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Statistical Test Applied to the Selection of a Measurement Method

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The Embalse Nuclear Power Station (CNE) is a CANadian Deuterium Uranium (CANDU) Reactor. The CANDU core is composed of hundreds of concentric tubes forming the fuel channel. The uranium fuel rods are contained within these pressure tubes, which in turn are contained within the calandria tube separated by spacers. In service, pressure tubes show deformation over time. At some point these deformation become severe enough for these pressure tubes to be decommissioned. The deformation behavior of these pressure tubes has been observed to be related to its microstructure. [1] [2] [3] [4]

These pressure tubes are made of a Zr-2.5Nb alloy which final structure is a biphasic structure α-Zr + β-Nb, being the α-Zr phase the majority phase. One of the acceptance criteria for the Zr-2.5Nb alloy pressure tubes of the CNE is based on the α-Zr phase width, which is measured manually by Scanning Electron Microscopy (SEM) taking about 5000 measurements for each sample. We proposed a semiautomatic measuring method. The first part of our method consists on superimposing a grid of parallel lines on the micrograph, obtaining the lengths of the intersections between the grid and the α-Zr phase.

Due to the high anisotropy of the Zr-2.5Nb microstructure, for each micrograph grids must be made at different angles in order sweep 360º. This results in strongly biased raw data towards values lower than those obtained manually, largely due to the high accumulation of values under 10nm. In order to obtain a more accurate value we developed six different methods of raw data cutting based on the micrographs and manual measurement data of the back and front end of 5 pressure tubes. The six methods consisted in a two step lower and upper data cut. Due to the difference between the back and front microstructure, we evaluate the optimal parameters for each method by separating the back samples from the front ones. Once the optimal parameters for each method were obtained, we proceeded to evaluate those whose results were most satisfactory.

In order to assess robustness we used the Youden-Steiner test [5] considering the following factors: 1. Upper cut of the micrograph histogram (histogram) - 2. Lower data cut for the first step (Xmin) - 3. Upper data cut for the first step (Xmax) - 4. Lower data cut for the second step (Pmin) - 5. Upper data cut for the second step (Pmax), being the only really variable factor the first one, due to the fact that the other factors once settled remain fixed.

For the Back samples, robustness test was successfully passed by the "B" method which makes a first fixed and equal data cut for all the micrographs and a second cut based on the percentiles of each micrograph. For the Front samples, robustness test was successfully passed by the “B minimum per photo” (Bmpp) method which makes a first fixed and equal upper data cut but a photo-to-photo lower data cut based on the data mode, followed by a second cut based on the percentiles of each micrograph. Back and front samples manual measures and semiautomatic method (B and Bmpp) final values for the

α-Zr phase width might be seen in table 1. Youden-Steiner results might be seen in table 2.

Repeatability was assessed by the relative standard deviation between the eight Youden-Steiner experiments and the value obtained by the method to asses. Accuracy was determined by the percentage bias between the manual value and the value obtained by the method to asses. Precision was asses by the F test using the standard deviation between runs with the same upper cut of the micrograph histogram. All samples successfully passed the statistical test described. [6] [7] [8] [9]

Due to similarity between method "B" and "B minimum per photo", both methods will be applied in future pressure tube samples, in order to determine their effectiveness.

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	Sample									
	L1B	L2B	L3B	L4B	L5B	L1F	L2F	L3F	L4F	L5F
Manual	248	244	255	232	275	288	334	239	273	273
B/Bmpp	258	237	241	244	296	282	323	238	309	254

Table 1. α-Zr phase width (nm)

Factor to asses		Method B					Method Bmpp				
		L1B	L2B	L3B	L4B	L5B	L1F	L2F	L3F	L4F	L5F
	√2 * S	8,28	8,30	9,06	9,24	10,18	8,04	8,10	6,37	9,26	8,61
Xmin	A-a	4,75	6,25	5,50	7,75	7,25	-	-	-	-	-
Xmax	B-b	3,25	2,75	3,00	3,25	4,75	4,00	6,50	1,75	5,50	2,00
Pmin	C-c	4,25	3,25	3,50	4,25	5,25	4,50	4,00	4,25	5,00	4,50
Pmax	D-d	8,25	7,75	7,50	7,75	8,75	7,50	7,50	6,25	8,00	7,00
histogram	E-e	0,75	1,75	6,00	0,75	1,25	4,50	0,50	3,25	5,50	7,50

Table 2. Youden-Steiner test results

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