

# Implementation of the reference force standard in the Croatian metrology and Interlaboratory comparison

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## Abstract

Laboratory for Testing Mechanical properties (LIMS) at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb is accredited laboratory for force and a holder of National standard for force in the Republic of Croatia. Reference force standard with measuring range 10 - 500 kN was installed in LIMS at the end of 2005 with the intent of continuous improvement of the metrology infrastructure of Croatia. The load is obtained hydraulically and the measuring system consists of double placed reference transducers with the nominal force 100 kN and 500 kN. Preliminary investigations have shown that the relative measurement uncertainty will be less than 5E-04. Further investigations are current.

LIMS has planned to participate in the interlaboratory comparison between two more laboratories. Intercomparison will be done in measuring range 10 – 500 kN using two commercial force transducers of 100 kN and 500 kN nominal values. The best measurements capability (CMC) of the participating laboratories varies from 0,002% to 0,05%. The calibration of the force transducers will be carried out using the laboratories own calibration procedure, the relevant classification data, i.e. rotation effect, repeatability, hysteresis as described in DIN EN ISO 376. Intercomparison will increase the level of Croatian metrology thus providing further cooperative investigations in association with European and Global National laboratories for force.

*Key words:* force, reference force machine, calibration, interlaboratory comparison

## 1. Introduction

Traceability can be defined as a property of the result of a measurement or the value of a standard whereby it can be related to stated references usually national or international standards through unbroken chain of comparison all having stated uncertainties.[1]

The term traceability is used to refer to an unbroken chain of measurements relating an instrument's measurement to a known standard. Traceability can be used to certify an instrument's accuracy relative to a known standard. Traceability in the field of force measurements starts with primary standard for force.

There is no primary international standard for force because force is derived unit in SI system. Each country has own primary standard for force also called National standard. National standard is defined as a standard which is accepted by State act to be basic standard.

Reference standard is defined as a standard with the highest metrological quality available on some territory where all measurements on that territory are derived from it [2]. Measurement uncertainty of reference standard is derived from national standard. Reference force standards are stable devices for force measurement and are situated in the accredited laboratories. Thereby measurement traceability between national standard and other devices is accomplished.

Reference force standard with measuring range 10 – 500 kN was installed in LIMS at the end of 2005 with the intent of continuous improvement of the metrology infrastructure of Croatia. In order to confirm measurement uncertainty of reference force standard interlaboratory comparison between LIMS and two more laboratories was carried out. In this paper the results of measurements are presented and discussed.

## 2. Force Measurement Traceability in Croatia

### 2.1. Traceability Before the Reference Force Standard Installation

Laboratory for testing mechanical properties of Materials (LIMS) at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb is accredited laboratory for force. LIMS is also a holder of the national force standard in measuring range 50N - 200kN with measurement capability  $\leq 0,12\%$ .

LIMS has become a holder of national force standard after accreditation given by DAR/PTB/ DKD (Deutscher Akkreditierungs Rat/ Physikalische Technische Bundesanstalt/ Deutsche Kalibrierdienst) for calibration of measuring equipment according to HRN EN ISO/IEC 17025 standard and signing the contract with State Office for Metrology (DZM) in 2005.

Traceability of LIMS after accreditation and before installation of the reference force standard is shown on Figure 2.1.1.

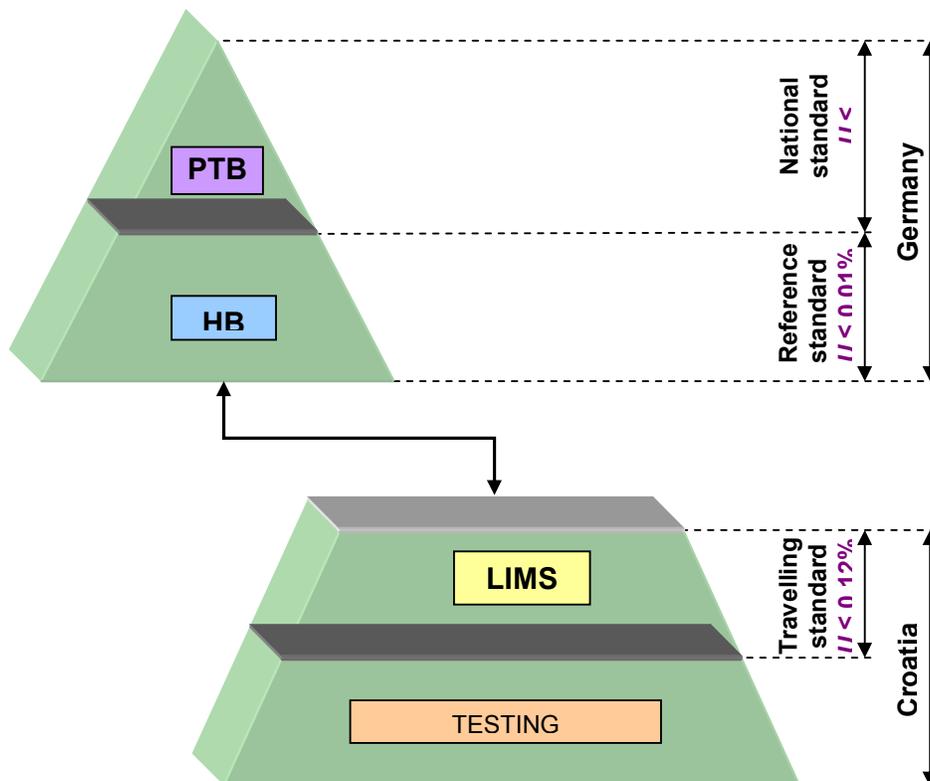


Figure 2.1.1 – Traceability before installation of the reference force standard [3]

As can be seen from the figure 2.1 on the top of the traceability pyramid is German institution PTB ((Physikalische Technische Bundesanstalt) which holds national standards for force with best measurement capability  $\leq 0,002$  %. LIMS is accredited laboratory for force with best measurement capability  $\leq 0,12$  %. Traceability assurance LIMS has achieved by calibration of travelling standards in PTB or HBM.

## 2.2. Installation of Reference Force Standard

Reference force standard with nominal value 500 kN and with measurement capability  $<0,05$  % was installed in LIMS at the end of 2005 to improve metrology infrastructure of Croatia.

Preparing process of appropriate environmental conditions and installation of reference force standard lasted for eleven months. Under the term environmental conditions are considered: appropriate location for the reference force standard, constant control and regulation of the temperature and humidity. Also, it was needed to prepare the ground to disenable influence of vibrations from the environment on the measuring results. Installation of the reference force standard has successfully finished at the end of 2005. Reference force standard is shown on the figure 2.2.1.



Figure 2.2.1 – Reference force standard installed in LIMS

Measuring system consists of two high precise reference transducers; KTN 100 kN and KTN 500 kN. On this way measuring range from less than 0,1% to 100% can be applied. According to that measurement uncertainty of the system can be less than 0,05 %.

The installation of the reference force standard has changed significantly measurement capability of LIMS and according to that metrology infrastructure for force in Republic of Croatia. Installation of the reference force standard has improved measurement capability of LIMS. LIMS has become one of the leading laboratories in the region. LIMS calibrates transfer standards and participates in interlaboratory comparison with other National laboratories.

Preliminary measurements had shown that measurement capability of the reference force standard can be confirmed.

### **3. Interlaboratory Comparison**

Interlaboratory comparison is defined as "Organization, performance and evaluation of calibrations on the same or similar items by two or more laboratories in accordance with predetermined conditions." [4]

Intercomparison was carried out in order to confirm measurement capability of the reference force standard and to increase the level of Croatian metrology thus providing further cooperative investigations in association with European and Global National laboratories for force.

#### *3.1 General Information*

Interlaboratory comparison was carried out between LIMS and two laboratories. In LIMS and LAB 1 the measurements were carried out on hydraulic reference standard and in LAB 1 on deadweight machine. Measuring range of intercomparison was from 10 kN to 500 kN using two commercial transducers with nominal values 100 kN and 500 kN connected with MGC plus amplifier. Transducer 100 kN has accuracy class 00 and transducer 500 kN accuracy class 05.

The best measurements capability (CMC) of the participating laboratories varies from 0,002% to 0,05%.

Laboratory 1 is a primary laboratory, and laboratory 2 was chosen because its best measurement capability (0,05%) is equal to LIMS measurement capability obtained in preliminary investigations.

Environmental conditions during the measurements have been controlled. Temperature variations more than  $21\pm 1^{\circ}\text{C}$  were not permitted during the measurements. Transducers used in intercomparison have been kept at the measurement temperature for about 24 hours before the measurements.

#### *3.2 Measurement Procedure*

The calibration of the force transducers was carried out using the laboratories own calibration procedure, the relevant classification data, i.e. rotation effect, repeatability, hysteresis as described in DIN EN ISO 376 [5]:

- a) The maximum force value was applied three times before the beginning of the measurement. Duration of the preloading was between 1- 1,5 minute
- b) After three preloading duration of the pause was 3 minutes
- c) Two series of calibration forces with increasing values were applied. After each series duration of a pause was 3 minutes. The number of force steps was 10. The forces were distributed uniformly over the calibration range starting with 10% of the nominal value of transducer
- d) Two series of increasing and decreasing values were applied. Before each of the series transducer was rotated for  $120^{\circ}\text{C}$ . After each rotation transducer was centered.

### 3.3 Measurement Results

Table 3.3.1 contains measurement values calculated from the interpolation equation for both transducers. Interpolation equations are polynomial of third degree.

Table 3.3.1  
Results of interpolated values

$F$ , kN	LIMS	LAB 1	LAB2	$F$ , kN	LIMS	LAB 1	LAB2
	$y$ , mV/V				$y$ , mV/V		
10	0,19997	0,19990	0,20026	50	0,20001	0,20018	0,20038
20	0,39992	0,39980	0,40037	100	0,40010	0,40035	0,40058
30	0,59986	0,59970	0,60038	150	0,60025	0,60051	0,60067
40	0,79978	0,79961	0,80029	200	0,80043	0,80066	0,80070
50	0,99970	0,99952	1,00016	250	1,00062	1,00078	1,00074
60	1,19962	1,19943	1,20000	300	1,20080	1,20089	1,20085
70	1,39956	1,39935	1,39984	350	1,40095	1,40098	1,40110
80	1,59952	1,59927	1,59971	400	1,60105	1,60105	1,60156
90	1,79950	1,79920	1,79965	450	1,80107	1,80110	1,80228
100	1,99951	1,99913	1,99968	500	2,00099	2,00112	2,00333

### 3.4 Measurement Results Discussion

Calculated deviations of the measurements made on the force transducers 100 kN and 500 kN for each laboratory are presented below. On the figures relative repeatability error without rotation  $b'$ , relative reproducibility error with rotation  $b$ , relative interpolation error  $f_c$ , relative reversibility error  $\nu$  and relative measurements uncertainties  $U$  for each laboratory are shown. The uncertainty evaluation has been made according to recommendations established in the EA-10/04 [6].

For force transducer 500 kN the results from 150 kN till 500 kN are shown because full measurement range of reference force standard is presented on figures.

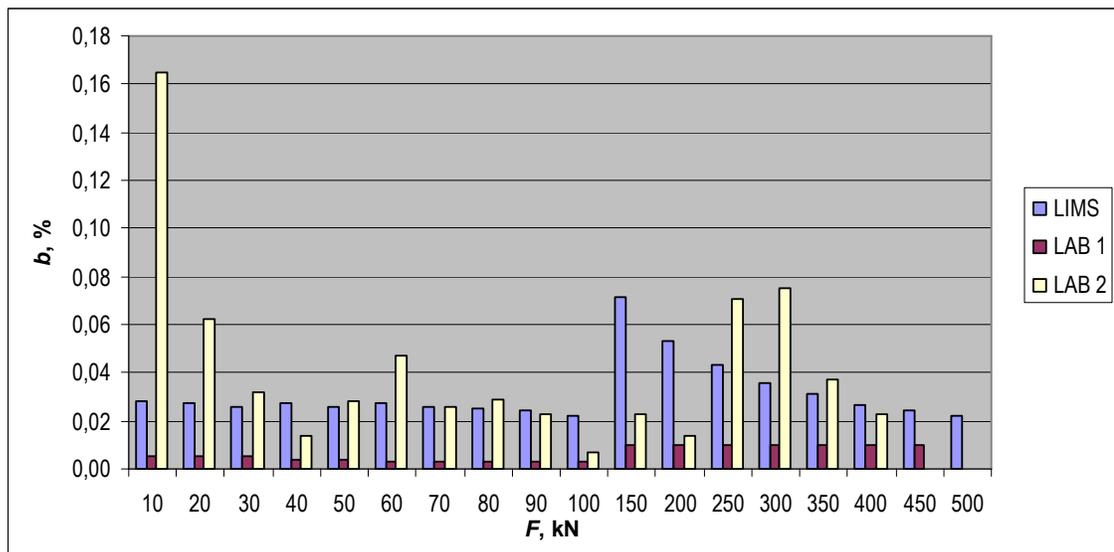


Figure 3.4.1 – Relative reproducibility error with rotation

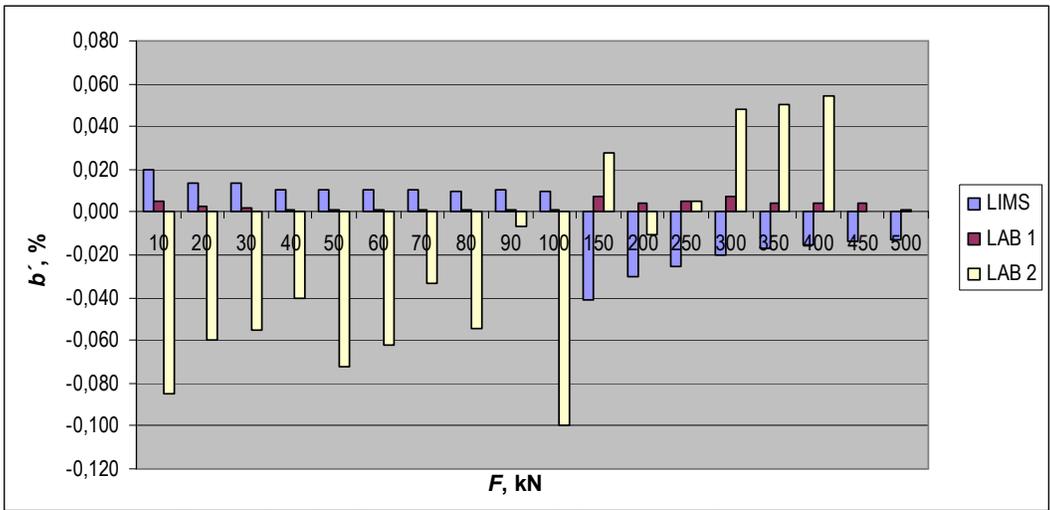


Figure 3.4.2 – Relative repeatability error without rotation

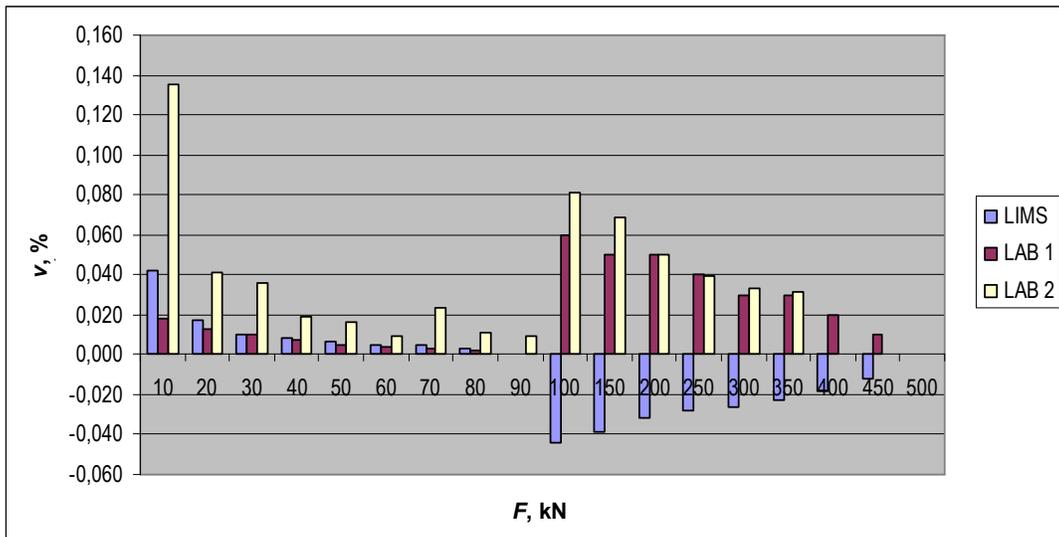


Figure 3.4.3 – Relative reversibility error

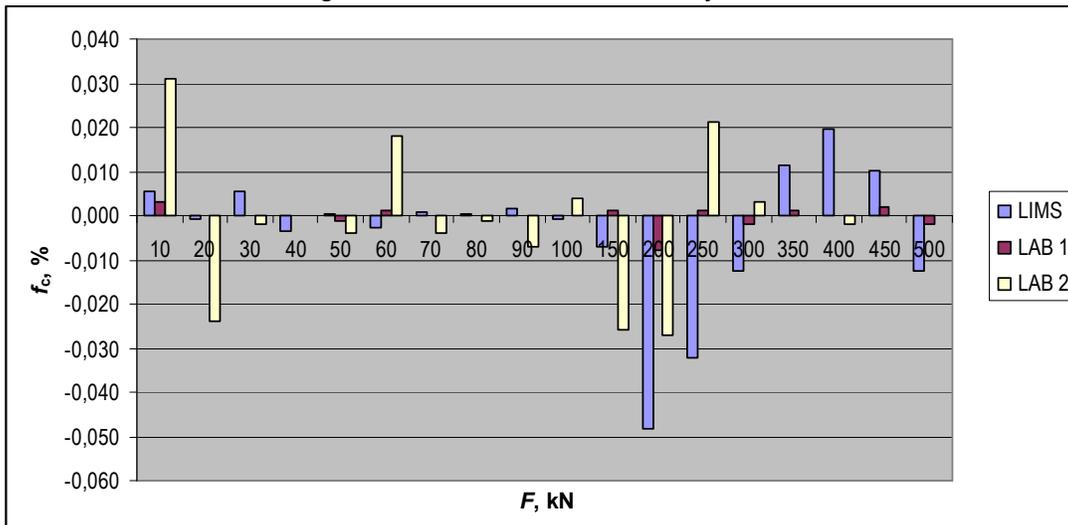


Figure 3.4.4 – Relative interpolation error

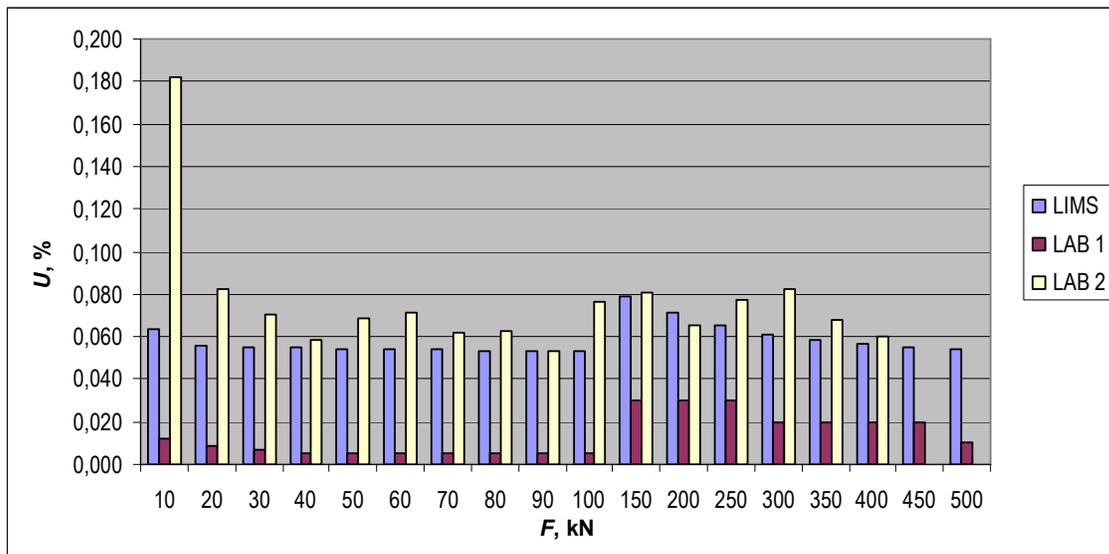


Figure 3.4.5 – Relative measurement uncertainty

As can be seen from the diagrams the best measurement results were achieved in the LAB 1 which has primary force standards and best measurement capability much better comparing with other two labs. Measurement results in this laboratory have shown that both analyzed force transducers should be classified as class 00 according to EN ISO 376. The highest values of particular measurement errors were obtained in LAB 2 which is accredited laboratory with measurement capability shown in Table 3.1.2. According to LAB 2 results, both force transducers are class 1.

Measurement results made in LIMS have shown that calculated relative errors except measurement uncertainty results fulfill class 0,5 requirements completely. The main cause of elevated relative measurement uncertainty values is LIMS CMC value. Increased values of particular measurement errors for 500 kN transducer were registered too. The possible reason could be longer period of the transducers exploitation.

#### 4. Conclusion

Installation of reference force standard definitely has improved the LIMS measurement capability and significantly changed measurement infrastructure in Croatia. In this way force measurement traceability in the country becomes much simpler and financially more convenient. Scheme of force measurement traceability in Croatia has new shape after installation of the reference force standard (Figure 4.1)

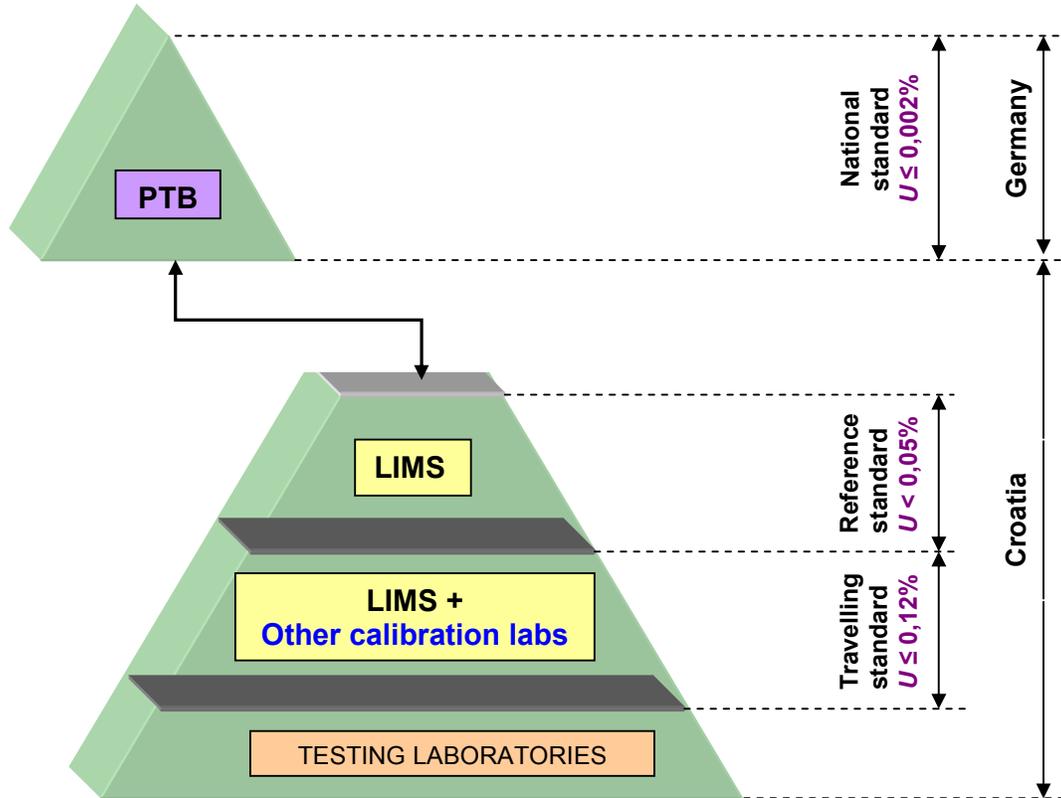


Figure 4.1 - Traceability after installation of the reference force standard

In this way, beside the improvement of LIMS measurement capability, for other calibrating and testing laboratories in Croatia traceability assurance is much easier. Given measurement intercomparison of two commercial traveling force standards together with two accredited laboratories with confirmed measurement capability has shown that LIMS measurement capability is better than 0,05%.

## 5. References

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- [4] <http://ts.nist.gov:80/WeightsAndMeasures/Publications/glossary.cfm>
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