientated perpendicular to the Surface Detected with Angle Probes



Legend

a: Largest acceptable individual indication area in cm"
b: Distance from test surface in mm
2: Severity level 2
3: Severity level 3
4: Severity level 4
5: Severity level 5

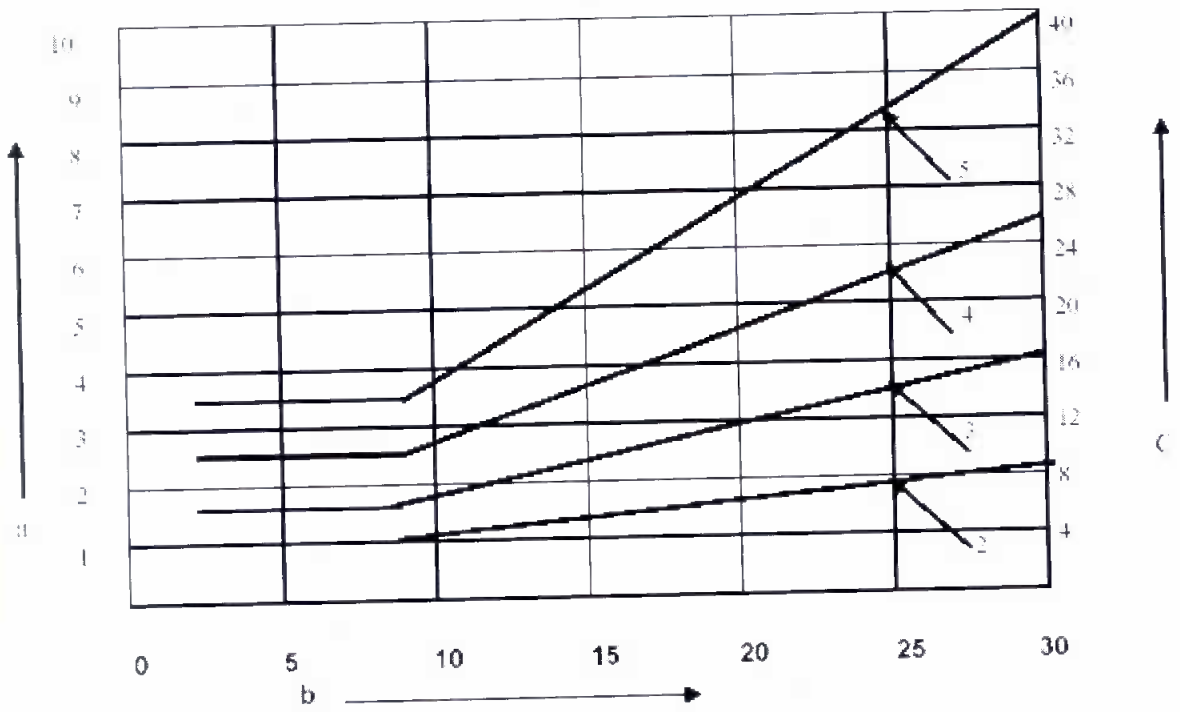
Remark

The maximum depth extension shall not exceed 10 % of the wall thickness, except indications with measurable length ≤ 10 mm. Such indications shall not exceed a depth extension of 25 % of the wall thickness or 20mm, whichever is less. The area A of an indication with measurable length but non-measurable depth extension shall be estimated as follows:

A = 0.3 cm x measured length in cm [cm"]; but the maximum acceptable length is 75 mm

The minimum distance between indications as criterion for evaluation as an individual indication (or indication area) perpendicular or lateral to the surface shall be 10 mm.

Figure 3: Recording and Acceptance Limits for Non-planar Indications with Measurable Dimensions in the Rim Zone Detected with Normal Probes. (The Rim Zones are defined as 1/3 of Nominal Section Thickness or maximum 30 mm)



Legends

a: Smallest indication area to be recorded in cm″
b: Shortest distance from test surface or back wall in mm
c: Largest acceptable individual indication area in cm″
2: Severity level 2
3: Severity level 3
4: Severity level 4
5: Severity level 5

Remark

Special rim zones (severity level 2) are marked in the order drawing; these can be thicker than 30 mm. The maximum acceptable single indication in these areas is 8 cm ″.

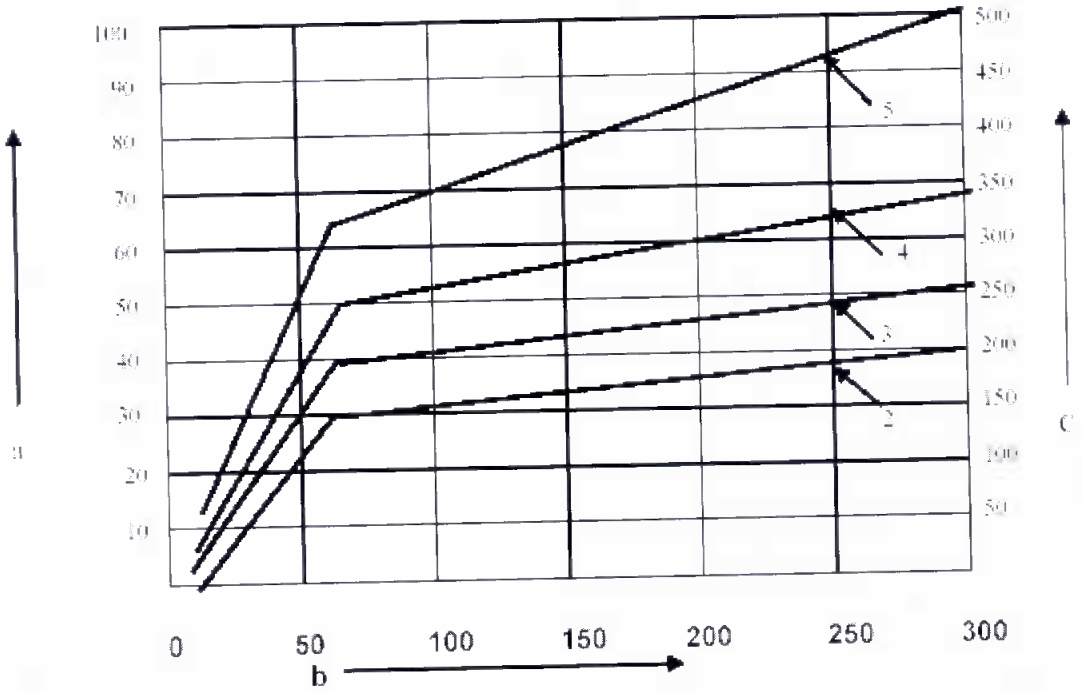
The maximum acceptable depth extension of discontinuities or indication areas shall not exceed 15 % of the rim zone thickness.

The area A of an indication with measurable length but non-measurable depth extension shall be calculated as follow:

A = 0.3 cm x measured length in cm [cm″]; but the maximum acceptable length is 75 mm

The minimum distance between indications as criterion for evaluation as an individual indication or indication area perpendicular or lateral to the surface shall be 10 mm.

Figure 4: Recording and Acceptance Limits for Nonplanar Indications with Measurable Dimensions in the Core Zone Detected with Normal Probes



Legend

a: Smallest indication area to be recorded in cm^2
b: Shortest distance from test surface or from back wall in mm
c: Largest acceptable individual indication area in cm^2
2: Severity level 2
3: Severity level 3
4: Severity level 4
5: Severity level 5

Remark

The maximum acceptable depth extension of discontinuities or indication areas shall not exceed 15 % of the nominal wall thickness.

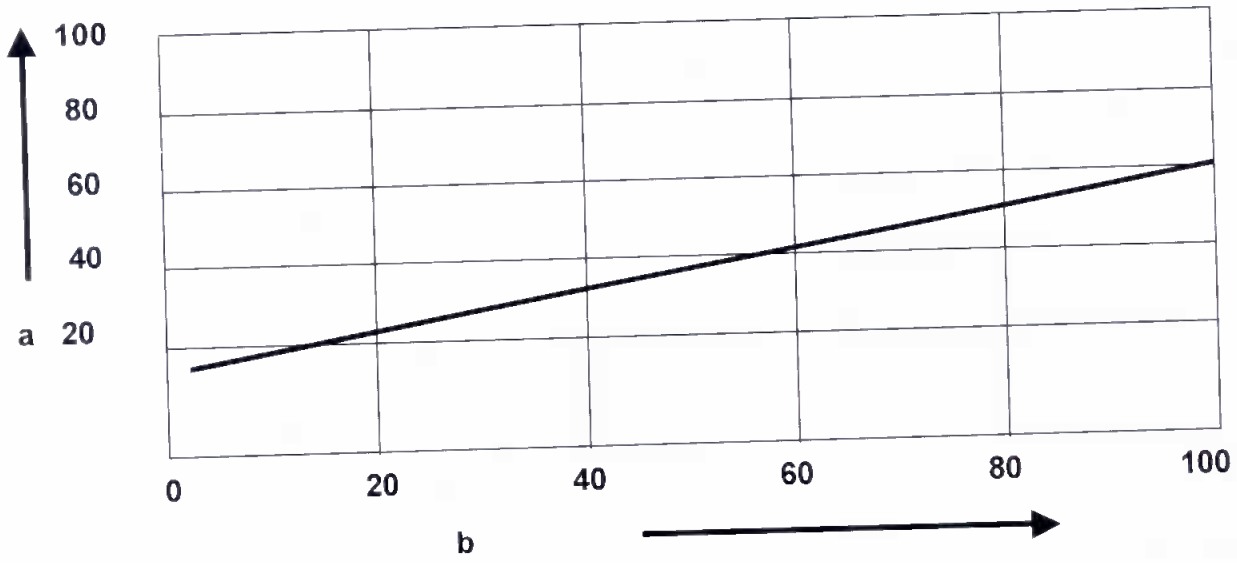
The area A of an indication with measurable length but non-measurable depth extension shall be calculated as follow:

A= 0.3cmxmeasured length in cm [cm^2]; but the maximum acceptable length is 180mm

The minimum distance between indications as criterion for evaluation as an individual indication or indication area perpendicular to or lateral to the surface, shall be 20 mm.

If the indication is in the mid zone, which does not exceed 10 % of the section thickness and is classified as a mid zone shrinkage, then, in case of severity level 2 to 4, 50 % higher values than those in the diagram are permitted; **or** unacceptable indications by UT - clearly positioned in the core zone - can be radiographed according to DIN 54111-2. The severity level for RT can be one grade lower as for UT (e.g. level 3 instead of level 2, compare as per **Annexure-1**, table 1).

Figure 5: Acceptance Limits for Indications in Design Weldings Detected with Normal and Angle Probes



Legend
a: maximum acceptable reflector length in mm
b: minimum distance from surface in mm

Remark

The maximum acceptable indication length is 60 mm for severity level 2 in design welding with nominal wall thickness > 200 mm.

Every indication which infer to measurable depth extensions as e.g. cracks or binding defects are generally **not** acceptable.

The minimum distance between indications as criterion for evaluation as an individual indication or indication area perpendicular to or lateral to the surface, shall be 20 mm.

Defect lengths (cumulative) are only acceptable up to maximum 3 x a per meter joint weld.

Unacceptable indications by UT can be radiographed according to EN 1435 in comparison to the Ultrasonic test. The evaluation shall be performed according **Annexure-1** , table 2.

15. Tandem Testing

- **Distance Calibration**

The probes are arranged at the component to be tested in such a way that the V through sonic echo signal of the component is placed in the center of the UT device screen. This indication corresponds with the distance indication for a reflector in the center of the test zone in question which is perpendicular oriented to the incidence surface. It is to be assured when adjusting the screen signal spreading that a sound path difference of at least 80 mm (640 of through sonic echo) can be evaluated.

- **Sensitivity Calibration**

The sensitivity calibration is done by V through sonic echo at the component. The transfer inconsistency is to be considered for guarantee of the registration limit. For that purpose the V through sonic level in dB is to be determined at least at five representative locations within the test area with constant probe distance.

$$\text{mean value} = \frac{\text{sum of single values}}{\text{number of single values}}$$

The adjusted test sensitivity is the result of the dB value of the basic sensitivity completed with the $\Delta V_{DGS=6\ mm}$ amplification according to the zone classification tables.
All echo indications to be evaluated must be clearly visible on the screen (minimum 2/5 screen height).

- **Probe Distances**

The distances of the probes for the V through sonic echo are defined by the distance Y_V of the sound penetration points at which the through sound indication gain it's maximum echo height. The distances of the probes result for various zone depths when moving both probes until the sound penetration points have reached the distance Y_m.

- **Test Performance**

The manual tandem testing must be performed separately for every depth zone. The coupling of the both probes is to be supervised by watching the noise level.

- **Determination of Reportable Length of Indications**

The reportable length of an indication is defined by the parallel shifting of the probe system until the echo decreases by 12 dB on both sides.

- **Registration of Indications**

For registration of indications the echo height which exceeds the registration limit of 6mm DGS by 6 dB and the corresponding depth position of the zone must be reported about.

Further details for documentation see clause 16.

Zone Classification for the Probes MWB45-2

wall thick-ness	zone	b_o [mm]	b_m [mm]	b_u [mm]	y_m [mm]	$\Delta V_{KSR=6mm}$ [dB]	S_{ges} [mm]
100	1	15	28	37	144	13.5	283
	2	37	55	62	90	16.5	283
	3	62	75	85	50	17	283
110	1	15	31	41	158	12	311
	2	41	61	68	98	16.5	311
	3	68	82	93	56	17.5	311
120	1	15	33	40	174	11.5	340
	2	40	63	73	114	15.5	340
	3	73	90	105	60	18	340
130	1	15	36	43	188	12	368
	2	43	68	79	124	16.5	368
	3	79	97	115	66	18.5	368
140	1	15	39	47	202	14	396
	2	47	80	93	120	20	396
	3	93	111	125	58	21	396
150	1	15	42	50	216	14.5	425
	2	50	86	100	128	21	425
	3	100	119	135	62	22	425

b_o = distance from the test surface to the upper zone boundary in [mm]
b_m = distance from the test surface to the zone center in [mm]
b_u = distance from the test surface to the lower zone boundary in [mm]
y_m = distance of sound penetration points at parallel surfaces in [mm]
$\Delta V_{KSR6\ mm}$ = add on to basic sensitivity in [dB]
S_{ges} = total sound path between sender and receiver in [mm]

Zone Classification for the Probes MWB45-2

wall thick-ness	zone	b_o [mm]	b_m [mm]	b_u [mm]	y_m [mm]	$\Delta V_{KSR=6mm}$ [dB]	S_{ges} [mm]
160	1	15	27	42	266	21.5	452
	2	42	56	68	208	21.5	452
	3	68	81	94	158	23	452
	4	94	107	120	106	24	452
	5	120	131	145	58	24.5	452
170	1	15	29	45	282	22	481
	2	45	59	72	222	22	481
	3	72	86	100	168	23.5	481
	4	100	114	127	162	24.5	481
	5	127	139	155	62	25	481
180	1	15	31	48	298	22.5	509
	2	48	62	76	236	22.5	509
	3	76	91	106	178	24	509
	4	106	121	134	118	25	509
	5	134	147	165	66	25.5	509
190	1	15	33	51	314	23	537
	2	51	65	80	250	23	537
	3	80	96	112	188	24.5	537
	4	112	128	141	124	25.5	537
	5	141	155	175	70	26	537
200	1	15	27	37	346	19.5	566
	2	37	52	63	296	20.5	566
	3	63	79	93	242	23.5	566
	4	93	109	124	182	24.5	566
	5	124	139	154	122	25	566
	6	154	169	185	62	25.5	566

b_o = distance from the test surface to the upper zone boundary in [mm]
b_m = distance from the test surface to the zone center in [mm]
b_u = distance from the test surface to the lower zone boundary in [mm]
y_m = distance of sound penetration points at parallel surfaces in [mm]
$\Delta V_{KSR6\ mm}$ = add on to basic sensitivity in [dB]
S_{ges} = total sound path between sender and receiver in [mm]

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Zone Classification for the Probes MWB45-2 (transducer size 10X20; 20X22)

wall thick-ness	zone	b_o [mm]	b_m [mm]	b_u [mm]	y_m [mm]	$\Delta V_{KSR=6mm}$ [dB]	S_{ges} [mm]
210	1	15	28	39	364	19.5	594
	2	39	55	66	310	21	594
	3	66	83	98	254	24	594
	4	98	114	130	192	25	594
	5	130	146	162	128	25.5	594
	6	162	177	195	66	26.5	594
220	1	15	29	41	382	19.5	622
	2	41	58	69	324	21	622
	3	69	87	103	266	24	622
	4	103	119	136	202	25.5	622
	5	136	153	170	134	26.5	622
	6	170	185	205	70	27.5	622
230	1	15	31	43	398	20	650
	2	43	61	72	338	21.5	650
	3	72	91	108	278	24.5	650
	4	108	124	142	212	26	650
	5	142	160	178	124	27	650
	6	178	193	215	74	28	650
240	1	15	32	49	416	22.5	679
	2	49	67	80	346	22	679
	3	80	101	117	278	25.5	679
	4	117	135	153	210	27	679
	5	153	170	188	140	28	679
	6	188	204	225	72	28.5	679
250	1	15	33	51	434	22.5	707
	2	51	70	83	360	22.5	707
	3	83	105	122	290	26	707
	4	122	141	159	218	28	707
	5	159	177	196	146	28.5	707
	6	196	212	235	76	28.5	707

b_o = distance from the test surface to the upper zone boundary in [mm]
b_m = distance from the test surface to the zone center in [mm]
b_u = distance from the test surface to the lower zone boundary in [mm]
y_m = distance of sound penetration points at parallel surfaces in [mm]
$\Delta V_{KSR6\ mm}$ = add on to basic sensitivity in [dB]
S_{ges} = total sound path between sender and receiver in [mm]

16. Documentation

The test report must contain the following information:

- supplier's name
- Identification of the test component on every page
- Condition of casting at the time of examination
- Material
- Surface conditions
- Ultrasonic test device, identification of the applied transducers (type, frequency, angle)
- Sound velocities, minimum detectable flaw size if necessary
- Values of sound path distance and sensitivity calibration according to table 6
- Name, certification and signature of the supervisor
- Recordable indications must be documented according to table 7 and must be documented in sketches which show the positions at the casting and the size of their indication
- Indications beyond acceptance level must be documented in sketches (to scale) to allow proper evaluation and when possible clearance for special acceptance.

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Table 6: Sensitivity Calibration

Probe	*Calibrat. reflect.*	S_j *Beam path* [mm]	V_G [dB]	ΔV [dB]	ΔV_T [dB]	V_K [dB]	V_{ges} [dB]	KSR *EFH* [mm]

Legend:

V_G: *base sensitivity*
ΔV : *difference of gain according to DGS-diagram*
ΔV_T: *transfer correction*
V_K: *correction value according to DGS-diagram*
V_{ges}: *total sensitivity*

Table 7: List of Discontinuities

No.	*Insp. Area*	*Probe*	*length* [mm]	*width* [mm]	*depth* [mm]	*Extension of depth* [mm]	*Wall-thickness* [mm]	RES *BEA* [dB]	KSR *FBH* [mm]	*Remarks*

Table 1: Maximum Permissible Discontinuities of Radiographic Testing in comparison to the Ultrasonic Testing from the Basic Material of the Casting

Defect				Maximum permissible defect for Quality class	
Type	Code letter as in ASTM[1)]	For section thick-ness in mm	Assessment as in ASTM[1)]	2	3
Blowholes	A	up to 50 over 50 up to 115 over 115 up to 300	E446 E186 E280	A3 A3 A3	A4 A4 A4
Non-metallic inclusions	B	up to 50 over 50 up to 115 over 115 up to 300	E446 E186 E280	B3 B3 B3	B4 B4 B4
Shrinkage	C	up to 50 over 50 up to 115 over 115 up to 300	E446 E186 E280	Ca3,Cb3, Cc3, Cd3 Ca3, Cb3, Cc3 Ca3, Cb3, Cc3	Ca4, Cb4, Cc4, Cd4 Ca4, Cb4, Cc4 Ca4, Cb4, Cc4

1) ASTM-E 446 Standard reference radiographs for steel castings up to 2 in. (51 mm) in thickness

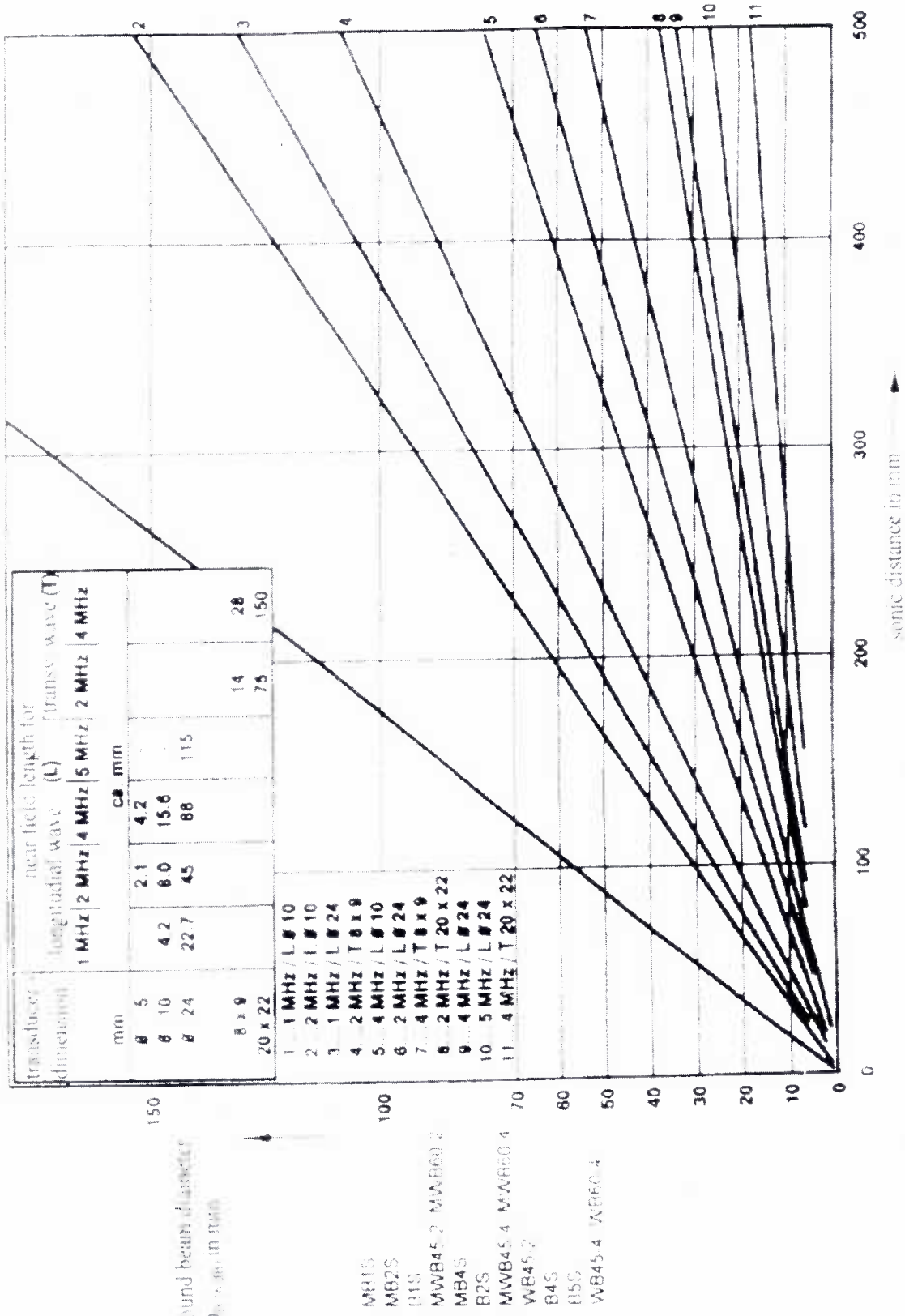
ASTM-E 186 Standard reference radiographs for heavy walled 2 to 4 ½ in. (51 to 114 mm) steel castings

ASTM-E 280 Standard reference radiographs for heavy walled 4 ½ to 12 in. (114 to 305 mm) steel castings

Table 2: Acceptance Limits for Discontinuities in Design Welding of Radiographic Testing in Comparison to the Ultrasonic Testing

Section thickness t mm	Maximum length of indications mm
[10	7
> 10 to [75	1/2 t
> 75 to [200	1/3 t

ANNEXURE-2



Approximation value of the near field length and the sound beam diameter (-6 dB) in the far field of usual transducers in dependence of the sonic distance