SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS2636

Issued 2012-09

Ultrasonic Immersion Inspection Titanium and Titanium Alloy Forgings Premium Grade

RATIONALE

AMS2636 is a new specification that provides requirements for the ultrasonic inspection of titanium forgings used for critical, rotating engine components.

1. SCOPE

1.1 Purpose

This specification covers procedures for ultrasonic immersion inspection of premium grade wrought titanium and titanium alloy forgings. Premium grade is a term used to describe titanium alloys used for critical rotating components in turbine engines. For details, see SAE AMS2380, the specification that covers the procedures for approval of products of premium-quality titanium alloys and the controls to be exercised in producing such products.

1.2 Application

This inspection procedure is intended for use in locating internal defects such as cracks, voids, inclusions, and other structural discontinuities that may or may not be exposed to the surface in forgings, but usage is not limited to such applications. Testing normally will be by longitudinal wave procedure, but shear wave procedure may be added when agreed upon by purchaser and vendor.

1.3 Classes

Class A – Acceptance based on signal-to-noise and amplitude (see Table 1)

Class B – Acceptance based on amplitude only (see Table 1)

1.4 Sensitivity

Inspection sensitivity shall be defined in relation to the flat-bottomed hole (FBH) size used for acceptance, i.e., a sensitivity level of 1 would be used to note a #1FBH (1/64" diameter flat bottom hole) inspection. Unless otherwise specified, a sensitivity level of #1FBH inspection shall be used (See 4.1). If units other than 1/64 inch increments are used, they shall be clearly defined in the purchase documentation.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS2636

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 317 Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

ASTM E 428 Standard Practice for Fabrication and Control of Metal, Other than Aluminum Reference, Blocks Used in Ultrasonic Examination

ASTM E 1065 Evaluating Characteristics of Ultrasonic Search Units

ASTM E 1316 Standard Terminology for Nondestructive Testing

2.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI B46.1 Surface Texture

2.3 AIA Specifications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.4 EN Documents

Available from the British Standards Institute, 389 Chiswick High Road, London, W4 4AL, United Kingdom, Tel: +44 (0)20 8996 9001, www.bsi-global.com.

BS EN 4179 Qualification and Approval of Personnel for Nondestructive Testing

3. TECHNICAL REQUIREMENTS

3.1 Qualification

3.1.1 Personnel

Inspection of parts by this inspection process shall be accomplished by qualified personnel having experience with ultrasonic inspection. Qualification of personnel shall be in accordance with NAS 410, or BS EN 4179. Interpretation and evaluation of indications shall be accomplished by a Level 2 inspector or higher.

3.1.2 Facilities

Facilities shall be subject to review and approval by purchaser. Reference specifications, procedures, and documentation necessary to verify the qualification of equipment and test personnel shall be available to purchaser upon request.

3.2 Scan Plans and Written Inspection Procedures

Ultrasonic inspections performed in accordance with this specification shall be detailed in written procedures that are applicable to a broad class of forging inspections or part specific instructions. Inspection procedures shall be prepared by the vendor and approved by purchaser. Specific criteria and instructions required by the Cognizant Engineering Organization (CEO) shall be met. Inspection procedures shall include not less than the following information:

3.2.1 Procedure identification number and the date the procedure was approved

3.2.2 Forging identifier, such as part number and alloy.

3.2.3 Equipment to be used, including manufacturer and model number of the instrumentation/system, recording equipment, alarm equipment, electronic distance-amplitude correction (DAC) / Time Corrected Gain (TCG) equipment, and software and software version numbers.

3.2.4 Description of manipulating and scanning equipment

3.2.5 Inspection configuration including inspection sonic shape, sound entry angle, entry surfaces, water path distance(s), and number of scans per zone.

3.2.6 Amplitudes for calibration, evaluation threshold, and reject limits.

3.2.7 Rotational speed and index.

3.2.8 Pulse repetition rate or specify “Pulse on Position"

3.2.9 Reference standard description including material, dimensions, reflector size, test metal distance, and correction factors where applicable.

3.2.10 Method used for distance amplitude corrections.

3.2.11 Method for attenuation correction.

3.2.12 Gate length and delay per zone, if applicable.

3.2.13 Methods for surface preparation and surface texture control.

3.2.14 Transducer description including frequency, element diameter, and nominal focus information

3.2.15 Zoning schemes as applicable, as described in Appendix B.

3.3 Exceptions

No exception shall be taken to the written procedure or this specification unless approved by purchaser.

3.4 Equipment

3.4.1 Ultrasonic Instrument

The ultrasonic instrument shall be capable of producing, receiving, and displaying electrical pulses at the required frequencies and energy levels. The instrument shall be able to operate in the pulse-echo mode at frequencies of 2.25 through 10 MHz. Gates, distance-amplitude correction system, and other electronic aids to ultrasonic testing and interpretation shall be used as required. An alarm system, auto-stop, recorder, or combination of these may be used.

3.4.1.1 Instrument Performance

The vertical limit and linearity, and the accuracy of calibrated gain controls shall be evaluated in accordance with ASTM E 317 with the following requirements and exceptions. Substitute performance checks are permissible when agreed upon by purchaser and vendor.

3.4.1.1.1 Vertical linearity shall be ±1 dB over the range of 10 to 90% of full scale.

3.4.1.1.2 Accuracy of calibrated gain control shall be within ±2 dB over the usable range of the instrument.

3.4.2 Ultrasonic Transducers (Search Units)

Transducers shall be evaluated in accordance with ASTM E 1065 to determine frequency response, peak frequency, and band width. The peak frequency shall be not less than 4 MHz.

Transducers shall be tested to determine the beam width. The beam width shall be determined in two directions perpendicular to one another as appropriate to establish the scan index used as defined in 3.8.3. The beam width measurements should be performed using flat-bottom hole targets close to the focal plane of the transducer, in reference standards such as those listed in Appendix A. Typical inspection zones and associated transducer descriptions for Class A and Class B inspections are provided in Appendix B.

3.4.3 Voltage Regulator

The line voltage shall not produce variations in signal response or noise which could interfere with the inspection.

3.4.4 Couplant

Clean water shall be used as the couplant material; rust inhibitors, wetting agents, or both, may be added. The water shall be free of visible air bubbles which may interfere with the ultrasonic test.

3.4.5 Data Acquisition System

If a digital data acquisition system is used to record the data, it shall meet the requirements listed in 3.4.5.1 to 3.4.5.6.

3.4.5.1 Components

The system shall consist of encoders for axes of programmable motion, an analog-to-digital (A/D) signal conversion device, a computer, display monitor, an archival storage system, and appropriate software.

3.4.5.2 A/D Conversion

For each pulse, the peak ultrasonic amplitude in the gated region of each inspection zone shall be digitized to a minimum resolution of 8 bits over the full range of amplitudes used for data acquisition. The A/D converter shall be adjusted using procedures recommended by the manufacturer.

3.4.5.3 Recording System Linearity

Recording system shall be shown to reproduce recorded amplitude data to an accuracy of ±2% of full scale.

3.4.5.4 Digital Data Storage

Digital amplitudes and the corresponding encoder positions shall be stored. For each ultrasonic amplitude, the corresponding encoder positions shall be retrievable by the operator for relocation and evaluation of indications. Data storage system shall provide traceability of the position of indications relative to the forging inspection surface.

3.4.5.5 Digital Data Archiving

When required by the purchaser, all inspection digital data files shall be archived and accessible on storage media acceptable to purchaser.

3.4.5.6 Analysis of Digital Data

Software to analyse the digital data shall perform not less than the following functions: display location and amplitude of indications above the evaluation threshold; allow selection of region of interest (ROI); and calculate the maxium signal, mean noise and peak noise to enable signal-to-noise ratio per 4.1.1 when required for Class A inspections.

3.4.6 Reference Standards

3.4.6.1 Manufacture of Reference Standards

Reference standards may be as defined by the CEO. If not defined by the CEO, reference standards shall be manufactured and certified to ASTM E 428.

3.4.6.2 Fabrication of Flat Bottom Holes (FBH)

Unless otherwise specified by the CEO, FBHs shall be a maximum of 1/64-inch diameter and certified to ASTM E428. FBH depths shall encompass the necessary near surface resolution and the depth of the intended inspection. Recommended FBH depths for multizone and conventional inspection are shown in Appendix A.

A distance-amplitude response curve shall be plotted as gain vs FBH depth for each set of reference standards. An example is shown in Figure 1, below. For an acceptable set of reference standards, no point shall be more than ±2 dB from a best fit curve. After dimensional check, FBH openings may be plugged, leaving an air pocket at the flat bottom hole end.

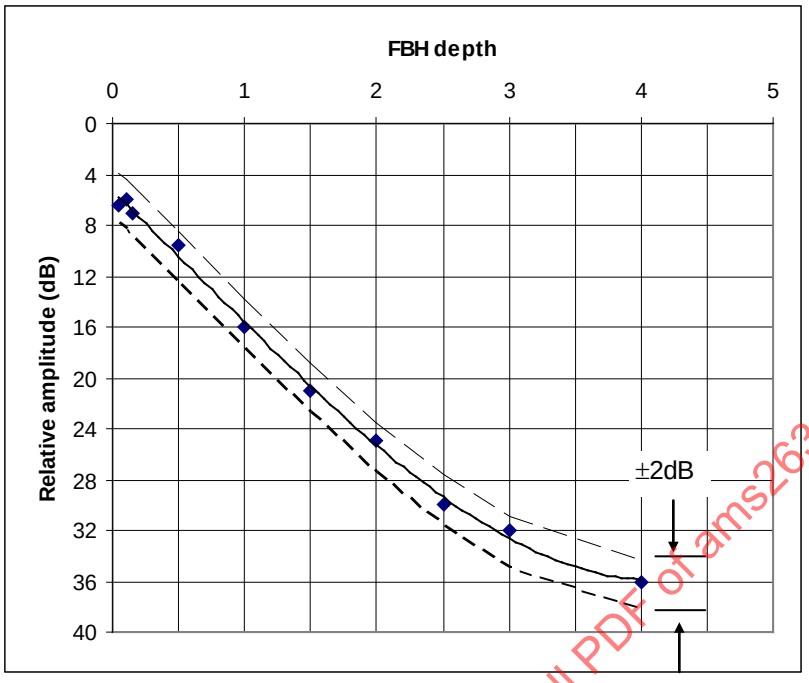

FIGURE 1. RELATIVE FBH AMPLITUDE (DB) AS A FUNCTION OF FBH DEPTH FOR ACCEPTABLE REFERENCE STANDARDS.

3.4.6.3 Selection of Material for Reference Standards

When not specified by the CEO, material used to fabricate reference standards shall be made from a base alloy similar to the parts to be inspected. All reference standards shall be made from forgings (wrought material) of homogeneous structure. The material used for reference standards shall be free of discrete ultrasonic discontinuity indications greater than twice the noise level. Consistency of the material attenuation characteristics for each set of reference standards shall be assured by determining the amount of gain that is required to raise the first backwall signal to a selected frontwall signal amplitude for each thickness. Results shall be plotted as dB vs. material thickness and a best fit line shall be drawn through the points as in Figure 2. For an acceptable set of reference standards no point shall be more than ±2 dB from this line.

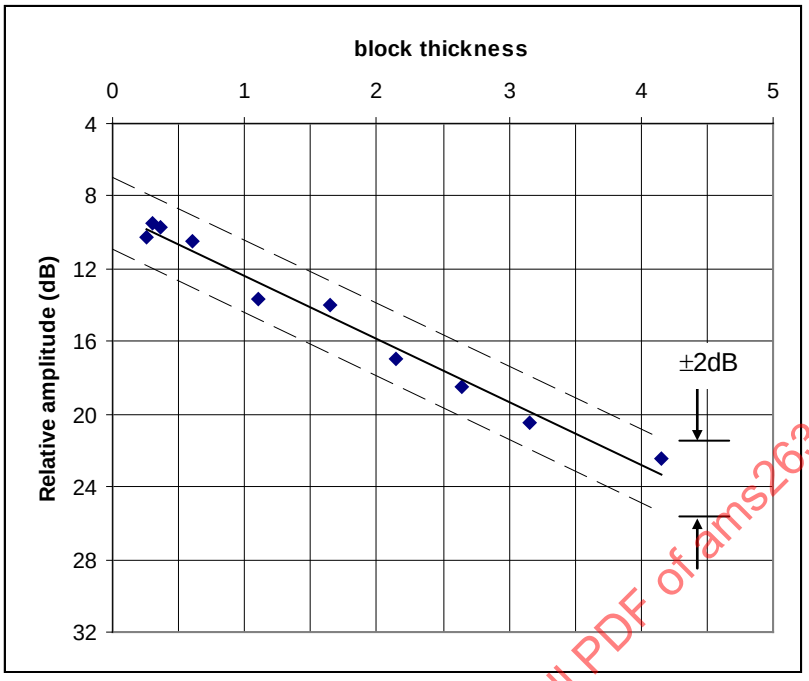

FIGURE 2. RELATIVE FIRST-BACKWALL AMPLITUDE (DB) AS A FUNCTION OF REFERENCE STANDARD THICKNESS.

3.4.6.4 Reference standards shall be subject to calibration, certification, and recall procedures required by purchaser.

3.4.7 System Operation (Dynamic Response)

The total system shall have dynamic response adequate to provide correct amplitude data for all inspection scan and recording parameters.

3.5 Surface Preparation

3.5.1 Surfaces to be inspected shall not produce ultrasonic reflections which interfere with the test. Acceptable surface roughness is dictated by achieving signal-to-noise and near surface resolution requirements. Regions with surface discontinuities, such as local grindouts, are not considered inspectable and shall be unacceptable unless approved by the CEO.

3.6 Zones

3.6.1 Class A shall be zoned such that the focal point of the transducer is placed at or near the center of the gated volume. This requires the waterpath, focal length and zone depth range to be synchronized for each zone. See Appendix B for examples of zones and transducers.

3.6.2 Class B shall be zoned such that the focal point of the transducer is at or near the beginning of the gated volume. This requires the waterpath, focal length and zone depth range to be synchronized for each zone. See Appendix B.

3.7 Calibration of Apparatus

Before inspecting the product, the equipment shall be adjusted, using appropriate reference standards, to produce clearly defined echoes, of amplitude equal to or exceeding 80% of full scale, from all calibration targets in each zone. The setup, i.e., waterpath, instrument settings, etc. shall be the same as that being used for the inspection.

3.7.1 Calibration amplitudes shall be achieved by use of electronic distance amplitude correction (DAC). DAC shall be used to set signal amplitudes equal to or exceeding 80% for all calibration targets within the gated zone(s).

3.7.2 Calibration shall be verified each shift. Verification following the initial calibration setup shall be within ±1 dB or as specified by the CEO. If post-calibration is more than 1 dB under sensitive, all product or parts tested since last successful calibration shall be retested. If post-calibration is more than 1 dB over sensitive, all rejected material shall be re-evaluated at the correct sensitivity. The interval between calibrations may be extended subject to purchaser agreement and documented history showing stability of equipment and consistency of calibration levels.

3.7.3 Post calibration shall be performed.

3.7.4 Any change in equipment that impacts signal response requires a recalibration of the test system.

3.8 General Scanning Procedure

3.8.1 Attenuation Compensation

Attenuation compensation can be accomplished using several acceptable methods, as described below.

3.8.1.1 For standards which are maintained internally by the suppliers, attenuation compensation shall be made for ultrasonic property differences between the part to be inspected and the reference standards which are described in Appendix A. Comparison of the average backwall signal shall be made in the forging at a location having parallel surfaces. In general, the comparison measurements are made at the thickest part of the forging for which there is a reference standard with comparable thickness. If the response from the part is -2 dB or lower than the response from the reference standard, the instrument calibrated gain shall be increased to make the two backwall signal amplitudes equal. The gain difference and depth at which it is measured are recorded as the compatibility difference. Appropriate adjustments are made at all FBH depths used for the inspection by applying the gain in dB/inch at depth. If the gain adjustments increase the baseline noise so that it exceeds the evaluation threshold, or, if an increase is greater than 12 dB, the part shall be considered uninspectable. If the backwall response from the part is higher than the backwall response from the reference standard, no adjustment is made to the calibration gain setting.

3.8.1.2 For standards which are maintained in compliance with master standards managed by the CEO, differences between the acoustic properties of the reference standards and the material being examined may require the use of correction factors to compensate for these differences. Because there are several methods that are acceptable for achieving this, the specific method used shall be approved by the CEO. For Class A inspection, attenuation compensation is accomplished using correction factors provided by the CEO.

3.8.2 Evaluation Threshold

An evaluation threshold shall be defined in the procedure such that any rejectable indication will be certain to exceed the evaluation threshold during scanning. Any signal exceeding the evaluation threshold shall be relocated and further evaluated ultrasonically. The transducer shall be traversed and angulated across the indication to determine the maximum signal amplitude.

3.8.2.1 For Class A inspections, evaluation limits shall be consistent with the effective beam width measurement method. For example, if effective beam width is measured using a 6 dB drop method, then the evaluation limit shall be set at least 6 dB below the sensitivity level. It may be necessary to use a lower dB value to accommodate noise levels in the material being inspected.

3.8.2.2 For Class B inspections, the evaluation threshold shall be set at least 2.5 dB lower than the acceptance signal amplitude.

3.8.3 Scan increment

Scan increment shall be selected as described below and in Fig. 3 to ensure that 100% of the region to be inspected is within the effective beam width. Index distance, pulse repetition rate, and rotational speed shall be controlled to provide adequate data sampling. These parameters shall be controlled such that a rejectable indication will exceed the evaluation limit regardless of its location relative to the sampled points. For example, if the evaluation threshold is -3 dB from the reject level, then the -3 dB sound beam diameter from adjacent and diagonal pulses shall provide complete coverage as illustrated in Figure 3.

3.8.3.1 For Class A inspections, the scan index is established by the beam width planned for the inspection, in conjunction with the evaluation limits defined in 3.8.2.1.

3.8.3.2 For Class B inspections, the maximum inspection speed and index increment shall be demonstrated to trigger at the evaluation threshold for a minimum of two consecutive rotations for response from the FBH where the focused beam has its smallest diameter.

3.8.4 The instrument control settings and test parameters established during calibration shall not be changed during testing with the exception of changes in gate length which may be required to inspect regions with varying thickness.

3.9 Inspection

3.9.1 Sound beam entry angle shall be controlled to within ±1.0 degree of specified angle.

3.9.2 Water Travel

The water travel distance shall be within ±0.125 inch (2.5 mm) of that used for calibration.

3.9.3 Volume to be Scanned

100% of the final part volume must be inspected except blind zones as allowed by the CEO. For Method B inspections, sonic shapes shall be inspected from multiple directions whenever geometrically practical. Special case inspections may be defined by the CEO to meet their requirements for geometric features. When multiple zones are used, overlapping shall be assured. Use of DAC and/or zoning shall not be changed from calibration to inspection.

4. QUALITY ASSURANCE PROVISIONS

4.1 Acceptance Criteria

Shall be as defined by the CEO to meet the life requirements for the specific component. Examples are provided below as guidance. Unless otherwise specified, a sensitivity level of #1FBH shall be used.

4.1.1 For Class A inspection, material containing indications with peak amplitudes equal to or greater than the sensitivity level shall be rejected. Materials with indications that have signal-to-noise ratios equal to or greater than 2.5 shall be rejected. If inspected products have material noise greater than the evaluation limit, these must be evaluated to determine if the peak amplitude exceeds the sensitivity level. If there are excessive evaluations in a specific zone (in excess of five, for example), the inspected product is subject to reject for noise. For purposes of determining signal acceptance based on its signal-to-noise ratio, signal-to-noise ratio is defined as:

(Signal - Mean) / (Peak - Mean)

where signal is the highest amplitude obtained from the suspected indication, mean is the mean value of noise in a region surrounding or adjacent to the indication, and peak is the highest amplitude value of noise in the surrounding or adjacent region excluding electrical noise signals.

4.1.2 For Class B inspection, acceptance levels for a given inspection are defined by the customer in terms of FBH size. Amplitude signals from a feature must be evaluated using the reference standard FBH with metal travel most similar to that of the indication, including any attenuation compensation used. Amplitude signals exceeding the reference standard FBH amplitude at the depth of the indication are cause for rejection.

4.2 Disposition

4.2.1 Product exhibiting ultrasonically evaluated indications that do not exceed acceptance limits may be accepted without remedial operations.

4.2.2 Indications in excess of acceptance limits shall be removed and metallographically evaluated. Evaluation and disposition of remaining product from the same heat shall be in accordance with purchaser agreement.

4.3 Records

4.3.1 The testing source shall prepare and maintain, for the time specified by purchaser, records of the requirements and techniques for each part number, and all recorded data from forging inspection. These records shall be accessible for review by purchaser at any reasonable time. When multiple zones are used, this information should be available for each zone. Information to be recorded includes:

4.3.2 Date

4.3.3 Inspector

4.3.4 Relevant specifications

4.3.5 Transducer make and model number

4.3.6 Instrument and instrument settings

4.3.7 Pulse width, voltage, filter, DAC gain values

4.3.8 Equipment model/serial number, including software and software version numbers

4.3.9 Instrument settings including receiver and pulser settings

4.3.10 Reference standard serial number(s)

4.3.11 Transducer manufacturer, model number, nominal diameter, nominal frequency, and serial number

4.3.12 Water path(s)

4.3.13 Date of last system calibration

4.4 Reports

The testing source shall provide a report with each shipment. Traceability to the name and address of the facility performing the inspection shall be documented. This report shall contain not less than the following information:

4.4.1 Description of the product tested including alloy, heat number, and forging identifications

4.4.2 Written procedure document number including applicable revisions

4.4.3 Name of inspector

4.4.4 Date of inspection

4.4.5 Report of all indications exceeding acceptance limits with disposition according to purchaser agreement

4.4.6 Report of all indications over evaluation threshold as required by purchaser

4.4.7 Forging map showing location of indication

4.4.8 Location of any regions not inspectable in accordance with 4.1.1 and 4.1.2

4.4.9 Noise level for each forging

5. PREPARATION FOR DELIVERY

Not applicable.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Product not inspected in accordance with this specification, or with modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 A change bar (|) located in the left margin is for the convenience of the use in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the documents, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Test Conditions

It is essential that a thorough understanding be developed between purchaser and vendor regarding interpretation of the results of inspection and how they shall be recorded and reported. Ultrasonic testing is so comprehensive that it is necessary that all interested parties fully recognize that indications may appear which do not reflect conditions detrimental to use of the product.

PREPARED BY AMS COMMITTEE “K”

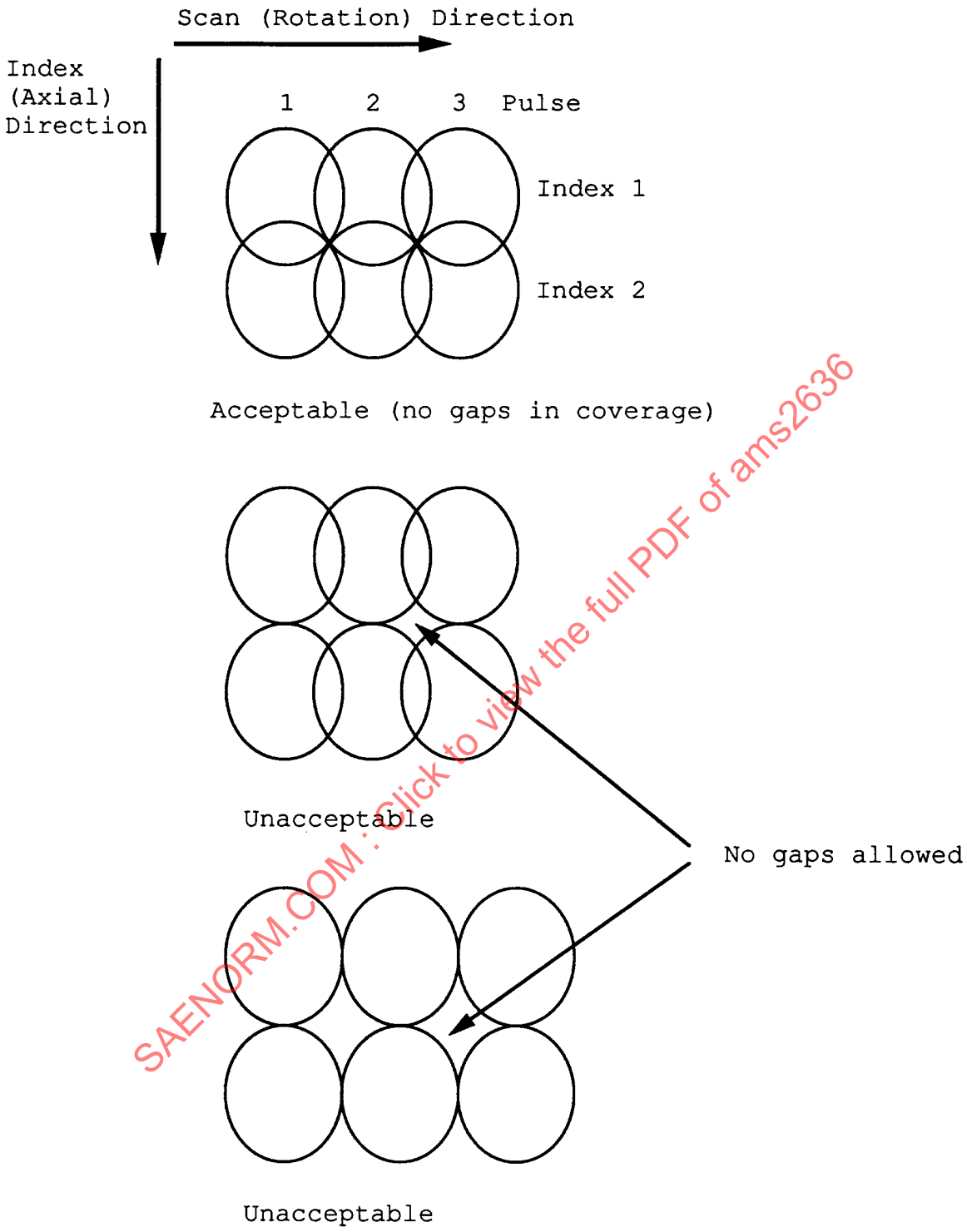

FIGURE 3 - ACCEPTABLE BEAM OVERLAP CONDITIONS IN ACCORDANCE WITH 3.8.3.