Re-Calibration of Temperature Sensors Using Phase-Change Cells

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Introduction

The goals of the Global Earth Observation System of Systems (GEOSS), which include providing information support for steady development of the entire world climate system and mitigating the effects of catastrophic phenomena, underscore the climate community's need for long-term stability and accuracy of optical measurements. To meet sensor accuracy requirements over the full life of a sensor and through a series of sensors, on-board calibration systems must be improved. A potential solution for IR sensors observing top of the atmosphere radiances that require a calibration target in the 234 to 310 K range is the development and space qualification of phase transition phenomenon temperature calibration devices. Including a reliable, SI traceable temperature calibration verification system in orbital calibration targets can help produce the required high-quality long-term (extending over decades) records.

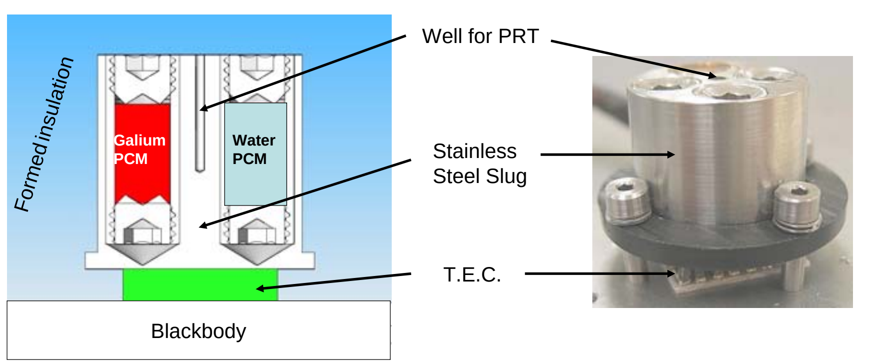

Figure 1. SDL's multiple phase change material (PCM) cell design.

SDL has developed a thermal reference system to provide re-calibration of temperature sensors. It can be used on-board flight systems to recalibrate temperature sensors that monitor internal blackbodies and are used to maintain calibration of space sensors. The Mini-Cell On-Orbit Temperature Recalibration (MOTR) cells are currently progressing on two fronts with a goal to create a space qualified operational package that is easily installed into a blackbody. The first thrust is to characterize the cells in cryogenic high vacuum conditions to prove the operational ability in an environment that is similar to space. With this characterization completed, a cell will be installed in one of SDL's working blackbodies, which will provide an on-going check of the blackbody's calibration. It will also demonstrate repeatability of the cells over an extended period of time. The second thrust is to flight qualify the MOTR cells in a space environment.

Eutectic Alloys Studied

While gallium (302.9146 K) and water (273.15 K) are commonly used references in terrestrial applications, their temperatures are not optimal for earth viewing calibration. We have been developing melting temperature curves for the bimetallic eutectic alloys Ga-In (288.5 K), Ga-Sn (293.5 K), Ga-Zn (298.5 K), and Ga-Al (300.2 K) in small-size cells suitable for space application. Our results show that Ga and some Ga-based eutectic alloys in small cells can be used as stable, SI-traceable melting fixed points. The repeatability of melting transition temperatures of Ga, Ga-In, Ga-Sn, and Ga-Zn fixed points have been shown to provide adequate fixed points.

Table 1. Phase Transition Temperatures of Eutectic Alloys and Pure Metals

Low-Temperature	
Substance	**Temp.(K)**
In	429.75
Ga	302.91
GaZn	298.5
GaSn	293.5
GaIn	288.5
H_2O	273.15
Hg	234.32

As shown in Figure 3, the temperature measured during the fixed-point realization varies slowly (dependent on heating rate), and the fixed point temperature is deduced from the temperature vs. time curve, at the point it begins to deviate from the linear phase3.

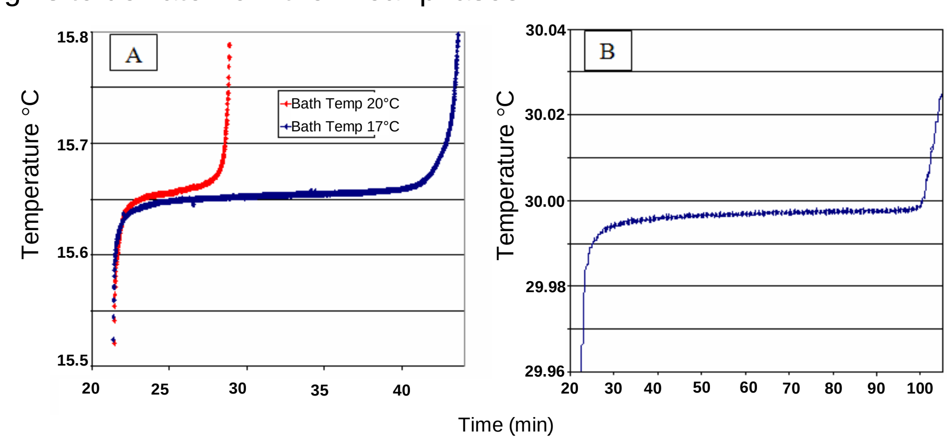

Figure 3. Typical fast and slow heating curves for a Ga-In cell (A) and the realization of a gallium fixed point in a TEC controlled cell (B).

Cell Design

The design of the MOTR cells is focused on ease of integration into existing blackbodies and minimal thermal impact on the blackbody during its recalibration cycle. The entire MOTR system is externally mounted to any blackbody surface by a thermo-electric cooling (TEC) device. This allows the MOTR temperature to be controlled independently of the blackbodies' so it can melt the PCMs for recalibration of MOTR sensors while the blackbody continues operation. When unpowered the TEC acts as a thermal link to allow MOTR to reach thermal equilibrium with the blackbody so that temperature knowledge can be transferred.

Project Status

A flight prototype of MOTR has been completed, and a flight qualification unit is currently being constructed to finish the flight certification testing for a space experiment in 2009.

A specialized version of the multiple PCM design shown in Figure 1 is being integrated into the LWIRCS blackbody for thermal cycle and vacuum testing and NIST calibration. The LWIRCS blackbody will provide the first true implementation testing of the technology as it operates to provide recalibration and long-term stability of blackbody temperature measurements.

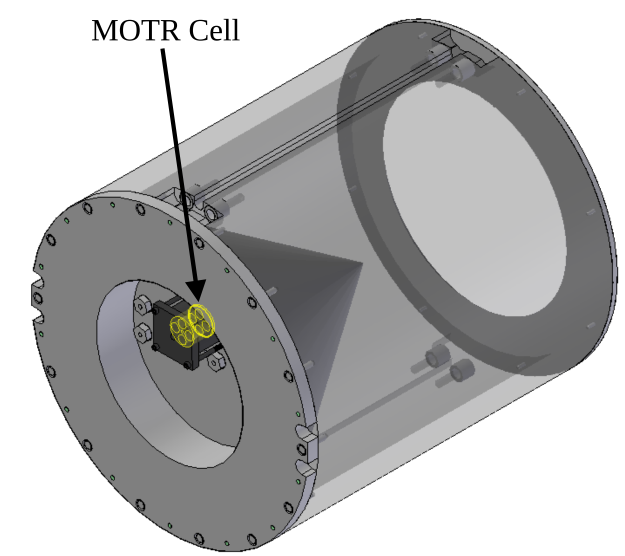

Figure 4. LWIRCS Blackbody with MOTR cell installed.

Conclusion

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) proposal suggests the use of International Temperature Scale of 1990 (ITS-90) phase change reference standards to recalibrate its on-board temperature sensors to provide lifetime temperature calibration for its IR reference targets. The calibration of sensors used to determine the reference source temperature must be accurate to better than 0.01 K (10 mK) to achieve climate record calibration accuracy. SDL's MOTR cells present a promising approach to the recalibration of CLARREO and other IR and microwave Earth radiance sensors.