Calibration and validation of thermal imagers

by G. Machin[1], R. Simpson, M. Broussely

National Physical Laboratory, Temperature Measurement Group, Teddington, Middlesex, TW11 0LW, UK
[1]Visiting Professor Universities of Glamorgan and Valladolid

Abstract

This paper will consider how to improve confidence in the use of thermal imagers quantitatively, that is for actual temperature measurement. The proposed route will be through the implementation of best international measurement practice via calibration, traceability and accreditation. Reference blackbody standards that have been rigorously qualified will be described – with emphasis on developments in clinical thermography.

1. Introduction

The practice of thermal imaging is at a crossroads. In the past, for the vast majority of applications, obtaining and qualitative analysis was sufficient. However there is a growing need to have properly quantified thermal imaging. For example if cross-centre image exchange is required to study a problem, if clinical or other decisions are made based on thermal imager temperature measurement (e.g. preventing or delaying transit through an airport) or the construction of a database of images taken by different thermal imagers then questions concerning normalisation and in particular calibration need to be addressed. This brings with it a requirement of measurement rigour that has not generally been practiced or appreciated.

The purpose of this paper is to outline how, through the use of available metrology tools, the accurate calibration of thermal imagers can be obtained. This will begin with the issues of calibration, traceability and accreditation. Emphasis will be given to the requirements of the international calibration standard ISO17025 and how its implementation in the thermal imaging community would significantly improve the quality of accurate thermal imaging. The paper will then describe, for illustrative purposes, the facilities at the NPL for performing the traceable calibration of thermal imagers. Particular attention will be paid to developments in lower temperature medical applications, both of a variable temperature blackbody source and novel in-field fixed point blackbodies, that are used to provie in-situ image assurance for critical applications.

In the full paper a review of the recent standard 62D_616_CDV for implementing thermal imaging in an airport environment will be given. This will highlight the requirement for key metrological input at the early stage of standards formulation.

2. Assuring temperature measurements

Proper temperature (in fact any) measurement requires the establishment of a rigorous process that enables all measurements to be able to be traced back to a national standard, which itself been qualified internationally through top-level comparisons with other standards in other national measurement institutes. From a temperature perspective the current standard is the International Temperature Scale of 1990 (ITS-90) [1]. All temperature measurements throughout the world should ultimately be traceable back to this scale. The process of ensuring that this is the case has three steps each one improving the rigour of the measurement, the steps are; calibration, traceability and accreditation.

2.1 Calibration

In order to be satisfied that the device is operating satisfactorily for its purpose it is important that it is periodically calibrated. Calibration is the attributing of a traceable temperature to a thermometer/thermal imager. Calibration provides information on the performance of a device, i.e. is it operating properly, does it need adjustment? The calibration of infrared thermometers and thermal imagers at the NPL is performed by comparison with well-characterised high precision blackbody standard sources, of which an outline description is given in Section 3.

2.2 Traceability

The traceability of a thermometer is derived through a demonstrable unbroken chain of measurements to a common standard (i.e. the ITS-90), held by a national measurement institute (in the UK this is the NPL). Traceability can be obtained through accredited calibration laboratories, which are in turn traceable to the local National Measurement Institute. If a thermometer is not calibrated to a traceable standard it is not measuring an internationally accepted temperature.

2.3 Accreditation

This is an often neglected but vital part of the process. Accreditation is an objective means of reviewing a calibration methodology. A third party (in the UK this is performed by the United Kingdom Accreditation Service (UKAS)) reviews and assesses calibration procedures, records, equipment and staff who carry out calibrations to ensure that the calibration provider is producing a traceable and therefore internationally recognised calibration service. The accreditation standard ISO17025 [2] covers the above requisites. UKAS third party accreditation ensures that any test or calibration laboratory meets the requirements of the international standard and is performing validated traceable measurement.

3. Reference sources for thermal imager calibration

To ensure that thermal imagers and IR thermometers are properly calibrated sources of known radiance are required. These are almost invariably blackbody sources. When constructing a blackbody source for such a purpose its design needs to be carefully considered to ensure that its radiance closely approximates to that of an ideal blackbody and that the temperature sensing is performed in such a way that the temperature measured is representative of the radiance emitted. The NPL has constructed a suite of blackbody reference sources for this purpose which are described briefly below [3].

Note that with the advent of focal plane array (FPA) imagers individual pixel gain and offsets need to be corrected for by the process of determining the “flat field” before calibration is performed. This requires a large source of uniform radiance. The blackbodies described here are not suitable for this purpose though such a source can relatively easily be constructed.

3.1 Variable temperature sources

The NPL has a suite of four blackbody reference sources for the accurate calibration of IR thermometers and thermal imagers [3]. These are based on heat pipe technology and cover the range -40 °C to nominally 1000 °C. Heat-pipes are utilised because they have ultra-low temperature gradients. The temperature of the blackbody radiators is determined through a calibrated contact sensor traceable to a primary realisation of ITS-90. Typical uncertainties for the blackbody sources are around 0.2 °C (k =2) at ambient temperatures. All calibrations undertaken at NPL using these facilities are accredited through UKAS.

3.2 Variable temperature and fixed-point blackbody cavities for medical applications

A blackbody cavity has been specifically designed for clinical thermography applications. It is directly traceable to ITS-90, and can be transported to clinical centres to determine the performance of their thermal imagers [4]. Its operating range is sub-ambient to around 80 °C with an uncertainty of 0.2°C (k =2). Studies with the source have shown dramatic and unknown variations in imager performance over the temperature range of clinical interest [5].

To obtain the ultimate in temperature performance requires that the thermal imager has a radiometric standard in the image field. A range of fixed-point blackbody reference targets based on fixed-points of Ga-Zn eutectic (~25 °C), Ga (29.7 °C) and ethylene carbonate (36.3 °C) have been produced for this purpose. These have repeatability of around 0.1 °C and are small enough to be located in the image plane and have been used in trials in clinical centres around the UK [6].

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