GUARD BANDING APPLIED IN THE LEGAL METROLOGY REQUIREMENTS OF WEIGHING INSTRUMENTS

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Abstract:
The guard banding approach is tested to meet the legal requirements for NAWIs. Different guard band multipliers were tried to compare the customer and manufacturer risks when initial and subsequent verification or service inspection were done. The results show that the producer's risk is always greater than the customer's risk, no matter if the metrological control is for initial and subsequent verification or service inspection.

Keywords: NAWI, guard band, legal metrology

1. INTRODUCTION

Non-Automatic Weighing Instruments (NAWIs) must accomplish that the error of reading in any instrument must be less than the corresponding maximum permitted error (MPE), as stated in the recommendation OIML R 76-1 [1]. The controls for conformity consist of type approval or initial and subsequent verifications or service inspections. For NAWIs, the mpe for the type approval and initial verification is the same, and they are half the ones for the service inspections [1]. On the other hand, for any randomly chosen NAWI, there is a risk that concerns both the manufacturer and the end user, it is the so-called global risk [2, 3], and it has to do with a wrong decision. The bad decision could be to accept a non-conforming instrument (risk to the consumer) or to reject a compliant device (risk to the manufacturer). Medina [4] reports that the risk of the manufacturer for NAWIs could be as high as 40 %. This work studies different values for a guard band multiplier to address the reduction of that levels of risk for manufacturers without compromising the low risk for customers that OIML R 76-1 demands [1].

2. NAWIS MPE

Following Medina's work [4], it was assumed that the manufacturing of the NAWI already has its type of approval conformity control. Also, two different scenarios were analysed: the NAWI passes the initial verification or passes the service inspection [4].

According to OIML R 76-1, the MPE only could take the values 0.5 *e*, 1 *e* or 1.5 *e* for the initial verification, and the double of those values for service inspection, where *e* is the verification scale interval. Here will be assumed, without loss of generality, that *e* is equal to the resolution of the NAWI. The tolerance limits (*TL*) used will always be the MPE in each case. Otherwise, the acceptance limits (*AL*) will be defined by the guard band strategy selected.

And additional assumption is that the measurement error on every load on the NAWIs is (or is well approximated by) a normal PDF (probability density function).

3. METHODOLOGY

The same three cases explored by Medina [4] were analysed here. The different cases depend upon the existence of prior information on the instrument. The first case assumes no previous data is available on the NAWI. Only the probability of non-conformity was computed in this case.

The second case considers the use of previous knowledge: requirements of the type approval were fulfilled. This previous knowledge is used in the form of the standard deviation of the probability density function.

The third case implies the consistent production of NAWI with type approval. Here, we no longer talk about conformity and the risk term arises. This case allows computing the risk for both the consumer and the manufacturer. For this case, results were obtained using CASoft software, jointly developed by LNE, NPL and RISE [5].

3.1. Probability of conformity

Sections 7.4 and 7.2 in [2] gives the formulae for the calculation of the probability of conformity, from which the probability of non- conformity is:

$$1 - p_c = 1 - \Phi\left(\frac{T_U - y}{u}\right) + \Phi\left(\frac{T_L - y}{u}\right). \qquad (1)$$

Where T_U is the upper tolerance limit, T_L is the lower tolerance limit, and $\Phi(y)$ is the standard normal distribution function. Also, y and u will be the mean and the uncertainty defined below.

When no previous data are available, $y = y_m$, with y_m as the mean of the measurement results, and $u = u_m$, with u_m the measurement uncertainty.

When the prior information of the NAWI follows a normal PDF with mean y_0, and standard uncertainty u_0, then y and u are given by:

$$y = \frac{\frac{y_m}{u_m^2} + \frac{y_0}{u_0^2}}{\frac{1}{u_m^2} + \frac{1}{u_0^2}}, \text{and } u = \sqrt{\frac{1}{\frac{1}{u_m^2} + \frac{1}{u_0^2}}}. \qquad (2)$$

For both cases, $y_m \in [-\ MPE,\ MPE]$, for the corresponding metrological control.

3.2. Acceptance intervals and consumer's and manufacturer's risks

Even when Annex A.5 in [2] brings the formulae for the risks (consumer and manufacturer) calculations, they will not be reproduced here, for the sake of space. Those equations will be solved inside the CASoft package [5].

In all cases, the acceptance limits will vary according to the cases defined on Section 3, following that $[A_L,\ A_U] \subseteq [-\ MPE,\ MPE]$, but changed by the guard band multiplier used.

3.3. Uncertainty determination

The contributions to the measurement uncertainty computations were the indicated in [4], and based in [1]. Table 1 shows their final relationship with *e*.

Table 1: Multipliers of the scale interval, e and its contributions with the measurement uncertainty.

Initial verification			
MPE	0.5 *e*	1 *e*	1.5 *e*
u_m	0.41 *e*	0.59 *e*	0.81 *e*
u_0	0.61 *e*	1.03 *e*	1.48 *e*
Service inspection			
MPE	1 *e*	2 *e*	3 *e*
u_m	0.59 *e*	1.04 *e*	1.51 *e*
u_0	0.75 *e*	1.34 *e*	1.96 *e*

4. RESULTS AND DISCUSSION

The ratios of the measurement results, y_m and y_0, against their corresponding MPE were used as independent variable when computing the probability of non-conformity, with or without guard band.

The results of risks for the manufacturer and the consumer computed with CASoft are shown in figures 1 to 13. Only the graphs when *AL* = *TL* are shown in this version of the full paper.

The worst-case / best-case scenario graph will be shown for every guard band strategy used.

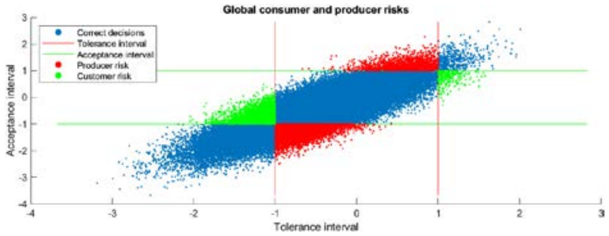

Figure 1: Global risk after initial verification. y_0 = –0.5, *MPE* = 0.5*e*.

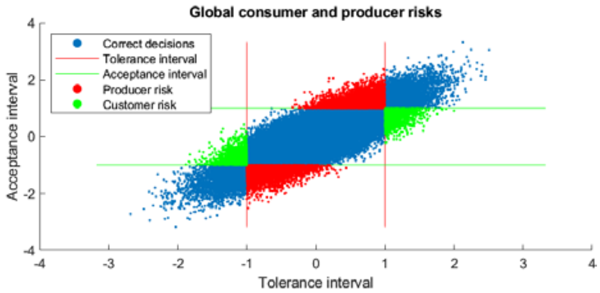

Figure 2: Global risk after initial verification. y_0 = 0, *MPE* = 0.5*e*.

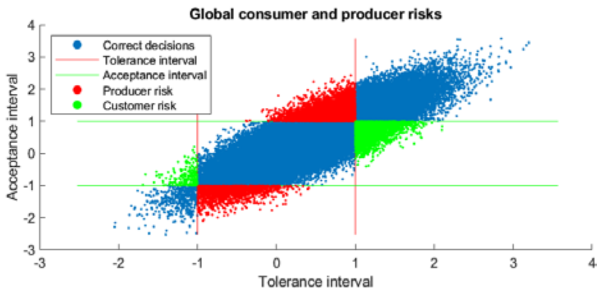

Figure 3: Global risk after initial verification. y_0 = 0.5, *MPE* = 0.5*e*.

Note that as with the no conformity graphs shown in [4], the results are symmetrical, which implies that the sum of risk for the manufacturer and the consumer (the global risk) is the same on the extreme values of y_0. Of course, the cloud of simulation points will be on the opposite side of *SL*. Then, for the rest of MPE values, only one the extreme value of y_0 will be illustrated besides the central value of y_0 = 0.

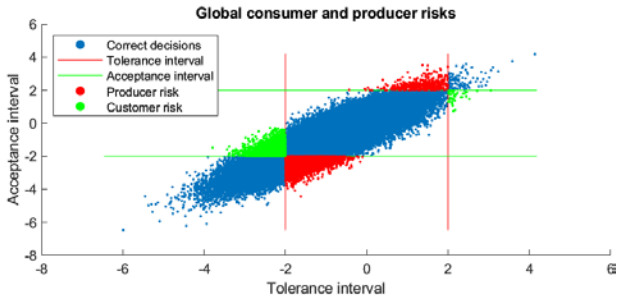

Figure 4: Global risk after initial verification. $y_0 = -1.0$, $MPE = 1e$.

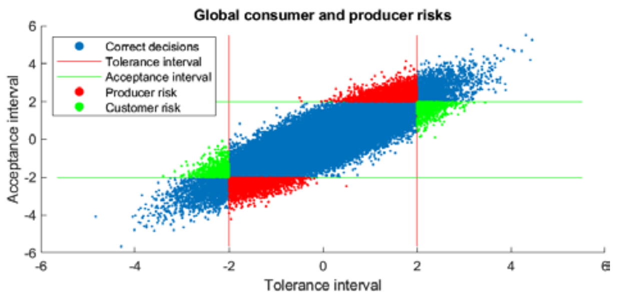

Figure 5: Global risk after initial verification. $y_0 = 0$, $MPE = 1e$.

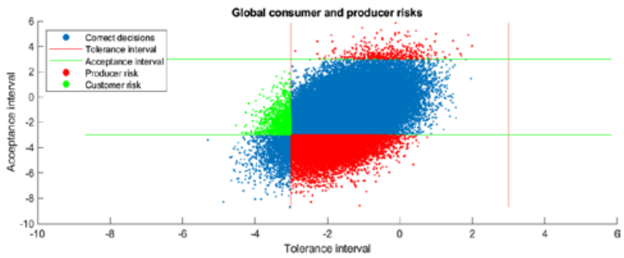

Figure 6: Global risk after initial verification. $y_0 = -1.5$, $MPE = 1.5e$.

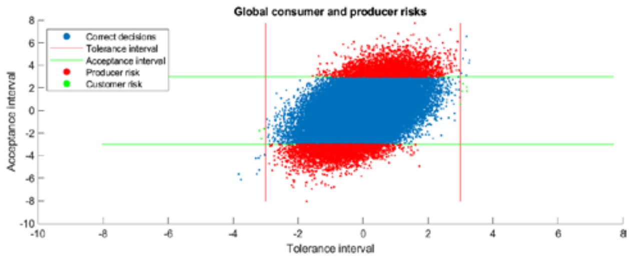

Figure 7: Global risk after initial verification. $y_0 = 0$, $MPE = 1.5e$.

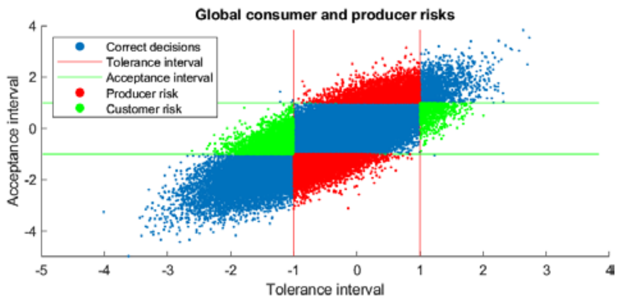

Figure 8: Global risk after service inspection. $y_0 = -1.0$, $MPE = 1e$.

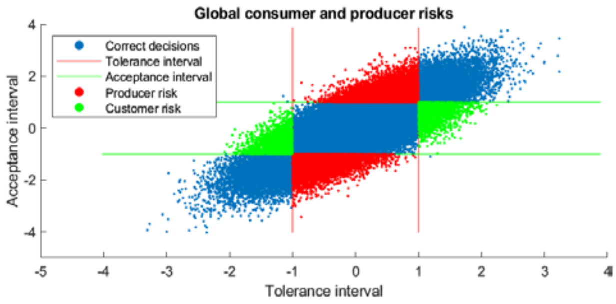

Figure 9: Global risk after service inspection. $y_0 = 0$, $MPE = 1e$.

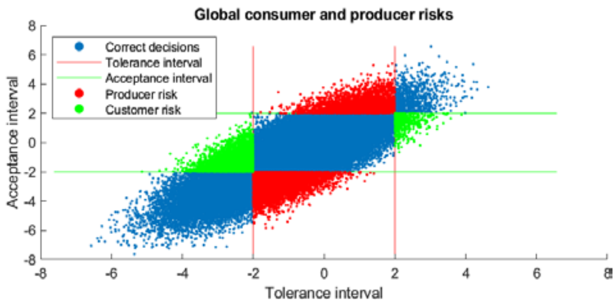

Figure 10: Global risk after service inspection. $y_0 = -2.0$, $MPE = 2e$.

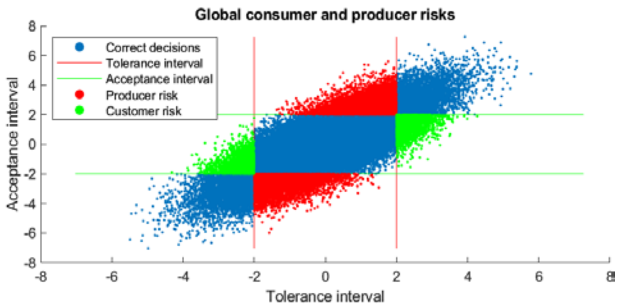

Figure 11: Global risk after service inspection. $y_0 = 0$, $MPE = 2e$.

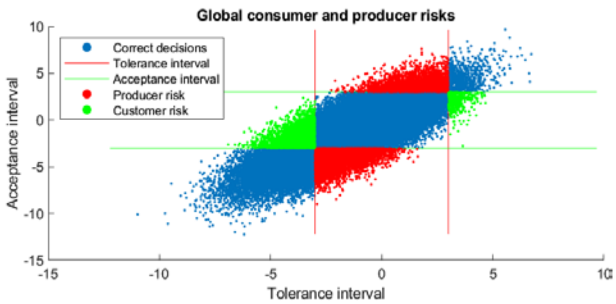

Figure 12: Global risk after service inspection. $y_0 = -3.0$, $MPE = 3e$.

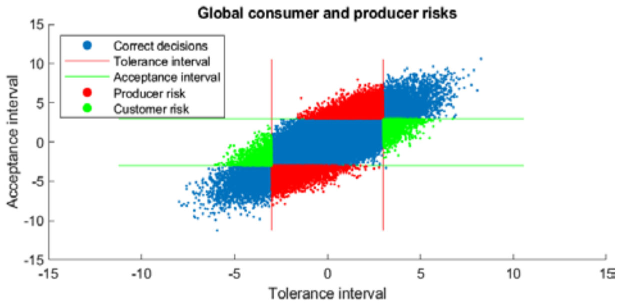

Figure 13: Global risk after service inspection. $y_0 = 0$, $MPE = 3e$.

Table 2 resumes the maximum and minimum risks computed for both metrological controls. For all values on Table 2, the producer's risk is always greater than for the customer, and this agree with the findings of Medina [4].

For initial verification, the greater value for the global risk belongs to the greatest value of *MPE*. On the other hand, for verification or subsequent inspection the greater value for the global risk belongs to the smallest value of *MPE*.

Table 2: Global risk extreme values for initial and subsequent verification and service inspection.

Initial and subsequent verification			
MPE	0.5 *e*	1 *e*	1.5 *e*
Consumer's risk (max)	0.053 5	0.039 6	0.013 2
Producer's risk (max)	0.108 1	0.077 5	0.172 3
Consumer's risk (min)	0.030 0	0.014 9	0.000 0
Producer's risk (min)	0.101 2	0.054 6	0.075 1
Service inspection			
MPE	1 *e*	2 *e*	3 *e*
Consumer's risk (max)	0.073 7	0.064 8	0.063 0
Producer's risk (max)	0.157 0	0.140 6	0.137 1
Consumer's risk (min)	0.054 7	0.041 7	0.039 1
Producer's risk (min)	0.167 6	0.144 4	0.139 1

5. SUMMARY

Guard band multipliers could be used to compare the customer and manufacturer risks when initial and subsequent verification and service inspection (metrological controls) are used. The results shown that the producer's risk is always greater than the customer's risk, no matter if the metrological control is for initial or subsequent verification or service inspection. Additionally, the biggest global risk, expressed as the sum of the producer's risk and the customer's risk, not always rest in the same extreme condition for the two metrological controls.

The final version of the paper shows the effect that a multiplier guard band has on the former results.

6. REFERENCES

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