

Designation: OV-STD-NMIUS10-17

Standard Practice for

DETECTION OF NON-METALLIC INCLUSIONS IN STEELS WITH HIGH CLEANLINESS DEMANDS SUCH AS CASE- OR THROUGH HARDENING BEARING STEELS BY THE ULTRASONIC METHOD

This standard is issued under the fixed designation E xxx; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last re-approval. A superscription epsilon (ϵ) indicates an editorial change since the last revision or re-approval.

1. Scope

- 1.2 This practice covers a procedure for rating of non-metallic inclusions on forged or rolled billets or bars with a minimum side length or diameter of 80 mm by immersion ultrasonic techniques.
- 1.3 Limits for acceptability are not given in this practice; the purchaser may specify the acceptance level by agreement with the steel supplier.

2. Referenced documents

- 2.1 ASTM Standards:
 - E 214 Practice for Determining the Inclusion Content of Steel¹
 - E 1316 Terminology for Nondestructive examinations²
- 2.2 ANST / NSI Standards:
 - Recommended practice SNT-TC-1A Personnel Qualification and Certification in Nondestructive testing³
 - CP-189 Qualification and Certification of Nondestructive Testing Personnel⁴
- 2.3 Military Standard:
 - MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification⁵

3. Basis of application

- 3.1 Personnel Qualification--Nondestructive personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice such as the standards referenced above or a similar document.

4. Sampling

- 4.1 For bottom poured products, a minimum of three samples per heat shall be examined, and shall represent the bottom of three ingots.
- 4.2 For strand cast products, a minimum of three samples per heat representing the first portion of the heat cast shall be examined. At least one sample shall be taken from each strand.
 - 4.2.1 For square products produced in a curved caster, samples may be taken from the surface zone. In that case, the top (inner bend of strand) shall be investigated.
- 4.3 The forming reduction from as cast to sampling dimension shall be minimum three times for bottom poured as well as strands cast products. For strand cast products, tests of core material may require a higher degree of reduction. This may be agreed upon between purchaser and steel producer.
- 4.4 Sample geometry and scanning zone are shown in Appendix 1 and 2.

¹ Annual Book of ASTM Standards, Vol 03.03

² Annual Book of ASTM Standards, Vol 03.03

³ Available from the American Society for Nondestructive Testing (ASNT) 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228

⁴ Available from the American Society for Nondestructive Testing (ASNT) 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228

⁵ Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS

5. Sample preparation

- 5.1 To minimize acoustic anomalies, samples may be heat-treated. High-carbon steels may be soft annealed. Low carbon steels may be normalized.
- 5.2. Samples for core parts shall have a minimum length of 200 mm. They should be cut and prepared in such a way that a central section with full as rolled width and a thickness of 40-60 mm remains, Appendix 1, figure 1. The sample may be divided lengthwise into two pieces before testing. The samples shall be marked for traceability.
 - 5.2.1 Samples for surface parts shall have a minimum length of 200 mm. They should be cut and prepared in such a way that a surface section with full as rolled width and a thickness of 40-60 mm remains, Appendix 2, figure 2.
- 5.3 The entrance surface of the scanned sample shall at least have a surface quality corresponding to $R_a < 2.0\mu\text{m}$ and $R_{\text{max}} < 10.0\mu\text{m}$.

6. Equipment

- 6.1 An immersion tank capable of accommodating samples as defined in 5.2 and with an immersion liquid depth enough to cover the transducer face when performing a scanning. The indexing (i.e. the parallel distance between transverse scans) must be 0.5 mm or less. It must be possible to align the probe perpendicular to the scanning surface.
- 6.2 The immersion liquid shall be tap- or distilled water and may have additives as corrosion inhibitors, wetting agents or antibacterial agents. Thermal gradients, which can affect the test performance, must not exist in the system. The immersion liquid shall have a temperature of 17 to 28 C°.
- 6.3 The probe shall be of point-focused immersion type. It shall be a 10 MHz high-resolution immersion probe with a crystal diameter of 19 mm (3/4") and a focal distance of 145 mm (5.7"). The probe shall be within 10 percent of the specified values above.
- 6.4 The ultrasonic instrument shall have amplifier characteristics which cover and can optimize the specified frequency. Ability to make adjustment of gain and attenuation in dB to obtain the correct reference level.
- 6.5 Distance Amplitude Correction (DAC) may be used.

7. Calibration

- 7.1 Reference (7.5) Flat Bottom Hole (FBH) and calibration blocks (for time base line correction) shall be available. They should be made from the same or from material with equal acoustic properties, as the test samples.
- 7.2 The probe beam is normalized to the entrance surface of the reference or the calibration blocks by angulation of the search unit.
- 7.3 The water gap is set by maximizing the echo of the FBH or by calculation according to Appendix 3.
- 7.4 The time base is calibrated against a calibration block with a known sound path.
- 7.5 The sound path to the reference defect, FBH with the diameter of 0.28mm, shall be equal to the distance from the surface top to the center of the scanning zone (focus line) in the test sample, Appendix 1 and 2.
- 7.6 Setting of sensitivity by adjusting the echo from the reference defect (7.5) to full screen height (100 percent= reference level). Add 8 dB to this amplification, Appendix 2, figure 3.
- 7.7 The monitor gate shall be placed on the focus line and cover 10 mm on both sides, Appendix 1 and 2. The trigger level shall be set 10 dB below the reference level.
- 7.8 Noise and disturbance level (grass) shall not influence the test results.

8. Scanning

- 8.1 The test samples shall be scanned automatically at a speed appropriate to the pulse repetition frequency of the ultrasonic instrument.
- 8.2 The indexing of the scanning transverse shall be 0.5 mm or less.
- 8.3 The scanning direction is normally perpendicular to the rolling direction.
- 8.4 The scanning should cover the total surface without interference from sample edges.

9. Evaluation of Results

- 9.1 The defects and their amplitudes should be recorded on a C-scan presentation.
- 9.2 Evaluation of the C-scan can be made according to alternative 1 or alternative 2.

9.2.1 Alternative 1

Maximum amplitude for each indication exceeding trigger level shall be classified and counted according to 9.3.

9.2.2 Alternative 2

The total area in mm² exceeding trigger level shall be classified and summarized according to 9.3.

9.2.3 Alternative 1 is suitable for punctual inclusions. Alternative 2 is suitable for linear inclusions.

Note: The result obtained from the two alternatives shall not be compared

9.3 Classification

(A) Amplitudes $\geq 30\%$ to $< 50\%$ screen height, corresponding to ≥ 10 to < 6 dB below the reference level

(B) Amplitudes $\geq 50\%$ to $< 100\%$ screen height, corresponding to ≥ 6 to < 0 dB below the reference level

(C) Amplitudes $\geq 100\%$ screen height, corresponding to ≥ 0 dB above the reference level.

A weighted severity index is then calculated for each sample employing the weight factors 1, 2.5 and 5 for the groups A-C respectively. This severity index is normalized to 10 kg of steel by dividing the severity index by the weight of steel (in kg) tested in each sample multiplied by 10. Appendix 4.

- 9.4 The total severity index (TSN number, 9.2.1, and/or TSA area, 9.2.2) is then calculated for the heat as the average for the individual sample severity indexes. Appendix 4.
- 9.5 The total severity index for number and for area represent different aspects of the inclusion contents and must treated as separate entities.
- 9.6 The reported results should contain all the information necessary to repeat the test in the same or other location.

10. Acceptance level

The results obtained by this procedure are not only influenced by metallurgical quality but also are dependent on steel composition and forming reduction. The reduction degree must always be known and stated together with the test results. Therefore, acceptance levels must be agreed upon between purchaser and steel producer.

APPENDIX 1

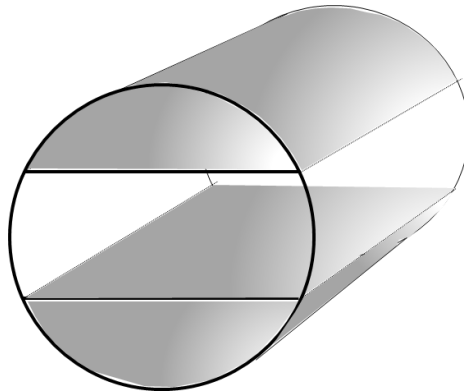


Figure 1a The rolled round (or square) bar or billet is milled on two sides (gray area removed) to create a flat piece, Fig 1b.

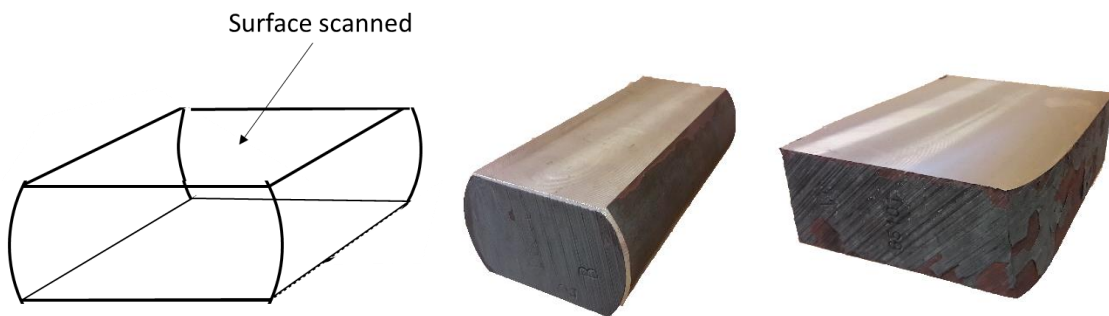


Figure 1b The flat piece is scanned on one of the milled surfaces (examples of round and square piece)

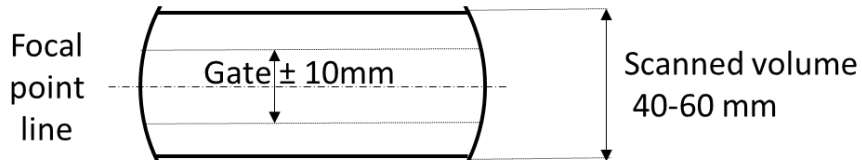


Fig 1c Scanned volume

APPENDIX 2

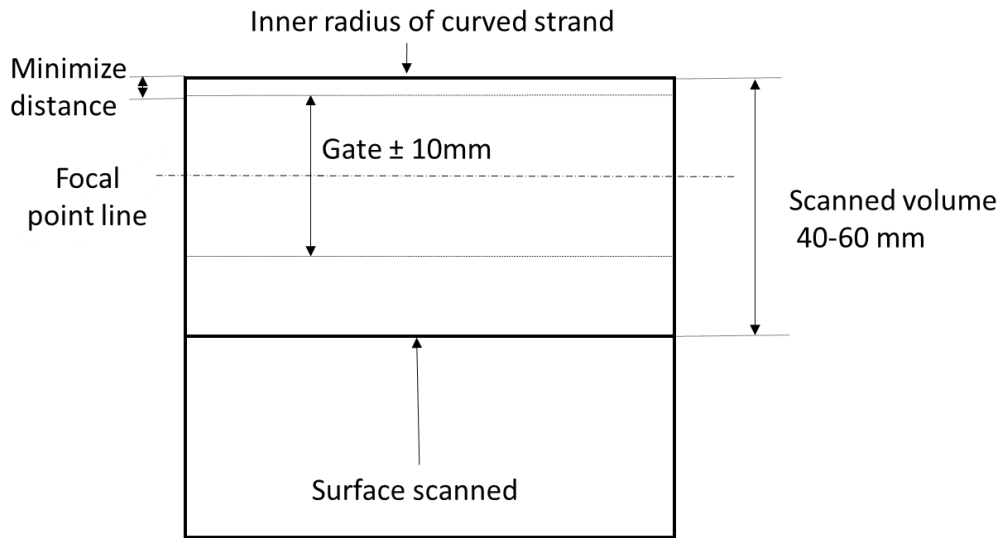


Figure 2. Recommended sample geometry and scanning zone for curved strand cast and rolled billets.

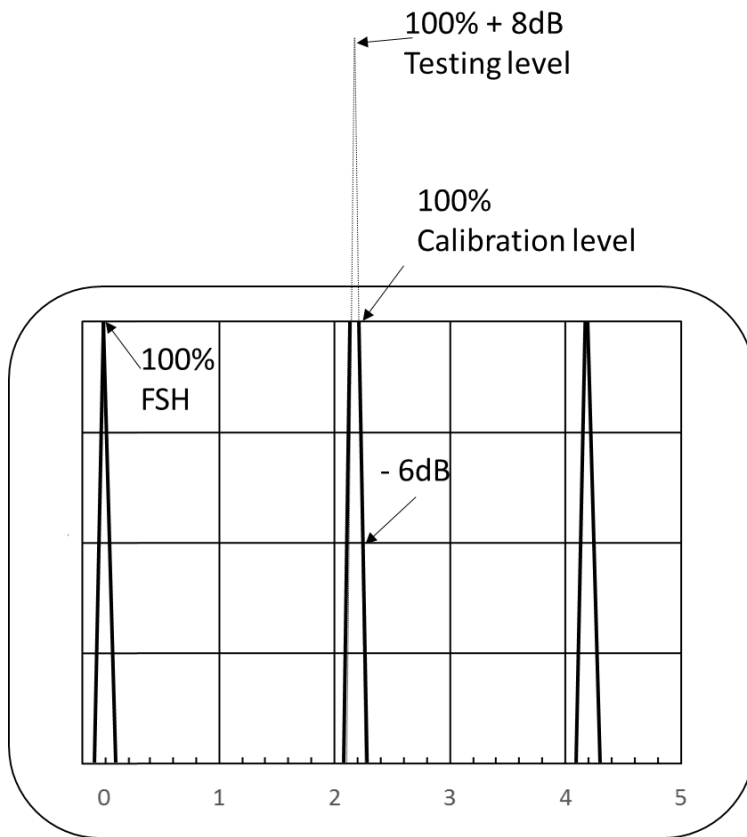


Figure 3. The ultrasonic screen with different levels of indications

APPENDIX 3

Calculation of water gap.

$$\text{Water gap} = F - (V_s/V_w) \times \text{FP}$$

F = Focal length of the transducer in water

V_s = Velocity of sound in steel

V_w = Velocity of sound in water

FP = Focal plane below the entry surface of the test piece

Example:

F = 145 mm

FP = 30 mm

V_s = 5900 m/s

V_w = 1490 m/s

$$\text{Water gap (mm)} = 145 - (5900/1490) \times 30 = 26.2$$

APPENDIX 4

Example of total severity index (TSN number or TSA area) evaluation

Three samples are tested. The total weight of the scanned zone is 5 kg.	Number of defects per defect amplitude class		
	A \geq 30%, < 50 % or \geq -10 to < -6 dB	B \geq 50%, < 100% or \geq -6 to < 0 dB	C \geq 100 % or \geq 0 dB
Example samples	Weight factor x1	Weight factor x2.5	Weight factor x5
1	4	2	0
2	11	1	0
3	6	4	1