SULZER

Test Procedure	Sulzer Pumps Technical Quality	
Non-destructive testing – Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings		

Document control sheet for the issuing of Test Procedures (NDE) by Level III
The signatures below indicate review and approval of this NDE procedure by NDE Level 3.

检测程序（无损检测）由NDE 3级 发布文件控制单

以下的签字表示本NDE程序已由NDE 3级人员审核及批准。

Dokumentkontrollblatt zur Erstellung von Testverfahren (ZfP) nach Level III
Die folgenden Unterschriften zeigen die Überprüfung und Genehmigung dieses ZfP-Verfahrens nach ZfP Level 3.

Hoja de control de documentos para la emisión de Procedimientos de prueba (ECM) por Nivel III
Las firmas a continuación indican la revisión y aprobación de este procedimiento de ECM por NDE Nivel 3.

Folha de controle de documentos para a emissão de Procedimentos de Teste (END) pelo Nível III
As assinaturas abaixo indicam a revisão e aprovação deste procedimento de END pelo Inspetor END Nível 3.

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Remarks / 备注 / Bemerkungen / Comentarios / Comentário:

1 Scope

1.1 This generic procedure prescribes the requirements for manual ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings.

1.2 This procedure is restricted to the Reference Block Technique, or under circumstances the DGS Method. The Back Reflection Technique shall not be applied.

1.2.1 All forgings and bars shall be examined by the straight-beam examination technique.

1.2.2 In addition to (1.2.1), ring forgings and other hollow forgings that have an axial length greater than 2 In. (50 mm) and an outside to inside diameter ratio of less than 2.0 to 1 shall also be examined by the angle-beam examination technique in two circumferential directions, unless wall thickness or geometric configuration makes angle-beam examination impractical.

Note: When examining coarse grained austenitic materials it is important to scrutinize indications to determine whether they result from defects or grain size. If the required sensitivity cannot be achieved due to coarse grain size acceptance of the forging shall be subject to agreement with Sulzer.

2 Reference Documents

2.1 The following documents are referenced in this specification. All documents shall be current issue unless specified otherwise. In case of any conflict between the current specification and the referred documents, the current document shall take precedence.

ISO 16810	Non-destructive Testing - Ultrasonic Testing – General principles
EN 10228-4	Non-destructive testing of steel forgings – Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings
ISO 16811	Ultrasonic testing - Sensitivity and range setting
ISO 16827	Ultrasonic testing - Characterization and sizing of discontinuities
ISO 22232-1	Non-destructive Testing – Part 1: Characterization and Verification of Ultrasonic Examination Equipment
ISO 22232-3	Non-destructive Testing - Characterization and Verification of Ultrasonic Examination Equipment – Part 3: Combined Equipment
ISO 9712	Non-destructive Testing - Qualification and Certification of NDT Personnel
ASME Boiler and Pressure Vessel Code Section V	
Art. 5	Ultrasonic Examination Methods for Materials
Art. 23, SA-388	Standard Practice for Ultrasonic Examination of Steel Forgings
Art. 23, SA-745	Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings
ASTM E 127	Standard Calibration Blocks
ASNT SNT-TC-1A	Personnel Qualification and Certification in Non-destructive Testing

2.2 Sulzer documents referenced may be downloaded from https://www.sulzer.com/q-documents

3 Qualification of Testing Personnel

3.1 The personnel shall be qualified and certified in accordance with a written procedure conforming to the Recommended Practice SNT-TC-1A, to the ISO 9712 or an equivalent national standard (e.g. CAN/CGSB 48.9712).

3.2 Examination, interpretation and evaluation of results shall be carried out by personnel qualified and certified UT-level II or higher, having a currently valid vision test.

3.3 All qualifications and certification must comply, in full, with at least one of the standards referenced in Section 2.1 of this document and, where applicable, shall be in full compliance with the Project Quality Plan (Inspection & Test Plan).

4 Examination Conditions

4.1 Timing of examination

Ultrasonic examination shall be carried out after final heat treatment and in the manner defined in the project Quality Plan (Inspection & Test Plan), both in chronological order and material condition.
Generally the forging shall be machined to provide cylindrical surfaces for radial examination in the case of round forgings; the ends of the forgings shall be machined perpendicular to the axis of the forging for the axial examination. Faces of disk and rectangular forgings shall be machined flat and parallel to one another.

4.2 Extent of examination

The extent or scope of the examination shall be as defined in the project Quality Plan (Inspection & Test Plan); see §8.5.

4.3 Material condition

All components shall be free from dirt scale and paint. They shall be machined to a surface finish of 6.35 µm (250 micro inches) or better.

When using Dual Element Transducers, the surface finish shall not exceed 125 µin (3.17 µm).

5 Equipment

5.1 The pulse-echo ultrasonic instruments shall be provided with a dB-scale, operating at a frequency of at least 1-5 MHz (0.4 MHz for austenitic stainless steel forgings) with a stepped gain control in units of 2.0 dB or less.

The digital ultrasonic instruments with “A”-scan presentation shall meet the calibration requirements (instrument linearity checks) per ASME Code Sect. V, Art.5, T-560, or ISO 22232-1.

Basic qualification of the ultrasonic test instrument shall be performed at intervals not to exceed 12 months or whenever maintenance is performed that affects the equipment function. The date of the last calibration and the date of the next required calibration shall be displayed on the test equipment.

5.2 Search units

Search units shall be selected with respect to the dimensions and the ultrasonic attenuation of the piece to be examined.

5.2.1 Frequency

Austenitic steel forgings and bars: 2.25 - 1 MHz
Coarse-grained austenitic materials: 1 - 0.4 MHz
For straight-beam examination use a nominal 2 ¼ MHz search unit whenever practicable; however, 1 MHz is the preferred frequency for coarse grained austenitic materials and long testing distances.
In many instances on examining coarse grained austenitic materials it may be necessary to use a frequency of 0.4 MHz.
The amplitude of the applicable Flat Bottom Hole (FBH) as required per §8.3 shall be at minimum 12 dB over the acoustic noise.

Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws.

5.2.2 Search unit size

Standard	Maximum Active Area in². [mm²]	Minimum Dimension in. [mm]	Maximum Dimension in. [mm]	Probe
SA-388	(650)	Ø ¾ (20)	Ø 1 1/8 (30)	Straight beam
	-	½ (13)	1 (25)	Angle beam
SA-745	½ (970)	½ (13) Ø ¾ (20)	Ø 1 1/8 (30)	Straight beam
	1⁄2 to 1 (325 to 650)	½ (13)	1 (25)	Angle beam
EN 10228-4	---	Ø 3/8 (10)	Ø 1 ½ (40)	Straight beam
	0.03 to 1 (20 to 625)	---	---	Angle beam
recommended	1 (650)	Ø 3/8 (10)	Ø 1 1/8 (30)	Straight beam
	1⁄2 to 1 (325 to 650)	½ (13)	1 (25)	Angle beam

Table 1: Dimensional requirements according Standard

5.2.3 Search units with contoured contact wedges may be used to aid the ultrasonic coupling. Where appropriate the immersion techniques may be used.

5.2.3.1 According to ASME search units shall be contoured as required by the following equation:

$$D \leq \left[\frac{(A \times A)}{0.113\,\text{in.}\,(2.87\,\text{mm})} \right]$$

where

A = length of search unit footprint during circumferential scanning or the width when scanning in the axial direction, (mm)

D = the component diameter at inspection surface (I.D./O.D.), (mm)

The footprint is defined as the physical dimension of the search unit in the curved direction of the component.

5.2.3.2 According to ISO 16811 search units shall be contoured as required, if;

Convex scanning surface:

For scanning on convex surfaces the probe face shall be contoured when the diameter of the test object, D_{obj}, is below ten times the length l_{ps}, or width w_{ps} of the probe shoe.

$D_{obj} < 10\ l_{ps}$ respectively $D_{obj} < 10\ w_{ps}$

Concave scanning surface:

On a concave scanning surface the probe shall always be contoured, unless adequate coupling can be achieved due to very large radii of curvature.

5.2.3.3 Resulting in following limits:

Search unit Dimension in. (mm)		Part Outside Diameter in. (mm)		
		acc. ASME	acc. ISO	Recommended
Ø 1 (25)		≥ 8.0 (200)	≥ 10 (250)	≥ 10 (250)
Ø 0.75 (20)		≥ 5 (125)	≥ 7.5 (200)	≥ 7.5 (200)
Ø 0.5 (12.5)		≥ 2.2 (55)	≥ 5 (125)	≥ 5 (125)
Ø 0.4 (10)		≥ 1.4 (35)	≥ 4 (100)	≥ 4 (100)
1x0.5 (25x13)	Radial	≥ 8.8 (225)	≥ 10 (250)	≥ 10 (250)
	Axial	≥ 2.2 (55)	≥ 5 (125)	≥ 5 (125)
2x1 (50x25)	Radial	≥ 34.5 (875)	≥ 20 (500)	≥ 20 (500)
	axial	≥ 8.8 (225)	≥ 10 (250)	≥ 10 (250)

Table 2: Minimum limits for part OD in relation to search unit dimension without contoured wedges; (values for orientation)

5.2.4 Transducers shall be utilized at their rated frequencies.

5.2.5 Type

5.2.5.1 Generally single crystal transducers shall be used.

5.2.5.2 Other search units including frequencies may be used for evaluating and pinpointing indications.

5.2.5.3 Twin-crystal search units ¾`in. (Ø 20 mm) can be used for forgings, bars and bolting-material with thickness T < 75 mm, done at the Reference Block Technique. The plane separating the elements of the twin-crystal search unit shall be positioned perpendicular to the axis of the forging.

5.3 Couplant

5.3.1 A suitable couplant shall be used, water, cellulose paste, light or medium oil or grease is acceptable.

5.3.2 The couplant shall not be detrimental to the material being examined (≤ 250 ppm sulphur, ≤ 250 ppm chlorides and fluorides).

5.3.3 The same couplant shall be used for calibration setting, sensitivity scanning and defect assessment.

6 Reference calibration blocks

6.1 Material and Heat Treatment

Reference calibration blocks shall be made of a material that has similar acoustic properties as the product to be tested (P-Nos. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent) and of the same heat treatment as the material being examined.

6.2 Surface

The test surface roughness on the calibration standard shall be comparable to, but no better than, the item to be examined. Adjust the instrument controls to obtain the required signal amplitude from the flat-bottom hole in the specified reference block.

Utilize the attenuator in order to set up on amplitudes larger than the vertical linearity of the instrument. In those cases, remove the attenuation prior to scanning the forging.

NOTE —When flat-surfaced reference block calibration is specified, adjust the amplitude of indication from the reference block or blocks to compensate for examination surface curvature.

6.3 Temperature

For contact examination, the temperature differential between the calibration block and examination surfaces shall be within 25°F (14°C). For immersion examination, the couplant temperature for calibration shall be within 25°F (14°C) of the couplant temperature for examination.

7 Calibrations

7.1 The calibration of the time base, probe angle and beam characteristics for each probe shall be checked prior to examination, using the IIW, K1, or V1 calibration blocks.

The time base shall be calibrated to a suitable range for the beam path required for the test.

7.2 A calibration check on at least one of the reflectors in the reference calibration block shall be performed;

7.2.1 at the completion of each examination or series of similar examinations,

7.2.2 when the personnel are changed,

7.2.3 at least once every 8-hour shift.

7.3 System changes

When any part of the examination system is changed, a calibration check shall be made on the calibration block to verify that the distance range points and sensitivity setting(s) satisfy the requirements.

7.4 Distance range points

If any distance range point has moved on the sweep line by more than 10% of the distance reading or 5% of full sweep (whichever is greater), correct the distance range calibration and note the correction in the examination record.

All recorded indications since the last valid calibration or calibration check shall be re-examined and their values shall be changed on the data sheets or re-recorded.

7.5 Sensitivity Settings

If any sensitivity setting has changed by more than 15% of its amplitude, correct the sensitivity calibration and note the correction in the examination record.

7.5.1 If the sensitivity setting has decreased, all data sheets since the last valid calibration or calibration check shall be marked void and the area covered by the voided data shall be re-examined.

7.5.2 If the sensitivity setting has increased, all recordable indications since the last valid calibration or calibration check shall be re-examined and their values shall be changed on the data sheets or re-recorded.

8 Examination

8.1 The Reference Block, or the DGS Calibration Technique shall be applied.

8.2 *The Back-Reflection Technique applicable at forgings with a wall thickness > 24 In. (600 mm) is not prescribed in this procedure.*

8.3 Reference Sensitivity

8.3.1 The applicable Flat Bottom Holes (FBH), or Side Drilled Holes (SDH) in relation to the thickness of the forging are listed in Table 3, or 4 and 5. The sizes of the bore diameters shall be considered as reference for the 100% DAC curve, respectively DGS line.

8.3.2 Reference block calibration shall be performed using at least three holes, spaced to approximate mini-mum, mean, and maximum thickness as tested, and shall be used to generate a distance amplitude correction (DAC) curve.

8.3.3 At straight beam scanning:

Thickness **in. (mm)**	**Flat Bottom Hole** **Ø in. (mm)**		
	ASME V Art. 23 SA-388	EN 10228-4 Class 3	Recommended
T ≤ 1.5 (40)	1/16 (1.5)	1/8 (3)	1/16 (1.5)
1.5 (40) < T ≤ 3 (75)	1/8 (3)	1/8 (3)	1/8 (3)
3 (75) < T ≤ 6 (150)	1/8 (3)	3/16 (5)	1/8 (3)
6 (150) < T ≤ 10 (250)	1/4 (6)	3/16 (5)	3/16 (5)
10 (250) < T ≤ 16 (400)	1/4 (6)	5/16 (8)	1/4 (6)
16 (300) < T ≤ 24 (600)	1/4 (6)	7/16 (11)	1/4 (6)

Table 3: Austenitic steel forgings

Thickness **in. (mm)**	**Flat Bottom Hole** **Ø in. (mm)**		
	ASME V Art. 23 SA-745	EN 10228-4 Class 2	Recommended
T ≤ 3 (75)	1/8 (3)	3/16 (5)	1/8 (3)
1.5 (40) < T ≤ 3 (75)	1/8 (3)	3/16 (5)	1/8 (3)
3 (75) < T ≤ 8 (200)	1/4 (6)	5/16 (8)	1/4 (6)
8 (200) < T ≤ 10 (250)	3/8 (10)	5/16 (8)	5/16 (8)
10 (250) < T ≤ 12 (300)	3/8 (10)	7/16 (11)	3/8 (10)
12 (300) < T ≤ 16 (400)	1/2 (13)	7/16 (11)	7/16 (11)
16 (400) < T ≤ 24 (600)	1/2 (13)	5/8 (15)	1/2 (13)

Table 4: Coarse Grain Austenitic steel forgings

8.3.4 The minimum test sensitivity for straight beam examination shall be 12 dB's above the DAC with the DAC being more than 30 % of full screen height at the test distance.

8.3.5 At angle-beam scanning

Calibration for Angle-Beam Examination:

The description for an alternative calibration block used for distance-amplitude correction (DAC) calibration technique can be found at Enclosure 2.

Section thickness of the forging *t*, in. (mm)	Basic Calibration Block Thickness *T*, in. (mm)	Side Drilled Hole Diameter, in. (mm)
t ≤ 1 (25)	3/4 or *t* (19 or *t*)	3/32 (2.5)
1 (25) < *t* ≤ 2 (50)	11/2 or *t* (38 or *t*)	1/8 (3)
2 (50) < *t* ≤ 4 (100)	3 or *t* (75 or *t*)	3/16 (5)
4 (100) < *t* ≤ 6 (150)	5 or *t* (125 or *t*)	1/4 (6)
6 (150) < *t* ≤ 8 (200)	7 or *t* (175 or *t*)	5/16 (8)
8 (200) < *t* ≤ 10 (250)	9 or *t* (225 or *t*)	3/8 (10)
10 (250) < *t* ≤ 12 (300)	11 or *t* (275 or *t*)	7/16 (11)
12 (300) < *t* ≤ 14 (350)	13 or *t* (325 or *t*)	1/2 (13)

Table 5: Applicable Ø SDH (for 100% DAC curve)

8.3.6 Calibration with a Reference Block and Side Drilled Holes

See Enclosure 2; Alternative Basic Calibration Block with the dimensions of Table 5.

8.3.7 Electronic DGS Calibration for Angle Beam

Prior to use verify that the electronic DGS curve matches the transducer size and frequency. Accuracy of the curve can be verified by reference blocks and procedures outlined in Practice E317.

Angle beam calibration can be established by use of flat bottom holes, side drilled holes, notches or the back reflection. Separate test blocks may be employed provided they are machined with a reflecting surface. Square-, U- or V-shaped notches, side drilled or flat bottom holes maybe machined into the test block for this purpose. For the back reflection calibration a concave curved surface such as contained on an IIW, K1, or V1 test block may be used.

8.3.8 The minimum test sensitivity for angle beam examination shall be with visible grain response (10-15% screen height) at the appropriate path distance using the material under test.

8.4 DGS Calibration Technique

8.4.1 Modern test instruments with DGS software are particularly easy to calibrate. Most ultrasonic test instruments with DGS software have 13 standard probes and corresponding DGS diagrams stored in the instrument. There are also custom settings by which the operator may program their own data sets. The operator may choose from flat bottomed hole, side drilled hole or back reflection to use for calibration. The instructions from the test instruments operator's manual for DGS calibration must be followed to properly calibrate the instrument. Operator errors are largely excluded due to the display of on screen messages.

8.4.2 Upon input of all necessary parameters for the flaw evaluation, the corresponding curve will be electronically displayed on the instrument screen. This method of calibration may be used for longitudinal (single and dual) and shear wave examination.

8.4.3 Prior to use, verify that the electronic DGS curve matches the transducer size and frequency. Accuracy of the DGS curve can be verified by reference blocks and procedures outlined in Practice E317. Instruments with electronic DGS must use the specified ultrasonic transducer for that electronic curve.

8.5 Scanning

8.5.1 The entire volume of the forging shall be scanned by a straight beam search unit from at least two directions perpendicular to each other.

8.5.2 Nozzle forgings shall be further examined using a 45° shear wave probe from the outer surface.

8.5.3 Scan disc forgings from at least one flat face and radially from the circumference.

8.5.4 Bars shall be scanned radially from the circumference. Additionally bolting material shall be axially scanned from both end surfaces.

8.5.5 Ring forgings and other hollow forgings by scanning over the entire surface area circumferentially in both the clockwise and counter-clockwise directions from the OD surface.

Examine forgings, which cannot be examined axially using a straight beam, in both axial directions with an angle-beam search unit.

For axial scanning, use rectangular or 60° V-notches on the ID and OD for the calibration. These notches shall be perpendicular to the axis of the forging and the same dimensions as the axial notch.

8.5.6 Manual scanning, scanning rate max. 150 mm/s; to assure complete coverage of the forging volume index the search unit with at least 15% overlap with each pass.

9 Assessment of indications

9.1 Acceptance criteria shall be as indicated on the Purchase Order, referenced purchasing specification, or project Quality Plan (Inspection & Test Plan).

In the case no other acceptance criteria is specified the following shall apply:

9.2 Unacceptable are:

Cracks or crack-like indications

9.3 Other indications as following:

9.3.1 Classification of inhomogeneities; see Enclosure 1.

9.4 Straight beam; Recording and Acceptance Criteria

9.4.1 Austenitic materials;

Thickness of Forging	Recording Criteria	Acceptance Criteria	
		Single discontinuities	Extended or accumulation of discontinuities
T in. [mm]	FBH in. [mm]	FBH in. [mm]	FBH in. [mm]
T ≤ 1.6 (40)	> 2.5/64 (1.0)	≤ 1/16 (1.5)	≤ 2.5/64 (1)
1.6 (40) < *T* ≤ 6 (150)	> 5/64 (2)	≤ 1/8 (3)	≤ 5/64 (2)
6 (150) < *T* ≤ 10 (250)	> 1/8 (3)	≤ 3/16 (5)	≤ 1/8 (3)
10 (250) < *T* ≤ 24 (600)	> 5/32 (4)	≤ 1/4 (6)	≤ 5/32 (4)
T > 24 (600)	Indication with 80% attenuation of back reflection	Indication with complete loss of back reflection. Complete loss of back reflection is assumed when the back reflections falls below 5% of full calibration screen height.	

Table 6: Recording & acceptance criteria

9.4.2 Coarse-grained austenitic materials

Thickness of Forging	Recording Criteria	Acceptance Criteria	
		Single discontinuities	Extended or accumulation of discontinuities
T in. [mm]	FBH in. [mm]	FBH in. [mm]	FBH in. [mm]
T ≤ 3 (75)	> 5/64 (2)	≤ 1/8 (3)	≤ 5/64 (2)
3 (75) < *T* ≤ 8 (200)	> 5/32 (4)	≤ 1/4 (6)	≤ 5/32 (4)
8 (200) < *T* ≤ 10 (250)	> 3/16 (5)	≤ 5/16 (8)	≤ 3/16 (5)
10 (250) < *T* ≤ 12 (300)	> 9/32 (7)	≤ 3/8 (10)	≤ 9/32 (7)
12 (300) < *T* ≤ 16 (400)	> 5/16 (8)	≤ 7/16 (11)	≤ 5/16 (8)
16 (400) < *T* ≤ 24 (600)	> 3/8 (10)	≤ 1/2 (13)	≤ 3/8 (10)
T > 24 (600)	Indication with 80% attenuation of back reflection	Indication with complete loss of back reflection. Complete loss of back reflection is assumed when the back reflections falls below 5% of full calibration screen height.	

Table 7: Recording & acceptance criteria

9.5 Angle beam; Recording and Acceptance Criteria

9.5.1 When using the DGS Method

Thickness of Forging	Recording Criteria	Acceptance Criteria	
		Single discontinuities	Extended or accumulation of discontinuities
T in. [mm]	FBH in. [mm]	FBH in. [mm]	FBH in. [mm]
T ≤ 3 (75)	> 1/8 (3)	≤ 3/16 (5)	≤ 1/8 (3)
3 (75) < *T* ≤ 10 (250)	> 3/16 (5)	≤ 5/16 (8)	≤ 3/16 (5)
6 (250) < *T* ≤ 16 (400)	> 5/16 (8)	≤ 7/16 (11)	≤ 5/16 (8)

Table 8: Recording & acceptance criteria

9.5.2 When using the DAC Method

Section thickness of the forging *t*, in. (mm)	Side Drilled Hole Diameter, SDH in. (mm)	Recording Criteria	Acceptance Criteria	
			Single discontinuities	Extended or accumulation of discontinuities
t ≤ 1 (25)	3/32 (2.5)	> 50% DAC	≤ 100% DAC	≤ 50% DAC
1 (25) < *t* ≤ 2 (50)	1/8 (3)			
2 (50) < *t* ≤ 4 (100)	3/16 (5)			
4 (100) < *t* ≤ 6 (150)	1/4 (6)			
6 (150) < *t* ≤ 8 (200)	5/16 (8)			
8 (200) < *t* ≤ 10 (250)	3/8 (10)			
10 (250) < *t* ≤ 12 (300)	7/16 (11)			
12 (300) < *t* ≤ 14 (350)	1/2 (13)			

Table 9: Recording & acceptance criteria

10 Reporting

10.1 For each examination and for each item tested a report shall be completed. This report has to include at least following information

10.1.1 date of the examination

10.1.2 name and/or identity and certification level (if applicable) for personnel performing the examination

10.1.3 identification of the part, or component examined including serial number, or other identifier

10.1.4 examination method, technique, procedure identification, and revision

10.1.5 results of the examination

10.2 The following information at items (10.2.1) through (10.2.8) may be included or attached in a separate calibration record provided the calibration record is included in the examination record.

10.2.1 ultrasonic instrument identification (including manufacturer's serial number)

10.2.2 search unit(s) identification (including manufacturer's serial number, frequency, and size)

10.2.3 beam angle(s) used

10.2.4 couplant used, brand name or type

10.2.5 search unit cable(s) used, type and length

10.2.6 calibration block identification

10.2.7 instrument reference level gain and, if used, damping and reject setting(s)

10.2.8 calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)

10.3 Items (10.3.1) through (10.3.4) shall be filed and maintained by the manufacturer internally.

10.3.1 identification of material or volume scanned

10.3.2 surface(s) from which examination was conducted, including surface condition

10.3.3 map or record of rejectable indications detected or areas cleared

10.3.4 areas of restricted access or inaccessible areas

10.4 Components shall be clearly identified as being either acceptable or rejectable. Non-conforming areas on components shall be marked on the components themselves, or where this is not possible on an NDE defect map.

11 Post Examination Cleaning

After evaluation and documentation the components shall be cleaned of residential couplant using a process that does not adversely affect the part (e.g. cloth).

Enclosure 1a Classification of inhomogeneities

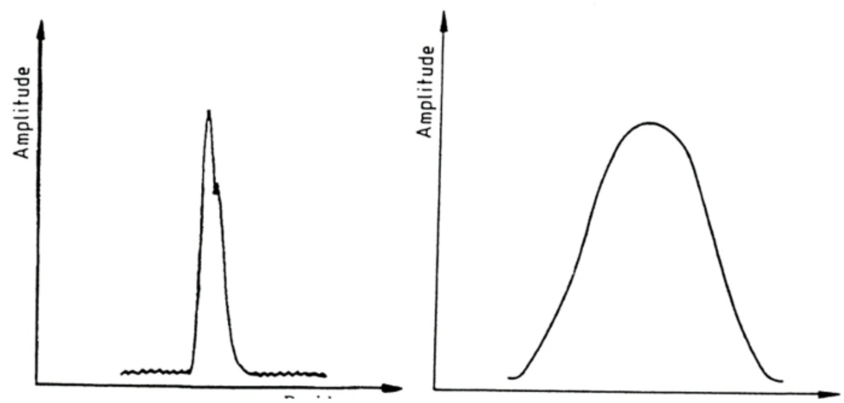
Classification, Display Classes

The indications are classified according to their echo-dynamic course as follows:

a) Type 1

If the probe is moved, a single sharp display is visible in the A-scan, which is in the amplitude increases smoothly to a maximum and then decreases smoothly to zero (see Figure 1).

This course is characteristic of inhomogeneities up to the − 6 dB sound beam width and also corresponds to this echo-dynamic course that is obtained when recording a directional characteristic of transverse bores.



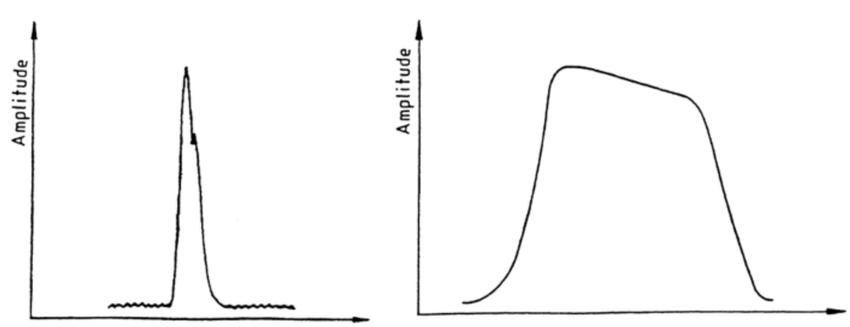
A-scan display (at typical probe position) Echo-dynamic course (change of signal amplitude while moving the probe)

Figure 1 - A-scan display and Type 1 echo dynamics

b) Type 2

If the probe is moved, the A-scan shows a single, sharp display that is uniform in amplitude increases up to a maximum value, maintains this value with or without changing the amplitude, and then steadily up to falls to zero (see Figure 2).

The course is characteristic of inhomogeneities that are larger than the − 6 dB sound beam width.



A-scan display (at typical probe position) Echo-dynamic course (change of signal amplitude while moving the probe)

Figure 2 - A-scan display and Type 2 echo dynamics

Classification of inhomogeneities

The inhomogeneities are to be classified according to the displayed echo-dynamic course as follows:

a) punctual inhomogeneity;

Type 1 echo-dynamic course and/or expansion up to − 6 dB sound beam width (see Figure 3 a).

b) inhomogeneity with extension;

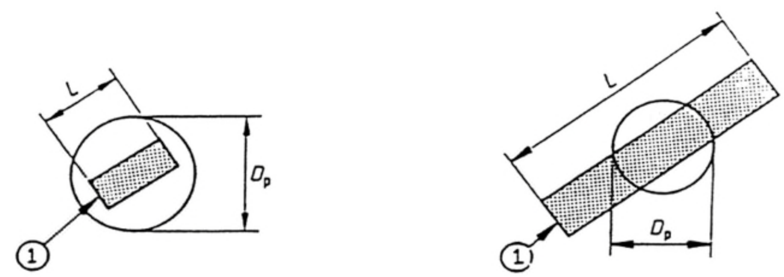
Type 2 echo-dynamic curve and/or extension greater than − 6 dB beam width (see Figure 3b).

c) single inhomogeneity;

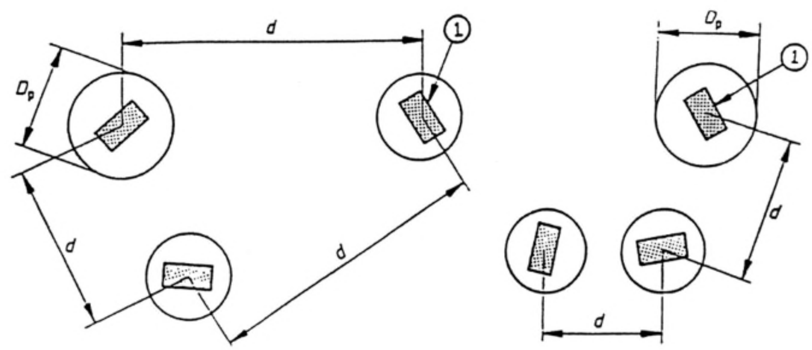
The distance *d* between points, each indicating the maxima for adjacent inhomogeneities, exceeds 40 mm (see Figure 3 c).

d) accumulation of inhomogeneities.

The distance *d* between points, each indicating the maxima for adjacent inhomogeneities, correspond to a maximum of 40 mm (see Figure 3 d).



a) punctual inhomogeneity ($L \leq D_p$) b) inhomogeneity with extension ($L > D_p$)



c) single punctual inhomogeneity ($L < D_p$; $d > 40$ mm)

d) accumulation of single inhomogeneities ($L < D_p$; $d \leq 40$ mm)

Legend

1 Definition of the outline of a − 6 dB inhomogeneity

Symbols used

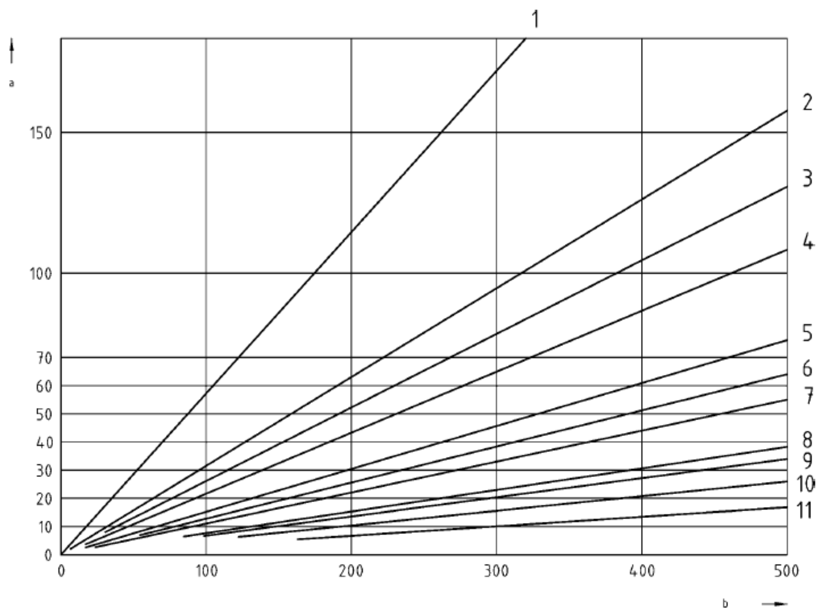
D_p sound beam width at the location of the inhomogeneity

d Distance between two inhomogeneities

L Defined length of a − 6 dB inhomogeneity

Figure 3 – classification of inhomogeneities

Enclosure 1b -6 dB Sound Beam Diameter (informative)



Legend

1	1 MHz, L, Ø 10
2	2 MHz, L, Ø 10
3	1 MHz, L, Ø 24
4	2 MHz, T, 8 x 9
5	4 MHz, L, Ø 10
6	2 MHz, L, Ø 24
7	4 MHz, T, 8 x 9
8	2 MHz, T, 8 x 9
9	4 MHz, L, Ø 24
10	5 MHz, L, Ø 24
11	4 MHz, T, 20 x 22

Crystal dimension (mm)	**Nearfield length in millimeter (approximate values)**					
	Pressure wave (L)				**Shear wave (T)**	
	1 MHz	2 MHz	4 MHz	5 MHz	2 MHz	4 MHz
Ø 10	4,2	8,0	15,6	--	--	--
Ø 24	22,7	45	88	115	--	--
8 x 9	--	--	--	--	14	28
20 x 22	--	--	--	--	75	150

a Sound beam diameter (-6 dB) in millimeter

b Sound path in millimeter

Figure 4 – Sound beam diameter as a function of sound path and near-field length

for different probes

Enclosure 2; ALTERNATIVE BASIC CALIBRATION BLOCK

This Appendix contains the description for an alternative to Article 4, T-434.2 for basic calibration blocks used for distance–amplitude correction (DAC) calibration techniques.

EQUIPMENT

Basic Calibration Block

The basic calibration block(s) containing basic calibration reflectors to establish a primary reference response of the equipment and to construct a distance–amplitude correction curve shall be as shown in Figure J-431. The basic calibration reflectors shall be located either in the component material or in a basic calibration block.

Basic Calibration Block Material

(a) Block Selection.

The material from which the block is fabricated shall be from one of the following:

(1) nozzle dropout from the component;

(2) a component prolongation;

(3) material of the same material specification, product form, and heat treatment condition as the material to which the search unit is applied during the examination.

(b) Clad.

Where the component material is clad and the cladding is a factor during examination, the block shall be clad to the component clad nominal thickness ±1/8 in. (3 mm). Deposition of clad shall be by the same method (i.e., roll-bonded, manual weld deposited, automatic wire deposited, or automatic strip deposited) as used to clad the component to be examined. When the cladding method is not known or the method of cladding used on the component is impractical for block cladding, deposition of clad may be by the manual method. When the parent materials on opposite sides of a weld are clad by either different P-, A-, or F-numbers or material designations or methods, the calibration block shall be clad with the same P-, A-, or F-numbers or material designations using the same method used on the side of the weld from which the examination will be conducted. When the examination is conducted from both sides of the weld, the calibration block shall provide for calibration for both materials and methods of cladding. For welds clad with a different material or method than the adjoining parent materials, and it is a factor during the examination, the calibration block shall be designed to be representative of this combination.

(b) Heat Treatment.

The calibration block shall receive at least the minimum tempering treatment required by the material specification for the type and grade and a post-weld heat treatment of at least 2 hr.

(c) Surface Finish.

The finish on the surfaces of the block shall be representative of the surface finishes of the component.

(e) Block Quality.

The calibration block material shall be completely examined with a straight beam search unit. Areas that contain indications exceeding the remaining back reflection shall be excluded from the beam paths required to reach the various calibration reflectors.

Calibration Reflectors

(a) Basic Calibration Reflectors.

The side of a hole drilled with its axis parallel to the examination surface is the basic calibration reflector. A square notch shall also be used. The reflecting surface of the notches shall be perpendicular to the block surface. See Figure J-431.

(b) Scribe Line.

A scribe line as shown in Figure J-431 shall be made in the thickness direction through the inline hole center lines and continued across the two examination surfaces of the block.

(c) Additional Reflectors.

Additional reflectors may be installed; these reflectors shall not interfere with establishing the primary reference.

(d) Basic Calibration Block Configuration.

Figure J-431 shows block configuration with hole size and location. Each weld thickness on the component must be represented by a block having a thickness relative to the component weld as shown in Figure J-431. Where the block thickness ±1 in. (±25 mm) spans two of the weld thickness ranges shown in Figure J-431, the block's use shall be acceptable in those portions of each thickness range covered by 1 in. (25 mm). The holes shall be in accordance with the thickness of the block. Where two or more base material thicknesses are involved, the calibration block thickness shall be sufficient to contain the entire examination beam path.

(e) Welds in Materials

With Diameters Greater Than 20 in. (500 mm). For examination of welds in materials where the examination surface diameter is greater than 20 in. (500 mm), a single curved basic calibration block may be used to calibrate the straight and angle beam examinations on surfaces in the range of curvature from 0.9 to 1.5 times the basic calibration block diameter.

Alternatively, a flat basic calibration block may be used provided the minimum convex, concave, or compound curvature radius to be examined is greater than the critical radius determined by Article 4, Nonmandatory Appendix A.

For the purpose of this determination, the dimension of the straight or angle beam search units flat contact surface tangent to the minimum radius shall be used instead of the transducer diameter in ~~Table A-10~~ (see § 5.2.3).

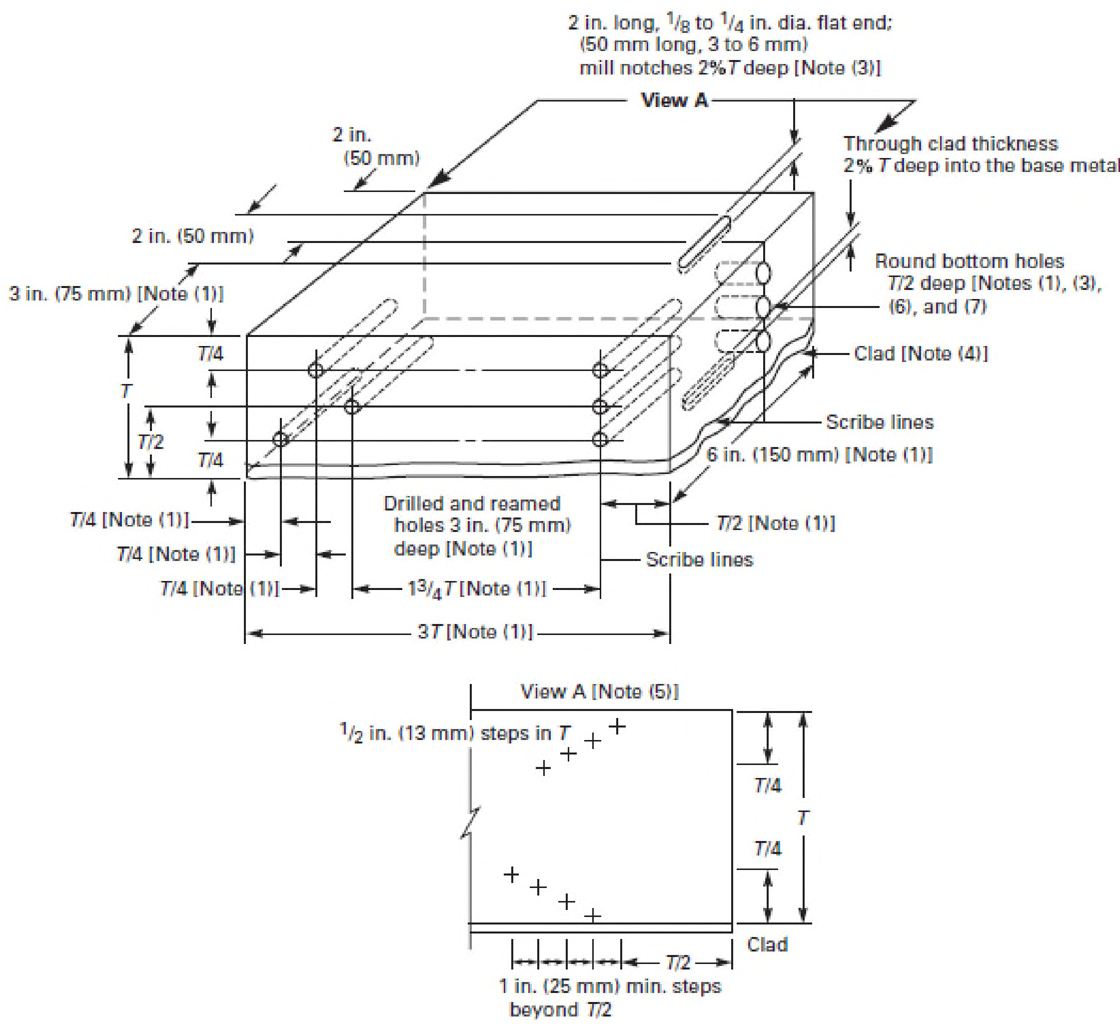
(f) Welds in Materials With Diameters 20 in. (500 mm) and Less.

The basic calibration block shall be curved for welds in materials with diameters 20 in. (500 mm) and less. A single curved basic calibration block may be used to calibrate the examination on surfaces in the range of curvature from 0.9 to 1.5 times the basic calibration block diameter. For example, an 8 in. (200 mm) diameter curved block may be used to calibrate the examination on surfaces in the range of curvature from 7.2 in. to 12 in. (180 mm to 300 mm) diameter. The curvature range from 0.94 in. to 20 in. (24 mm to 500 mm) diameter requires six block curvatures as indicated in Figure T-434.1.7.2 for any thickness range as indicated in Figure J-431.

(g) Retention and Control.

All basic calibration blocks for the examination shall meet the retention and control requirements of the referencing Code Section.

Figure J-431 **Alternative Basic Calibration Block**



NOTES:

(1) Minimum dimensions.

(3) The tolerances for the hole diameters shall be ±1/32 in. (0.8 mm); tolerances on notch depth shall be +10 and −20% (need only be held at the thinnest clad thickness along the reflecting surface of the notch); tolerance on hole location through the thickness shall be ±1/8 in. (3 mm); perpendicular tolerances on notch reflecting surface shall be ±2 deg tolerance on notch length shall be ±1/4 in. (±6 mm).

(4) Clad shall not be included in T.

(5) Subsurface calibration holes 1/8 in. (3 mm) (maximum) diameter by 11/2 in. (38 mm) deep (minimum) shall be drilled at the clad-to-base metal interface and at 1/2 in. (13 mm) increments through T/4 from the clad surface,

also at 1/2 in. (13 mm) from the unclad surface and at 1/2 in. (13 mm) increments through T/4 from the unclad surface. In each case, the hole nearest the surface shall be drilled at T/2 from the edge of the block. Holes at 1/2 in. (13 mm) thickness increments from the near surface hole shall be drilled at 1 in. (25 mm) minimum intervals from T/2.

(7) T/2 hole may be located in the opposite end of the block.

Enclosure 3 other Acceptance Criteria

E 3.1 ASTM A-388 Reporting Criteria

Reference block calibration shall be performed using at least three holes, spaced to approximate minimum, mean, and maximum thickness as tested, and shall be used to generate a distance amplitude correction (DAC) curve.

The following hole sizes apply:

	Flat Bottom Hole (FBH)	for thicknesses
1	1⁄16 in. [1.5 mm]	less than 1.5 in. [40 mm]
2	1⁄8 in. [3 mm]	of 1.5-6 in. [40-150 mm] inclusive
3	1⁄4 in. [6 mm]	over 6 in. [150 mm]

Reporting criteria include:

1. All indications exceeding the DAC curve
2. Two or more indications separated by 1⁄2 in. [12 mm] or less

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E 3.2 ASTM A-745 Quality Levels for Acceptance

One of the following quality levels may be specified by the purchaser:

Straight Beam:

Material producing an indication response whose maximized amplitude equals or exceeds 100 % of the primary reference or distance-amplitude correction curve at the estimated discontinuity depth shall be considered unacceptable.

Quality Level	Generally practical for thicknesses	A distance-amplitude curve shall be based upon the amplitude response from	FBH Sizes
QL-1	up to 3 in. [75 mm]	No. 8 flat-bottom hole	8⁄64 in. [3 mm]
QL-2	up to 8 in. [200 mm]	No. 16 flat-bottom hole	16⁄64 in. [6 mm]
QL-3	up to 12 in. [300 mm]	No. 24 flat-bottom hole	24⁄64 in. [10 mm]
QL-4	up to 24 in. [600 mm]	No. 32 flat-bottom hole	32⁄64 in. [13 mm]
QL-5	over 24 in. [600 mm]	A back-reflection examination shall be performed guaranteeing freedom from complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection of less than 5 % of full screen height shall be considered complete loss of back reflection	

The applicable quality level will necessarily vary with test metal distance, purchasers' requirements, and the type and size of forging involved. Large disks, rings, or solid forgings and complex forgings present extraordinary problems and quality level application shall be a matter of agreement between the manufacturer and the purchaser. For general guidance purposes, the following list of test metal distances versus quality level attainable is provided for general information.

E 3.3 ASME V Art. 5, T-534.3 Straight Beam Calibration Blocks for Bolting

Diameter of Bolting Material to be examined, *d*	**Calibration Block Diameter, *D***	**Flat-Bottom Hole Diameter, *Dh***
≤1 in. [≤25 mm]	*d* ± d/4	1/16 in. [1.5 mm]
>1 in. [>25 mm] to 2 in. [50 mm]	*d* ± d/4	1/8 in. [3 mm]
>2 in. [>50 mm] to 3 in. [75 mm]	*d* ± d/4	3/16 in. [5 mm]
>3 in. [>75 mm] to 4 in. [100 mm]	*d* ± d/4	5/16 in. [8 mm]
>4 in. [>100 mm]	*d* ± 1 in. [25 mm]	3/8 in. [10 mm]

E 3.4 EN 10228-4 Quality class 3; recording and acceptance criteria

Thickness of the Forging	**Recording Criteria**	**Acceptance Criteria**	
t In. [mm]	FBH In. [mm]	Single discontinuities FBH In. [mm]	Extended or accumulation of discontinuities FBH In. [mm]
t < 3 (75)	> 5/64 (2)	≤ 1/8 (3)	≤ 5/64 (2)
3 (75) < *t* ≤ 10 (250)	> 1/8 (3)	≤ 3/16 (5)	≤ 1/8 (3)
10 (250) < *t* ≤ 16 (400)	> 3/16 (5)	≤ 5/16 (8)	≤ 3/16 (5)
16 (400) < *t* ≤ 24 (600)	> 5/16 (8)	≤ 7/16 (11)	≤ 5/16 (8)
t > 24 (600)	Indication with 80% attenuation of back reflection	Indication with complete loss of back reflection. Complete loss of back reflection is assumed when the back reflections falls below 5% of full calibration screen height.	

E 3.5 EN 10228-4 Quality class 2; recording and acceptance criteria

Thickness of the Forging	**Recording Criteria**	**Acceptance Criteria**	
t In. [mm]	FBH In. [mm]	Single discontinuities FBH In. [mm]	Extended or accumulation of discontinuities FBH In. [mm]
t < 3 (75)	> 1/8 (3)	≤ 3/16 (5)	≤ 1/8 (3)
3 (75) < *t* ≤ 10 (250)	> 3/16 (5)	≤ 5/16 (8)	≤ 3/16 (5)
10 (250) < *t* ≤ 16 (400)	> 5/16 (8)	≤ 7/16 (11)	≤ 5/16 (8)
16 (400) < *t* ≤ 24 (600)	> 7/16 (11)	≤ 9/16 (15)	≤ 7/16 (11)

t > 24 (600)	Indication with 80% attenuation of back reflection	Indication with complete loss of back reflection. Complete loss of back reflection is assumed when the back reflections falls below 5% of full calibration screen height.

Compare between the different acceptance criteria;

required Flat Bottom Hole (FBH) in relation to the Forging thickness

100% DAC

Thickness (mm)	**Diameter FBH (mm)**						
	ASME V, Art. 5 T-534.3	**ASME V, Art. 23 SA-388**	**EN 10228-4 Class 3**	**Sulzer Pumps § 9.4.1**	**ASME V, Art. 23 SA-745**	**EN 10228-4 Class 2**	**Sulzer Pumps § 9.4.2**
< 25	1.5	1.5	3	1.5	3	5	3
> 25	3	1.5	3	1.5	3	5	3
< 40	3	1.5	3	1.5	3	5	3
> 40	3	3	3	3	3	5	3
< 50	3	3	3	3	3	5	3
> 50	5	3	3	3	3	5	3
< 75	5	3	3	3	3	5	3
> 75	8	3	5	3	6	8	6
< 100	8	3	5	3	6	8	6
> 100	10	3	5	3	6	8	6
< 150	10	3	5	3	6	8	6
> 150	10	6	5	5	6	8	6
< 200	10	6	5	5	6	8	6
> 200	10	6	5	5	10	8	8
< 250	10	6	5	5	10	8	8
> 250	10	6	8	6	10	11	10
< 300	10	6	8	6	10	11	10
> 300	10	6	8	6	13	11	11
< 400	10	6	8	6	13	11	11

> 400	10	6	11	6	13	15	13
< 600	10	6	11	6	13	15	13
		Austenitic Material			Coarse Grain Aust. Material		
> 600		Back Reflection Technique					