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Ultrasonic calibration and certification of V1 and V2 type reference standard blocks for use in Non-Destructive Testing

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Abstract. Ultrasonic Non-Destructive Testing (US-NDT) has many industrial applications, such as flaws detection, welding integrity evaluation and solid material thickness measurement. To evaluate the instrumentation conditions, before a measurement begins, a "calibration" should be carried out with the aid of a reference standard block (RSB). Types V1 (ISO 2400) and V2 (ISO 7963) are the most widely used in US-NDT. Due their characteristics, V1 and V2 RSB can be classified as Reference Material, so that they can be certified, resulting in a Certified Reference Material (CRM). This paper describes technical aspects of a V1 and V2 RSB certification, based on ISO 2400, ISO 7963, EN 12223 and EN 27963. According the certification protocol established at Inmetro's Laboratory of Ultrasound, RSB relevant dimensions were determined through calibration. Ultrasound velocity was assessed by using a scope and a signal generator at 5 MHz. Uncertainties were determined including measurement accuracy under repeatability conditions. A complete uncertainty budget was determined for both parameters. Within the specimens used, velocities were in accordance with specifications 5920 ± 30 m/s).

1. Introduction

We live in a world in which technology improves quickly and becomes more present in our daily life. However, this technology can offer risks if is not developed and used properly. Even small defects can be troublesome with potential to generate accidents and injuries, besides causing the customers unsatisfaction. To detect such failures special inspection methods are necessary. Therefore, the Non-Destructive Testing (NDT) arises, defined as a method to evaluate materials, pieces, equipment or detects the failure without causing damage to the inspected element. There are different forms of NDT, such as: Eddy Current, Magnetic Particle, X-Ray, Gamma- Ray and Ultrasound [1].

NDT by ultrasound, especially in thickness measurement and structure failure detection, uses the Pulse-Echo (A Scan-Mode) equipment. In the calibration of this equipment, standard blocks called V1 and V2 are employed. To assure the metrology reliability of all the measurement process, it is

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necessary that standard blocks are used, preferentially if they were certified such as a CRM (Certified Reference Material) [2]. These follow the principle of CRM and the technical requisites of ISO 2400 [3], ISO 7963 [4], EN 12223 [5] e EN 27963 [6] standards. The longitudinal velocity is the main characteristic to be evaluated.

The aim this work was to calibrate the reference blocks, evaluating its main dimensions and acoustic properties. Therefore, four reference blocks, being two V1 blocks and two V2 blocks were used. The main scales and dimensions and the longitudinal velocity were assessed.

2. Experimental Procedure

The dimensional calibration of two V1 blocks (Nº 121 e Nº176) (Figure 1A) and two V2 blocks (Nº 255 and Nº182) (Figure 1B) was carried out in the Dimensional Metrology Laboratory (Lamed)/INMETRO. A system composed by laser interferometer (reference value), a table with a system of horizontal micrometric displacement (maximum range: 300 mm), moved by c.c. motor and a microscope with camera CCD coupled to a computer were used. Specific software to determine the measurements was used. The scale is aligned to the laser and to the microscope in this system.

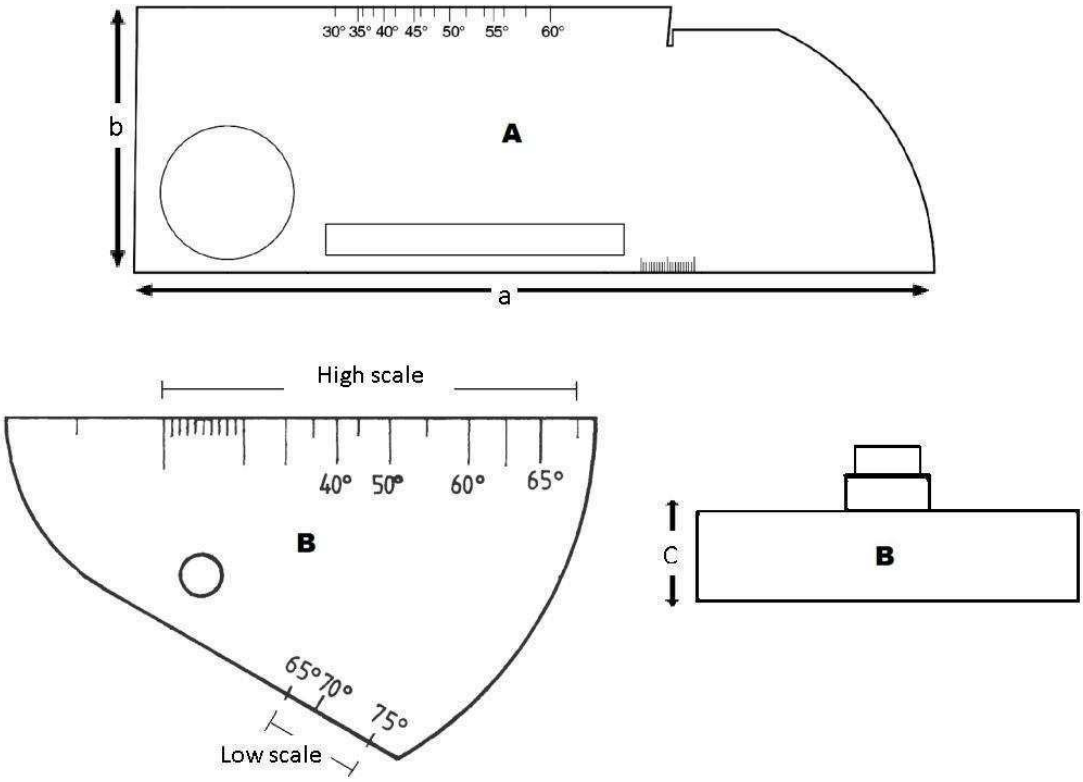

Figure 1. V1 standard block [5] (A) and V2 standard block [6] (B)[5].

In V1 blocks, the specified tolerance is ± 0.10 mm, in accordance with ISO 2400 and EN 12223 standards. V2 blocks, tolerance is ± 0.10 mm, except for the scales length ± 0.50 mm, in accordance EN 27963 standard.

The US GE equipment (figure 2A) in conjunction with a straight beam probe (5MHz Ø=10 mm) (figure 2 B) and a broadband pulse were used to measure the time-of-flight. An attenuator (figure 2C) and a Tektronix oscilloscope (figure 2D) were also used. To acquire the pulse-echo signal and

calculate the longitudinal velocity, a Labview program (BlockCalibration6) was developed and it is showed in figure 3. The time difference between the first and second back-wall echoes was measured.

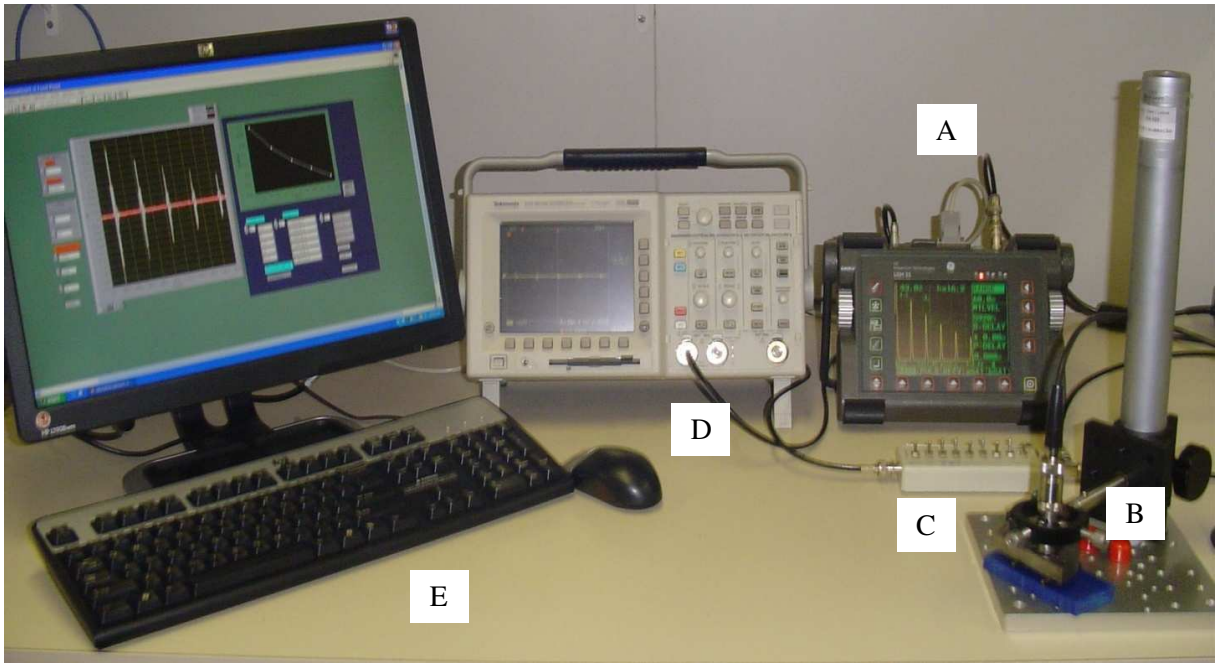

Figure 2. Experimental setup: GE equipment (A), transducer (B), attenuator (C), oscilloscope (D) and computer (E).

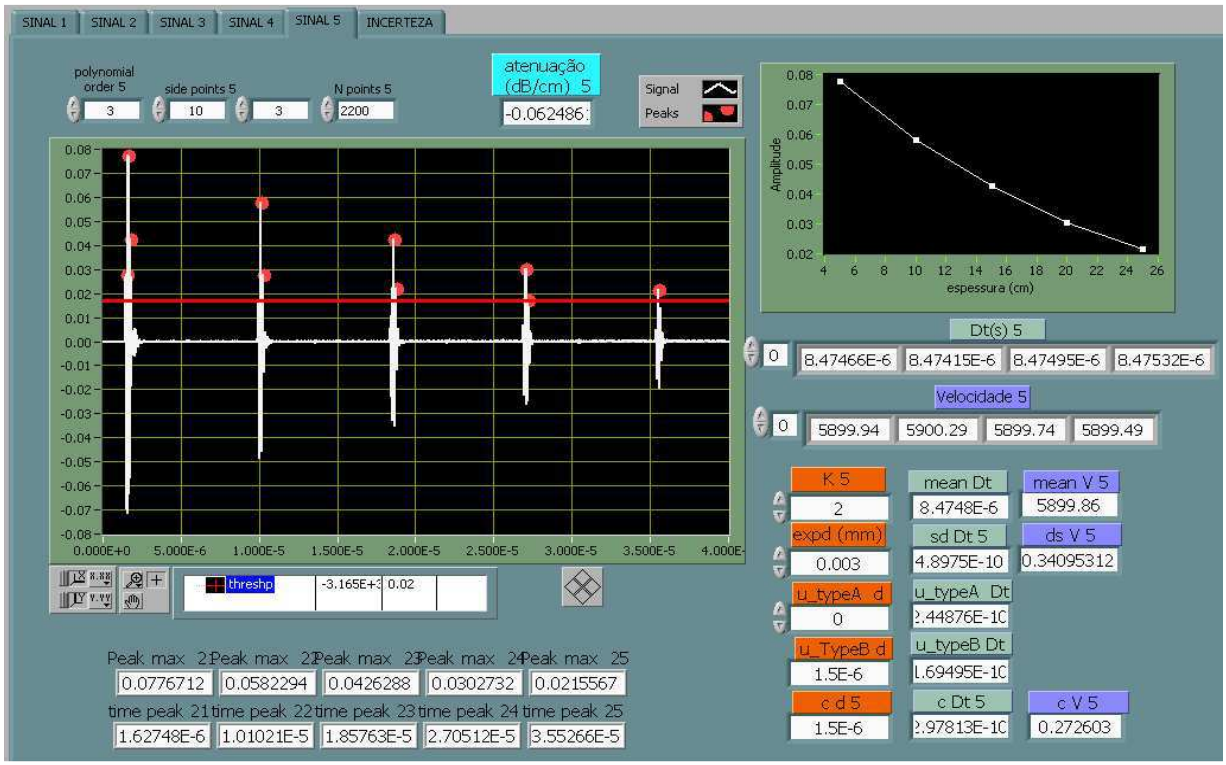

Figure 3. BlockCalibration6, program used to measure longitudinal velocity and uncertainty of standard block.

3. Results and Discussion

The dimensional calibration of both sides (with and without serial number) of V2 standard block scale data (figure 1B) can be seen in table 1. The nominal value scales (present in the EN 12223 standard) were compared with the average calculated values of 3 measurement cycles. The difference between these values was compared with the tolerances found in ISO 7963 standard. (Systematic error means that it would result from an infinite number of measurements of the same measurand carried out under repeatability conditions, minus a true value of the measurand [7]). The main dimensions to calculate V1 and V2 blocks longitudinal velocity are given in table 2.

Table 1. Nominal value and systematic measurement error of V2 standard blocks dimensional scales.

Scales	Nominal value	V2 block - N 255				V2 Block - N 182			
		Side A (w/ serie number)		Side B (w/ serie number)		Side A (without/ serie number)		Side B (without/ serie number)	
		Measured quantity value (mm)	Systematic measurement error + uncertainty*	Measured quantity value	Systematic measurement error+ uncertainty*	Measured quantity value	Systematic measurement error+ uncertainty*	Measured quantity value	Systematic measurement error+ uncertainty*
High	5.00	-5.01	0.02	-5.02	0.04	-5.00	0.01	-4.99	0.02
	5.00	5.01	0.02	5.00	0.01	5.00	0.01	5.00	0.01
	14.00	14.01	0.02	14.00	0.01	14.00	0.01	14.00	0.01
	16.80	16.81	0.02	16.81	0.02	16.79	0.02	16.81	0.02
	20.00	20.01	0.02	20.01	0.02	20.00	0.01	20.00	0.02
	23.80	23.81	0.02	23.81	0.02	23.79	0.02	23.81	0.03
	28.60	28.60	0.01	28.60	0.01	28.59	0.02	28.60	0.02
	34.60	34.62	0.03	34.61	0.02	34.59	0.02	34.59	0.03
	42.90	42.92	0.03	42.92	0.03	42.90	0.01	42.90	0.02
Low	4.60	4.60	0.01	4.61	0.02	4.60	0.01	4.60	0.02
	12.20	12.21	0.02	12.20	0.01	12.20	0.01	12.20	0.02

***measurement uncertainty* = 0,01mm**

Table 2. Nominal value and systematic measurement error + measurement uncertainty of V1 and V2 standard blocks main dimensions.

Block	Serial number	quota	Nominal value	Measured quantity value (mm)	Measurement uncertainty (mm)	*k*	Systematic error+ measurement uncertainty
V1	121/06	a	100	100.002	0.003	2.0	0.005
		b	25	25.036	0.003	2.0	0.039
	0176/09	a	100	99.995	0.002	2.0	0.007
		b	25	25.000	0.002	2.0	0.002
V2	0182/09	c	12.5	12.519	0.003	2.0	0.022
	225	c	12.5	12.503	0.002	2.0	0.005

Thus, scales and dimensions of V1 and V2 blocks were dimensionally verified. In V2 and V1 blocks it could be observed that the systematic measurement error + the measurement uncertainty of the main dimensions were lower than the tolerances established by ISO 7963 and EN12223 standard, which is ± 0.01mm. In V2 blocks it could be observed that the scales systematic measurement error + the measurement uncertainty were lower than the tolerances (± 0.5mm) established by ISO 7963. Nevertheless, in V1 blocks the scale values were not in accordance with EN 12223. Therefore, it is important to notice, that these scale dimensions are not specified in ISO 2400 standard. Difference in the marks positions as well as in their quantity variation could be observed. This prevented V1 block analysis.

Table 3 presents the longitudinal velocity and measurement uncertainty of V1 and V2 standard blocks. As seen, all the measured blocks found longitudinal velocity value lower than the tolerances (0.2 %) i.e. with measurement uncertainty of ±12 m/s for compressional waves as described in ISO 7963 and EN12223.

Table 3. Ultrasound properties and measurement uncertainty of V1 and V2 blocks.

Standard Block	Nominal value (m/s)	Measurement velocity-average (m/s)	Measurement Uncertainty (m/s)	*k*	%	Systematic error+ measurement uncertainty
V1 SN. 121	5920 ± 30	5910.29	6.25	2.36	0.11	14.85
V1 SN. 0176_09	5920 ± 30	5917.16	8.47	2.78	0.14	11.31
V2 SN. 0182/09	5920 ± 30	5910.77	9.52	2.08	0.16	9.52
V2 SN. 225	5920 ± 30	5925.59	5.14	2.78	0.09	10.73

4. Conclusion

This work concludes that V2 blocks in calibrated dimensions are in agreement with the technical specifications of EN 27963 standard. However, V1 blocks standard are not in accordance with EN 12223 standard. Concerning the longitudinal velocity calibration, all blocks are in accordance with EN 27963 and EN 12223 standard.

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