ATLAS BARE HALF RING OUTER ENDCAP QUALITY CONTROL. A FOCUS ON THE THERMAL CONTROL.

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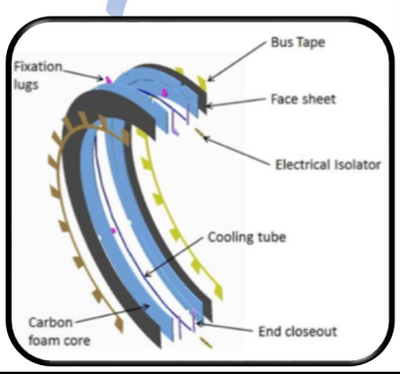
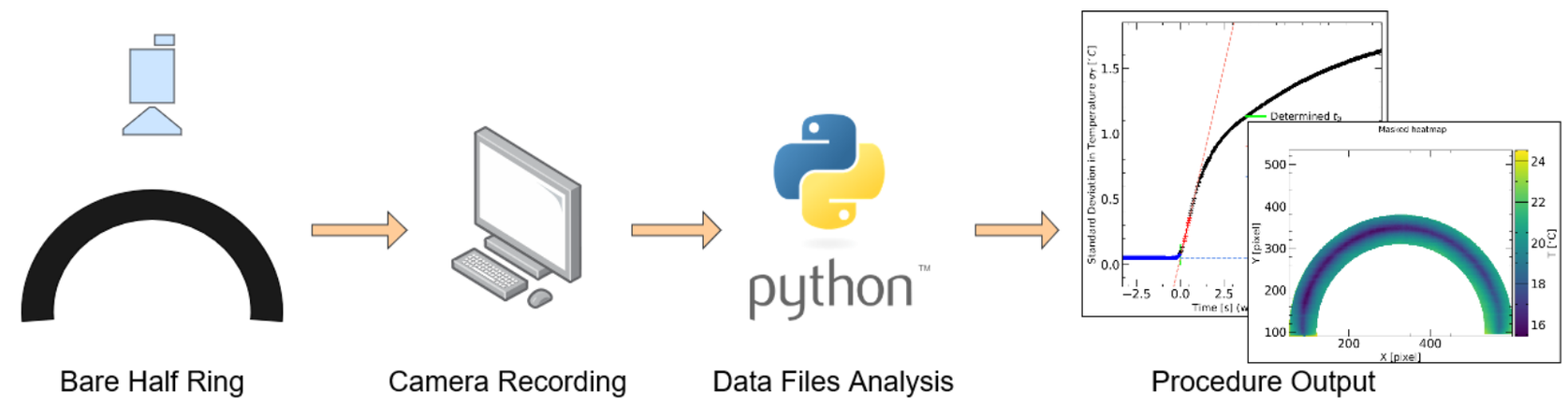


Abstract

The ATLAS ITk outer endcap bare Half Rings (HRs) are made of carbon fiber and carbon foam in order to achieve a low mass in the detector volume while achieving very good thermal performance.
The supports are cooled with two-phase CO_2 flowing in a titanium pipe, placed between two carbon foam Half-Sandwiches, which compose the local support.
A qualification procedure was developed to verify the bare HR performances, which is crucial for the following assembly steps.
A special focus is given to the thermal control system which allows to identify structural defects. The measurement is performed by means of infrared thermography thus being non-destructive and contactless. This work presents the procedure developed and agreed between Italy and UK.

1. The Quality Control (QC) Procedure Flow [1]



Bare Half Ring Thermal Measurement (a) | Camera Recording Conversion to Data Files (b) | Data Files Analysis (c) | Procedure Output (d)

2. Why QC?

- Aim: detecting construction defects in HRs
- It is needed to avoid poor thermal conduction inside HRs
- Thermal anomalies cause inhomogeneous temperature profiles in the HR
- Good thermal performance are fundamental for the sensors to work properly and avoid their damaging
- Functioning HRs with lower thermal performance will be used in safer zones of the detector, limiting the radiation damage

3. The Experimental Setup

The setup allows to acquire the thermal camera recordings in a controlled environment.
The setup aims to simulate the temperature gradient of the operational detector with a low-temperature coolant.

While differences exists, the experimental setups in IT and UK are composed of those common components:

- Thermostatic Bath (to regulate the cooling fluid temperature)
- Novec N7100 (Coolant Fluid) hydraulic circuit
- Thermal Camera mounted inside a Black Box

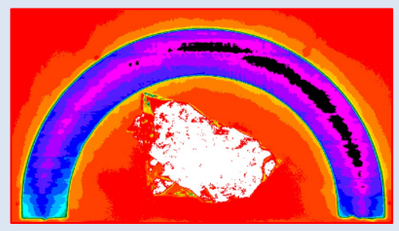
A NUC (Non-Uniformity Correction) calibration is performed to ensures that all the pixels have the same response.
A RAT (Reflected Apparent Temperature) calibration corrects the perturbations induced by external infrared reflections phenomena.

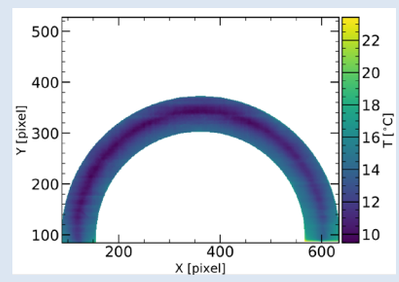
4. The Procedure

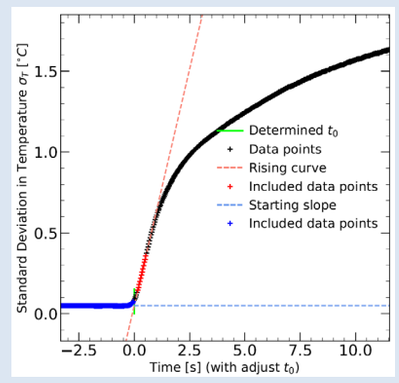
A recording (10-15 sec) of the HR cooling process is acquired by the IR camera and each frame (300-450) is converted into an .csv file.

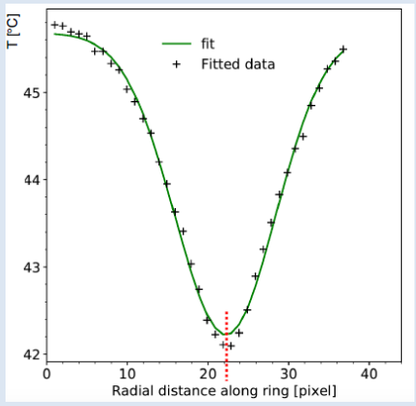
Then a dedicated python script performs the following steps:

- Shape recognition of the HR is performed applying a Canny Filter and subsequently a RANdom SAmple Consensus method (RANSAC)
- Start time of the cooling (t0 = 0 sec) is required to synchronize every measurement, and it is determined from the temperature standard deviation (σ_t) of the Region of Interest (RoI) as a function of the recording time.
- Temperature profiles perpendicular to the cooling pipe are extracted at different angles and at the chosen time t = t0 + t' sec
- The temperature values along the profile are interpolated from the raw data





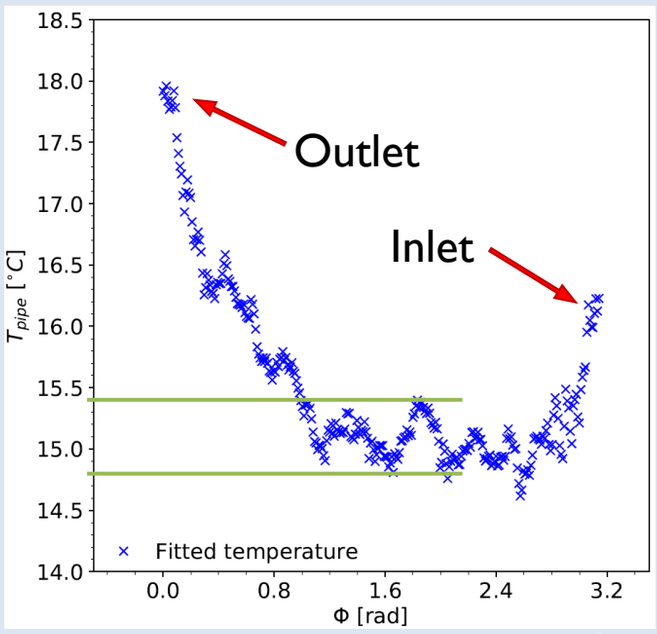




The procedure is totally contactless, so it allows to fully preserve the HR while being analyzed. This is very important because the HR are very fragile, and they are easily damaged.

5. The Procedure Output

- The temperature along the pipe (at the time t0+t') is plotted against the radial position.
- Temperature is expected to increase from inlet to outlet.
- Any spike in the temperature distribution may indicate the presence of a defect in the HR.
- The border regions may exhibit a non-linear behavior, but this is induced by the edge influence.



6. Results

The proposed QC methodology is used to assess the thermal properties of the manufactured Half Rings, before they are loaded with the electrics and electronics components. The noninvasive procedure can identify assembly defects and thermal dis-homogeneities which may degrade the thermal performance during the ATLAS ITk operation/life-time. Defective HR found will not be discharged as they are still able to cool-down the sensors mounted on them, but instead they will be either kept as spare parts or mounted in low radiation area of the detector, thus limiting the radiation damages over time.

[1] ATLAS REPORT ATL-ITK-PUB-2021-001

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ATLAS EXPERIMENT