

INTERNATIONAL TRUCK AND ENGINE CORPORATION		
CEMS (CORPORATE ENGINEERING MATERIAL SPECIFICATION)		NUMBER: CEMS AT-1
TITLE: Ultrasonic Steel Cleanliness Test		CURRENT ISSUE DATE: October 2001
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<i>This specification may involve hazardous materials, equipment, and procedures. This specification does not purport to address all of the safety issues associated with its use. The user is responsible to consult appropriate safety and health practices and to determine the applicability of regulatory limits prior to use.</i>		
Change Notice: Editorial Changes		

1.0 SCOPE

This method covers a procedure for rating steel cleanliness by means of an automatic computerized ultrasonic system. The test is performed on a volumetric rather than a surface examination basis and thus inherently has a much greater capability of providing reliable inclusion content information. The system provides for detecting and counting various size inclusions. It consists of an ultrasonic test instrument, a search unit, a means of recording signals, reference test blocks and an immersion tank with suitable scanning facilities. Pulsed sound waves penetrate the steel sample through a fluid coupling and upon encountering a discontinuity such as a nonmetallic inclusion, are reflected with an energy level dependent upon the defect area and contour. The reflected ultrasound is sorted into 16 evenly spaced categories or inclusion size levels and counted. The computer calculates a cleanliness index which is based upon the percentage of counts in each category multiplied by an empirical weighting factor for each category.

2.0 APPARATUS

- 2.1 Sperry Model UM721 Reflectoscope with pulse Receiver Unit Model 10N and Transigate E550.
- 2.2 Automation Industries search unit Type SIL, Style 50A 2248, $\frac{3}{4}$ inch (19.05) 5 MHz.
- 2.3 Digital Equipment Corporation, A-D Converter Model AF-1, Computer Model PDP 8/I, Analog Digital Interface as designed by International.
- 2.4 Immersion tank with suitable scanning and indexing equipment.

3.0 MATERIAL – TEST SPECIMENS

3.1 Specimen Size

Specimens will be rolled or forged to a 4 in (102 mm) or 5 in (127 mm) square with sufficient length to scan at least 6 inches (152 mm).

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3.2 Surface Finish Requirements

The test surface (surface through which the sound energy enters the sample) is normally machine-finished to within 0.38 in (9.5 mm) of the sample edges. This surface will have a surface finish of preferably not less than 14µin (0.36µm) nor more than 77 µin (1.96 µm) AA in any direction over the surface.

3.3 Thermal Treatment

Thermal conditioning of sample is required to minimize acoustic anomalies. Treatment of medium and low alloy steel samples consists of normalizing at 160°F (71°C) (nominal) above the Ac₃ Transformation Temperature for one to two hours at heat.

4.0 PROCEDURE

4.1 Calibration and Operation

4.1.1 Counter

A count is recorded in one of the 16 evenly spaced categories with each transmitted pulse. This provides a sampling rate equal to the pulse repetition rate of the pulse generator. If no signal is evident, counts will occur in Category 1. An electronic counter or analog/digital converter is used. It is essential to synchronize the counter with the analog output signal to assure that sampling occurs during peak voltage period and does not occur during signal rise time, fall time or at a quiescent voltage state. The block diagram of a computerized ultrasonic system is shown in Figure 1.

4.1.2 Sensitivity Setting

To determine the sensitivity setting for inspecting a selected gated depth, a reference step block (or individual blocks) is required which contain 0.015 in (0.38 mm) diameter flat bottom holes. Metal travel to the holes will coincide dimensionally with the metal path that is traveled from the entry surface to gate center. A reference step block is shown in Figure 2.

4.1.2.1 The reference step block is required to be made from the material to be tested or that which is acoustically similar. Reference standards will be prepared of premium quality vacuum degassed material which has been inspected ultrasonically to verify cleanliness.

4.1.2.2 Instrument sensitivity will be set by aligning the 5 MHz search unit over a 0.015 in (0.38 mm) diameter flat bottom hole in applicable gated range to allow proper water path. The sensitivity control is adjusted to obtain a 2.0 in (51 mm) video amplitude on a cathode ray tube.

4.1.2.3 The highest order counter (Category 16) must be adjusted (interface sensitivity control) to respond to a video amplitude signal of 2.0 in (51 mm) with an output voltage corresponding to the midpoint of the upper level range. The lower order counter is adjusted via interface offset control to respond to a video amplitude signal of 0.2 in (5 mm) with an output voltage as determined by the following relationship:

$$\text{Low Level Voltage} = \frac{0.2 \times \text{high Level Midpoint Voltage}}{2}$$

4.1.2.3.1 This adjustment must be made after warm up before operating the equipment.

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4.1.2.4 Water Path: The proper water path for a 5 MHz transducer is 2.000 ± 0.015 in (50.80 ± 0.38 mm) and the water path for a 10 MHz transducer is 1.000 ± 0.015 in (25.40 ± 0.38 mm). The water temperature will be 67 to 78°F (19 to 26°C).

4.2 Miscellaneous Requirements

4.2.1 Scanning will be parallel to rolling direction.

4.2.2 Pulse repetition rate will be 750 pulses/second.

4.2.3 Scanning speed will be 6.0 in/sec (150 mm/sec).

4.2.4 Lateral indexing will be 0.050 in (1.3 mm). See Figure 3.

4.2.5 Gated inspection zones will consist of three regions as indicated in Figure 3. Other gated zones may be inspected upon agreement between purchaser and supplier.

5.0 COMPUTATION AND REPORTING OF TEST RESULTS

5.1 All data accrued on number of various inclusion sizes at the termination of the scan is mathematically treated by the computer to obtain a cleanliness index rating.

$$\text{Cleanliness Index Rating} = \sum_{n=1}^x FP$$

Where

F = Percent of counts occurring for each category

P = Weighting factor for each category P

5.1.1 For example, the following test results are reported and mathematically treated as indicated:

Category Count Level	Number of Count	% Counts	Weighting Factor	Product
1	N ₁	N ₁ /N _t	A	A (N ₁ /N _t)
2	N ₂	N ₂ /N _t	B	B (N ₂ /N _t)
15	N ₁₅	N ₁₅ /N _t	O	O (N ₁₅ /N _t)
16	N ₁₆	N ₁₆ /N _t	P	P (N ₁₆ /N _t)

$$\text{Cleanliness Index Rating} = \text{-----} + P (N_{16}/N_t)$$

(N_t = Total Number of Counts)

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