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Nondestructive Testing Procedure

"Ultrasonic Testing of Railroad Axles"

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Attachments

1.0 Purpose

1.1 The purpose of this "Ultrasonic Testing Procedure" is to outline the process by which Transportation Technology Center, Inc. (TTCI), or their designee, will conduct ultrasonic inspection of railroad axles.

2.0 Scope

2.1 This procedure provides the minimum requirements for performing railroad axle inspection for axles used in the FAST consist.

3.0 Methodology

3.1 By monitoring a 50 percent drop in signal amplitude; during scanning at the surface of a railroad axle, internal and external discontinuities can be detected. The 6 dB drop method uses an amplitude drop of 6 dB on each side of the peaked ultrasonic signal to determine defect width and height as depicted on the cathode ray tube (CRT) of the ultrasonic flaw detector.

4.0 Personnel

4.1 Personnel performing ultrasonic inspection of railroad axles shall be certified to Level II, or Level III in accordance with the minimum requirements as defined by the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-1A.

5.0 Definitions

- **A-scan display:** A display in which the received signal amplitude is shown as a vertical excursion from the horizontal sweep time trace. The horizontal distance between any two signals represents the material distance between the two conditions causing the signals. In a linear system, the vertical excursion is proportional to the amplitude of the signal.
- **Acceptance Criteria:** A standard against which test results are to be compared for purposes of establishing the functional acceptability of a part or system being examined.

- **Calibration reflector:** A reflector with a known dimensioned surface established to provide an accurately reproducible reference level.
- **Certification:** Written testimony of qualification by an authorized body.
- **Couplant:** A substance (usually liquid) used between an ultrasonic transducer and the test surface to permit or improve transmission of ultrasonic energy into the test object.
- **Defect:** A discontinuity whose size, shape, orientation, or location make it detrimental to the useful service of its host object in which it occurs or which exceeds the accept/reject criteria for the given design.
- **Detection:** When a specimen or grading unit containing a flaw site is correctly interpreted as being flawed.
- **Decibel (dB):** A comparative measure of two signal amplitudes, obtained by multiplying by ten the common logarithm of the ratio of the amplitude of the two signals:

  $$dB = 20\log_{10}A_1/A_2$$

  where: A_1 and A_2 are the signal amplitudes.
- **Experience:** Work activities accomplished in a specific NDT method under the direction of qualified supervision including performing the NDT method and related activities but not including time spent in organized training programs.
- **Internal Flaw:** Those flaws located internal to the axle structure that are not open to any of the axles outside surfaces.
- **Qualification:** Demonstrated skill and knowledge and documented training and experience required for personnel to properly perform the duties of a specific job.
- **Outside agency:** A company or individual who provides NDT services and whose qualifications to provide these services have been reviewed by TTCI.
- **Shall:** A verb used to express the minimum requirements of this written practice.
- **Should:** A verb used to express the desired requirements of this written practice.

- **Surface Flaws:** Those flaws located at the outside surface of the axle.
- **Training:** The organized program developed to impart the knowledge and skills necessary for qualification.
- **ultrasonic testing:** Nondestructive testing using acoustic energy at frequencies above the human hearing range (20 kHz and above)
- **Written Practice:** A written description of the requirements and actions that apply specifically to personnel involved in NDT.

6.0 References

- Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," December 1998.
- ISO - 9712
- Military Standard 410D
- Association of American Railroads, Field Manual of the A.A.R. Interchange Rules, 2004.

7.0 Equipment and Accessories:

7.1 Ultrasonic flaw detector with a minimum frequency range of between 1 and 10.0 MHz

7.2 2.25 MHz transducer, 0.5-inch (12.7 mm) circular or 0.625-inch (15.9 mm) rectangular

7.3 45-degree Lucite wedge contoured to fit the radius of the axle body

7.4 International Institute of Welding (IIW) or Distance and Sensitivity Calibration (DSC) reference blocks

7.5 Axle sample containing saw cuts or electro-discharge machined (EDM) notches that simulate fatigue cracks at the outside surface of the axle as shown in Attachment 1.

7.5.1 Saw Cut (EDM Notch) 1 (1.0 inch (± 0.025) long, 0.063 inches (± 0.010) deep at center, and 0.040 inches (± 0.010) wide)

- Parallel to axle ends
- Center between axle ends

7.5.2 Saw Cut (EDM Notch) 2 (2.0 inches (± 0.025) long 0.125 inches (± 0.010) deep at center, and 0.040 inches (± 0.010) wide)

- Parallel to axle ends
- Center between axle ends and 180-degrees from saw cut (EDM Notch) 1

7.5.3 Saw Cut (EDM Notch) 3 (1.0 inch (± 0.025) long, 0.063 inches (± 0.010) deep at center, and 0.040 inches (± 0.010) wide)

- Parallel to axle ends
- 1-inch out from the wheel seat edge closest to the axle body

7.5.4 Saw Cut (EDM Notch) 4 (2.0 inches (± 0.025) long 0.125 inches (± 0.010) deep at center, and 0.040 inches (± 0.010) wide)

- Parallel to axle ends
- 1-inch out from the wheel seat edge closest to the axle body and 180-degrees from saw cut (EDM Notch) 3

7.6 Couplant (glycerin based for adhesion and acoustic impedance match)

7.7 Ruler or measuring tape

7.8 Lint free towels

8.0 Calibration Procedure:

8.1 Turn on ultrasonic flaw detector

8.2 Connect 2.25 MHz transducer with 45-degree wedge to flaw detector

8.3 Set horizontal display for 30 inches (76.2 cm)

8.4 Apply couplant to IIW or DSC calibration block and scan surface of block

8.5 Verify beam angle by matching 45-degree reference mark on block with the peak amplitude from the monitored ultrasonic signal

8.6 Assure a minimum peak signal of 80 percent full screen height (FSH)

8.7 Apply couplant to axle calibration sample and scan top surface of axle

8.8 Monitor the signal amplitude across Saw Cut 1 and adjust gain until signal is peaked at approximately 80 percent full screen height (FSH) as shown in Attachment 2.

8.9 Repeat scans over Saw Cuts 2, 3, and 4 verifying a minimum of 80 percent FSH at these locations (without increasing or decreasing the gain)

8.10 Set gate at 40 percent screen height

8.11 Examine axle without readjustment to the gain established during calibration

9.0 Railroad Axle Scanning

9.1 Apply couplant to the top surface of the axle and scan in the longitudinal direction along the axle body at a rate of no faster than 6 inches/second (15 cm/second)

9.2 Repeat step one across the axle body until the entire surface of the axle body has been scanned from wheel seat to wheel seat and 360-degrees around the axle body.

9.3 After scanning in one direction (i.e. – left to right) repeat scans in the opposite direction (i.e. – right to left) once the probe direction has been turned 180 degrees

9.4 Transverse flaws are detected when a signal on the flaw detector screen appears and its amplitude is above the 40 percent screen height of the gate set during calibration

9.5 Sizing of flaws is performed using the 6 dB drop method as follows

9.5.1 Once an indication surpasses the 40 percent gate you can determine the height of the flaw by continuing to scan the length of the axle until you peak the signal to its greatest amplitude (apply more couplant if required)

9.5.1.1 After establishing peak amplitude scan forward longitudinally until the signal drops to just below the gate (40-percent screen height), mark that longitudinal location with a paint or marker stick on the axle and note the number of divisions on the horizontal scale

9.5.1.2 Repeat the longitudinal scan in the opposite direction of the peaked signal with the transducer facing in the same direction as the scan in "9.5.1.1", when the signal drops to below the gate in that direction again mark the axle and note the number of divisions on the horizontal scale

9.5.1.3 Determine the difference in divisions on the horizontal screen from the forward and backward scans (i.e. – if the peak (at 40-percent screen height) was located at the second grid block for scan 1 and the third grid block for scan 2 then the difference in divisions on the horizontal screen represents 3 inches (7.6 mm)) for a 30-inch screen range.

9.5.1.4 The flaw height is determined by dividing the tangent of 45 degrees (tan 45 = 1) by the difference identified in "9.5.1.3" and dividing that answer by 2 which represents the distance of the surface scan (reference marks made on the rail surface) the formula is as follows:

$$\text{Flaw Height} = \frac{\text{(surface distance/tan 45 degrees)}}{2}$$

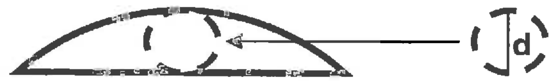
9.5.2 The width of the flaw is determined by scanning the axle circumferentially while monitoring the peak amplitude of the ultrasonic signal

9.5.2.1 After establishing the peak amplitude scan circumferentially to one direction of the axle until the signal drops to below the gate (40-percent screen height) mark that location on the axle

9.5.2.1 Repeat the circumferential scan to the opposite direction of the axle until the signal drops to below the gate – mark that location on the axle

9.5.2.1 Measure the distance between the marks (this is your flaw width)

9.5.3 The size of the flaw can be determined by using the information obtained in "9.5.1" and "9.5.2" above for the height and width of the flaw and applying them to the formula for the area of a cycloid as follows:



d (diameter)

Flaw Area = $3\pi r^2$

Where "r" is ½ the height identified in "9.5.1" or, $r = d/2$ and $\pi = 3.1416$

Example:

Height = 0.55 inch (1.4 cm)

Flaw Area = $3\pi(0.55/2)^2 = 0.713$ inch^2 (1.8 cm^2)

9.5.4 In order to apply a percentage of the axle cross sectional area (CSA) to the flaw size you must divide the area of the flaw by the area of the axle.

Using the area of the flaw from "9.5.3" (0.713 inch^2) the CSA for that size of transverse defect in an 8-inch diameter axle section would be:

Area of a circle: $A = \pi r^2$

$= \pi(4^2)$

$= 50$ inch^2 (127 cm^2)

Flaw Size: Flaw Size = flaw area/axle area

= 0.713 inch^2/50 inch^2

= 1.4-percent

9.5.5 Scanning procedure outlined above would be performed from both sides of the flaw and the largest value would be recorded as the flaw size.

10.0 Acceptance Criteria

10.1 Damage (nicks, dings, scratches, gouges, etc.) between wheel seats, determined to be 1/8-inch or deeper, is not acceptable.

10.2 Indications, ultrasonically measured to be greater than 1-inch long and 0.063-inches deep at center, as represented on the flaw detector A-scan screen are not acceptable.

Note: Discontinuities identified, during ultrasonic inspection, shall be addressed in accordance with the 2004 Field Manual of the Association of American Railroads Interchange Rules, Rule 43.

11.0 Reporting

11.1 After completing the scan along the axle, document the condition of the axle by recording as a minimum the following information:

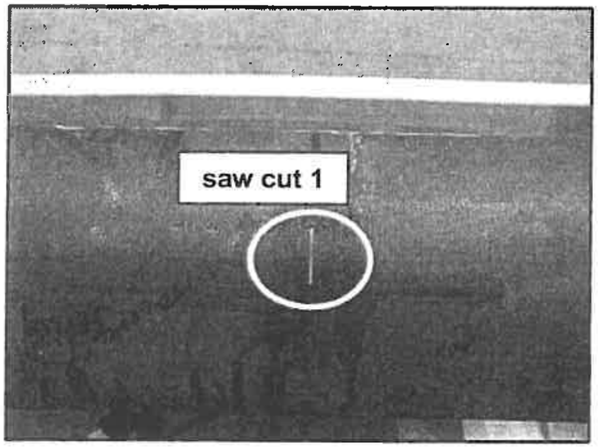
- Inspection Company
- Inspector name
- Inspector level of certification
- Inspection date
- Inspection procedure
- Axle identification
- Type of defect
- Number of defects
- Defect location
- Defect height
- Defect width
- Defect area

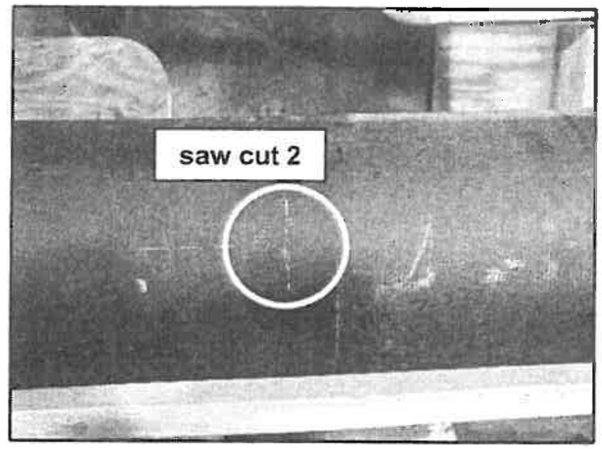
11.2 Inspection report form shown in Attachment 3 shall be filled out and forwarded to TTCI after axle inspection is complete.

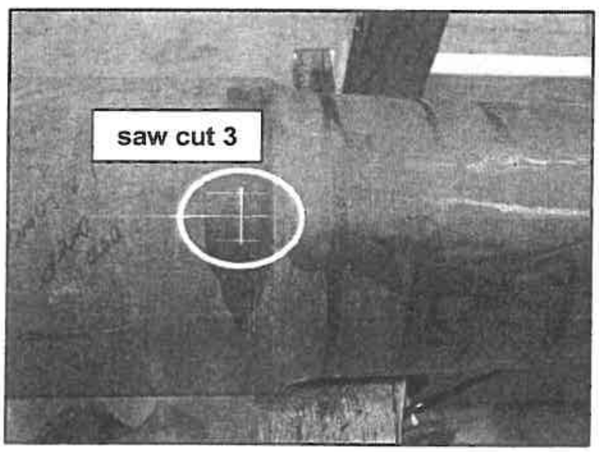
ATTACHMENT 1

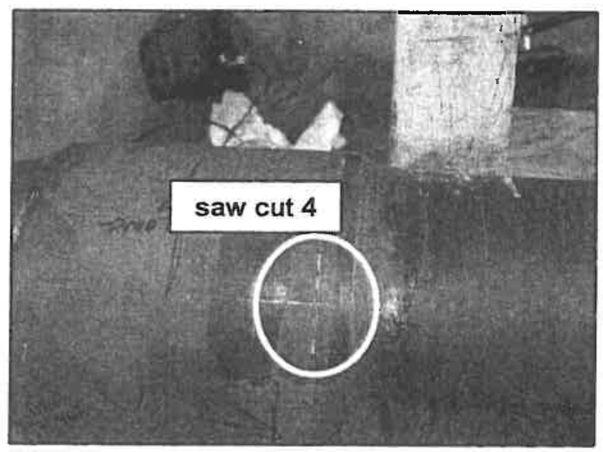
Axle Sample With Saw Cuts

Photographs of saw cuts 1 through 4, show the simulated fatigue cracks required for the railroad axle ultrasonic inspection calibration axle. Locations and sizes of saw cuts or EDM notches are identified in paragraph 7.6 of the ultrasonic inspection procedure.



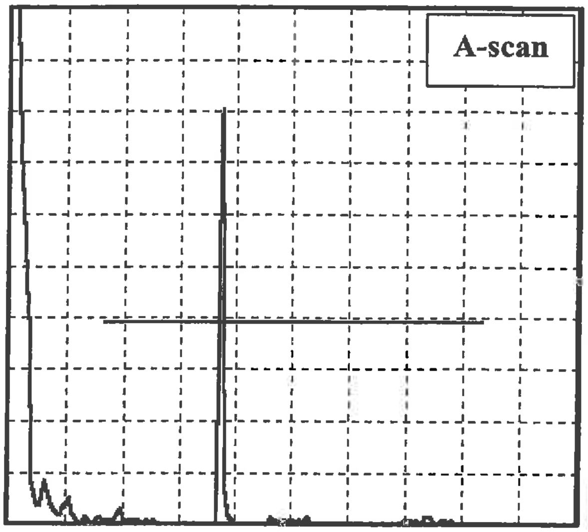


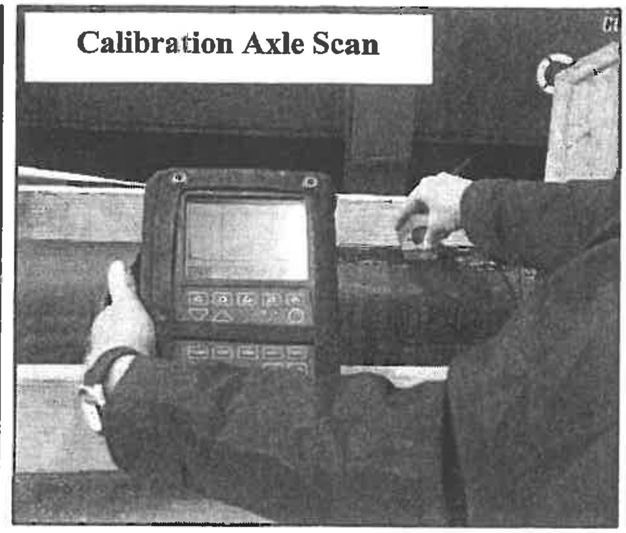




ATTACHMENT 2

Calibration Reference for dB Setting and Parameter Setup





PULSER		RECEIVER		RANGE	
Pulser	250	Gain	66.0	Range	30
Damping	200	Display	FULLWAV	Delay	0.0
Mode	SINGLE	Frequency	2.25MHZ	Velocity	0.1218
Voltage	150	Reject	0	Rep Rate	150
		dB diff	36.0		
GATE		**THICKNESS**		**SPECIAL**	
Gate 1	+	T-Gauge	A IP-1ST	Units	1
Level	39	Trigger	EDGE	Peak hold	OFF
Position	5.0	Offset	23.8916		
Width	20.0	T-Velocity	0.1316	TRANSDUCER	
Gate 2	OFF	Trig	ON	Model	
Level	50	Angle	45.0	Serial #	
Position	0.5	Thickness	8.5		
Width	0.25	O-Diameter	7.6	DAC	OFF

Calibration Parameters using a 45-degree wedge and showing the reflected signal on the flaw detector at approximately 80-percent screen height. Reflector in this case is "saw cut 1" which is approximately 1-inch long and a maximum of 0.063-inches deep.

ATTACHMENT 3

Transportation Technology Center, Inc.

Railroad Axle

Ultrasonic Inspection Report Form

Inspection Company: ______________________________

Inspector: ____________________ Level of Certification: ____________

Inspection Procedure: ____________ Inspection Date: ____________

Plate Serial Numbers: ________________________

Axle ID Number: ____________ Axle Accepted: yes no

Ultrasonic Inspection Results:

Type of defect: ____

Number of Defects: ____

Defect Locations: ____

Defect Height: ____

Defect Width: ____

Defect Area: ____

Comments: ____

____

____

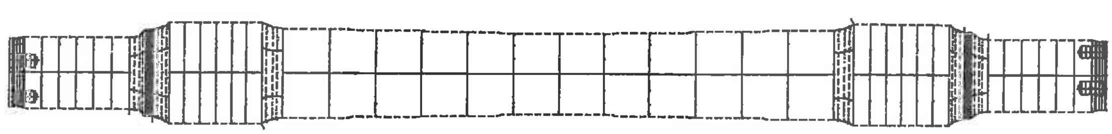


Plate S/N: ________ Plate S/N: ________