Simulation of industrial environment in Large Volume Metrology

Mariusz Wiśniewski[1,*], Dariusz Czułek[1] and Robert Szumski[1]

[1] _Length and Angle Department, Central Office of Measures, Warsaw Elektoralna Street 2, Poland_

[*] _Corresponding author: m.wisniewski@gum.gov.pl_

Abstract

The monitoring system which consist of 40 air temperature sensors, 5 relative humidity sensors and one air pressure sensor was prepared and used for determination of environmental conditions on the 50 m interferometric comparator. Large gradients along the test bench and rapid changes in local conditions were obtained. The uncertainty of the measuring system was estimated using Monte Carlo method. The uncertainty of calculation of refractive index of air was estimated on $u(n) = 4{,}2\ 10^{-7}$. This level of uncertainty fulfils requirements for the verification of the CNAM and PTB measurement systems in harsh condition environment.

1 Introduction

The Central Office of Measures (GUM) is taking part in EMRP project JRP IND53 LUMINAR „Large Volume Metrology In Industry” [1]. Aim of LUMINAR project is to find innovative technical solutions for performing accurate measurements of the size, position, location, and shape of objects of large size, assembly of large objects, and machines. The task of project is development of the innovative measurement systems capable of providing a measurement uncertainty of 50 microns in volume (10 × 10 × 5) m in industrial conditions and measurement systems to determine the absolute distance (ADM) with environmental conditions compensation. Also computer simulations of thermal variations in sizes and shapes of large structural elements will be carried out.

During last phase of the LUMINAR project the GUM laboratory will be used for verification of the effectiveness of the measurement systems developed during the project by CNAM and PTB. The laboratory room, with the tape bench with controlled environment, has been prepared to simulate the harsh conditions typical for the production hall.

2 The monitoring system

The monitoring system which consist of 40 air temperature sensors type YSI 44031 (10kΩ), 5 relative humidity sensors and one air pressure sensor was used for determination of environmental conditions on the 50 m interferometric comparator (see Figure 1). Sensors were placed in regular distances to cover 50 m range. All sensors were calibrated before simulation for wide range of possible environmental conditions. The parameters of the characteristic has been estimated. The software for real time recording and data analysis of all parameters was developed. Summary of the system was presented on Table 1.

Table 1: Sensors of the monitoring system.

Sensor type	No. of sensors	Sensor uncertainty
temperature	40	± 0,05 °C
relative humidity	5	± 0,2 %
air pressure	1	± 1,0 hPa
CO_2	1	± 47 ppm

Figure 1: The 50 m interferometric comparator.

3 Results of the simulation

Adjustments of the operating parameters of two independent air conditioners (AC) were used to obtain large gradients along the test bench and rapid changes in local conditions. The AC were located at the both ends of 50 m comparator and use common pipe to distribute air. The AC were set to work in three states: N-Normal, standard temperature 20 °C for calibrations; C-Cooling to 15 °C; H-Heating to 25 °C. Measurements was made 2 hours after changing AC settings.

A combinations of cooling, heating and normal state was examined. Achieved gradients of temperature and humidity are presented on Figure 2 and 3. During preliminary tests the air temperature gradient on the level of 4 °C and relative humidity gradient on the level of 11% for distance of 50 m were achieved. The highest gradient of temperature was achieved for heating on the beginning and cooling at the end of 50 m comparator (H-C state). Additional test are needed to increase gradients for 10 m range.

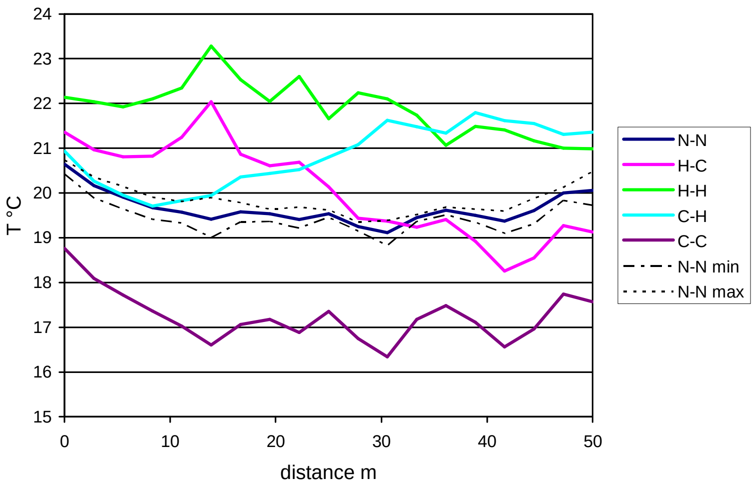

Figure 2: Gradients of temperature for combinations of cooling (C), heating (H) and normal (N) state of two air conditioners.

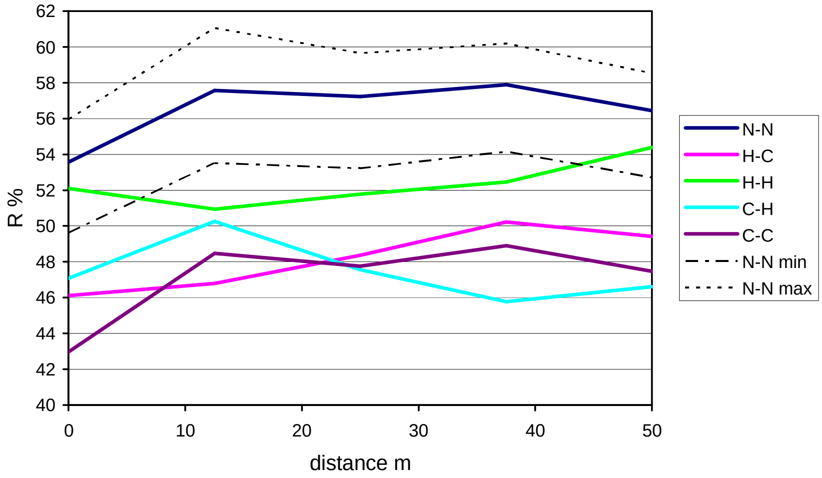

Figure 3: Gradients of relative humidity for combinations of cooling (C), heating (H) and normal (N) state of two air conditioners.

4 Estimation of the refractive index uncertainty

Measurements of temperature, humidity, air pressure, and CO2 from the monitoring system of the environmental conditions and the Edlen equation was used for calculation of refractive index of air *n*.

The uncertainty of the measuring system was estimated using Monte Carlo method. 400 series of raw data collected in N-N state was used. 1000 measurements was randomly generated for each series, with assumption of uncertainties of the sensors given in Table 1.

Correlation between amplitude of changes of temperature and humidity was observed. This fact was used to estimate uncertainty of mean humidity calculation. Results of 40 temperature sensors was compared with 5 humidity sensors. Uncertainty of mean relative humidity along 50 m bench was estimated on 0,4 %.

Differences between *n* value calculated using raw and randomly generated data was used to estimate uncertainty of the system. The uncertainty was estimated on $u(n) = 4{,}2\ 10^{-7}$.

The second method for refractive index of air measurement is under development. It will be based on interferometric measurements using Michelson interferometer with signals from femtosecond optical frequency comb. Procedure and data processing for this method will be developed in next phase of project.

5 Conclusion

The monitoring system on 50 m test bench was prepared and the software for real time recording and data analysis was developed. The uncertainty of calculation of refractive index of air was estimated on $u(n) = 4{,}2\ 10^{-7}$. This level of uncertainty fulfils requirements for the verification of the CNAM and PTB measurement systems planed in LUMINAR project.

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References

[1] http://projects.npl.co.uk/luminar/