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METROLOGICAL CHARACTERIZATION and CALIBRATION of THERMOGRAPHIC CAMERAS in the TEMPERATURE RANGE from 50 °C to 960 °C

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Summary:
We present the metrological characterization and calibration of four different types of thermographic cameras for quantitative temperature measurement traceable to the International Temperature Scale of 1990 (ITS-90). All measurements are performed according to the Technical Directives VDI/VDE 5585. Results achieved with different calibration procedures are compared for each type of camera and among the four cameras. An uncertainty budget for the calibration of each camera is set up according to the "Guide to the Expression of Uncertainty in Measurement" and VDI/VDE 5585 Part 2.

Keywords: Thermographic camera, infrared, technical specifications, metrological characterization, calibration

Introduction

New manufacturing methods for uncooled microbometer thermographic detectors have resulted in a rapid development of miniaturized and high-resolution, inexpensive sensors hence opening up an ever-increasing number of new application areas [1]. This development makes contactless temperature measurement with thermographic cameras available to a large number of users. Furthermore, thermographic cameras are more and more applied for quantitative measurements, e.g. to control production processes. It is therefore important to define the relevant technical specifications and to set up dedicated calibration schemes traceable to national and international standards. The German standardization committee VDI/VDE FA 8.16 *Temperature Measurement with Thermal Imagers* has published the Technical Directive VDI/VDE 5585 Part 1 *Metrological Characterization of Thermographic Cameras* [2] in March 2018. This is now being extended into an IEC Technical Specification by the international standardization committee IEC SC65B WG5 *Temperature Sensors*. Currently the Technical Directive VDI/VDE 5585 Part 2 *Calibration of Thermographic Cameras* [3] is in the process of completion. Part 2 specifies in detail different calibration methods of thermographic cameras and the related uncertainties. We have carried out a complete quantitative metrological characterization and calibration according to the Technical Directives VDI/VDE 5585 for different types of thermographic cameras in the temperature range from 50 °C to 960 °C. The thermographic cameras used differ in their wavelengths and detector types.

Metrological characterization

VDI/VDE 5585 Part 1 gives definitions and standardized procedures for the determination of the relevant technical specifications for non-contact temperature measurement with thermographic cameras. In the following we have determined the relevant specifications for absolute temperature measurement: the non-uniformity, i.e. inhomogeneity of detector responsivity, (NU), the noise equivalent temperature difference (NETD), the inhomogeneity equivalent temperature difference (IETD) and the size-of-source effect (SSE). The SSE of two investigated cameras at 100.0 °C is plotted as an example in Figure 1. The size of the radiating source was gradually increased and the averaged displayed temperatures in the center of the images of the cameras was recorded.

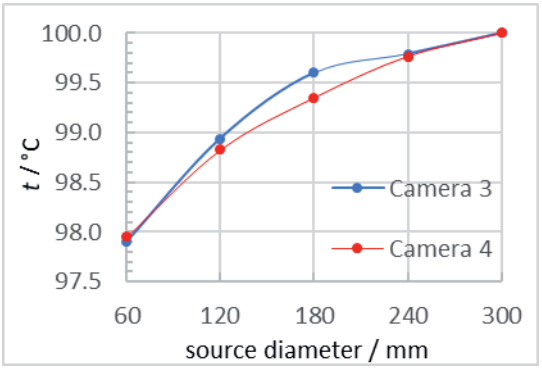

Fig. 1. The SSE of two investigated cameras

Method to improve the NU and IETD

We will present the improvement of the NU and the IETD of thermographic cameras utilizing the Data Reference Method (DRM) [4]. This method was, for example, applied to Camera 3 at a radiator temperature of 100 °C. Figure 2 shows the original image of Camera 3. The observed temperature inhomogeneities partly result from the true temperature inhomogeneity across the plate and, partly, from the imperfect NUC of the camera. In Figure 3 the true radiation temperature distribution of the plate radiator obtained with the DRM is shown.

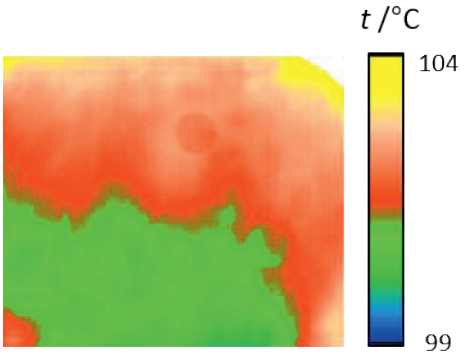

Fig. 2. Radiation temperature image of a plate radiator, setpoint at 100.0 °C taken by Camera 3

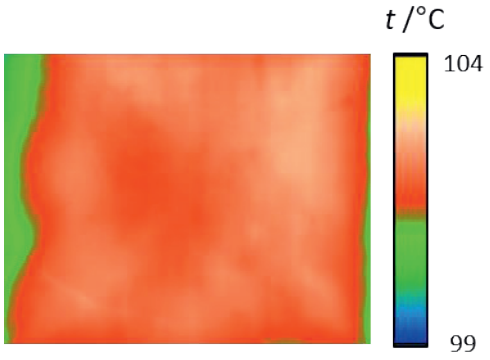

Fig. 3. True radiation temperature distribution of the observed plate radiator after the application of the DRM

Metrological Calibration

The technical directive VDI/VDE 5585 Part 2 distinguishes three calibration procedures: A, B and C. The distinction is drawn by the irradiated detector area. With Procedure C, for example, only the center of the detector array is irradiated and an average temperature is calculated over a defined region of interest (ROI) within the irradiated area (Figure 4). We will introduce all three methods and show exemplary calibration results of the investigated cameras in the temperature range from 50 °C to 960 °C.

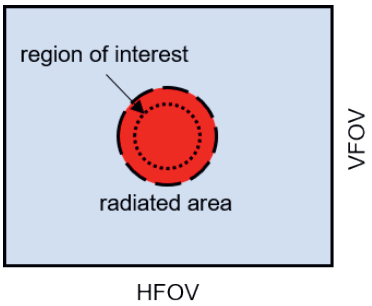

Fig. 4. Calibration Procedure C (VDI/VDE 5585 Part 2): the center of the detector array is irradiated

Uncertainty budget

An estimation of the overall uncertainty budget of the calibration traceable to the International Temperature Scale (ITS-90) was done according to the Guide of the Expression of Uncertainty [5] for the four cameras. The uncertainty budget is essentially dominated by two parts. The SSE has the greatest influence on the camera side and the temperature homogeneity of the calibration radiator used on the source side. Results will be given in the presentation.

References

[1] Budzier H. and Gerald G. *Thermal infrared sensors: theory, optimisation and practice*. John Wiley & Sons, 2011

[2] VDI/VDE 5585 Part 1, Technical temperature measurement – Temperature measurement with thermographic cameras - Metrological characterization, Verein Deutscher Ingenieure, Düsseldorf 2018

[3] VDI/VDE 5585 Part 2, Technical temperature measurement – Temperature measurement with thermographic cameras - Calibration, Verein Deutscher Ingenieure, Düsseldorf 2020

[4] Gutschwager B. and Hollandt J.: Nonuniformity correction of imaging systems with a spatially nonhomogeneous radiation source, Applied Optics 54, Issue 36, 10599-10605, 2015

[5] ISO, IEC, and BIPM OIML. "Guide to the Expression of Uncertainty in Measurement." *Geneva, Switzerland* 122 (1995)