Fast combined temperature, pressure, and heat flux sensors for rough environments

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Abstract:

Accurate measurement of pressure, temperature, and heat flux at high frequency is often required in a harsh environment, such those found in rocket launchers, atmospheric entry or on-ground rocket and conventional engine tests. Alta has developed a general, small sensor unit layout (typical sensing diameter between 10 and 30 mm) that can measure pressure, temperature and retrieve heat flux on a surface. The sensor unit is provided with fast commercial sensors flush mounted; the sensor choice can be tailored to the customer needs.

Description:

Small size metallic sensor units (typically 15-30 mm in diameter) are provided with high-frequency temperature and/or pressure sensors to be flush mounted on the measurement surface. Pressure is directly measured from the embedded sensors, with the possibility of measurement down to 10 Pa levels. Temperature is measured through coaxial thermocouples and heat flux is derived from the post-processing software. During calibration activities, uncertainty in pressure measurement is below 0.5%, below 2% for convective-conductive heat flux and below 5% for radiative heat flux. The architecture is very robust and was qualified for space including severe launch conditions and atmospheric re-entry. In general, the units are suitable for strong vibrational, hot, and/or humid environments. The sensor units are provided along with dedicated post-processing software that can be used to retrieve the instantaneous heat flux from the measured temperature using each probe's individual calibration. Units operating with a single temperature sensor can be provided and calibrated to retrieve heat flux from a single temperature measurement. Dedicated amplification and signal conditioning electronics can be provided with bandwidth up to 20 kHz.

Innovations and advantages of the offer:

The technology is more flexible and rugged than straight application of commercial items, that often are not available for the user requested conditions.
It is qualified for much harsher than typical sensor environments providing cheap, robust and accurate high-frequency results.
The dedicated calibration of each unit allows a high degree of customization with respect to the application requirements in terms of dimensions, sensors, conditions

Further Information:

The sensor unit layout is defined taking into account two different requirements:

1. The unit has to function as a calorimeter, so its dimensions should be uniform and sufficiently bigger than the central flush mounted thermocouple to allow the correct numerical reconstruction of heat flux during the post-processing.

2. The unit has to allow the placement of different sensors, in particular pressure sensors, that could be much bigger and survive vibrations, shocks etc.

The suggested minimum diameter resulting from the constraint in the first bullet is around 10-15 mm. The minimum height is around 25 mm.

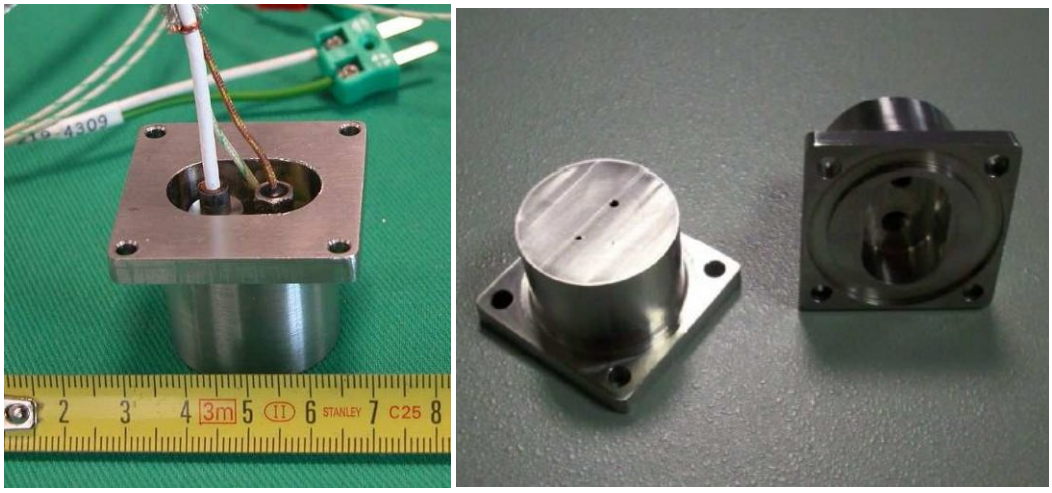

Fig. 1 Example of unit: EXPERT Streamlined Sensor Unit (2 thermocouples, 1 pressure sensor)

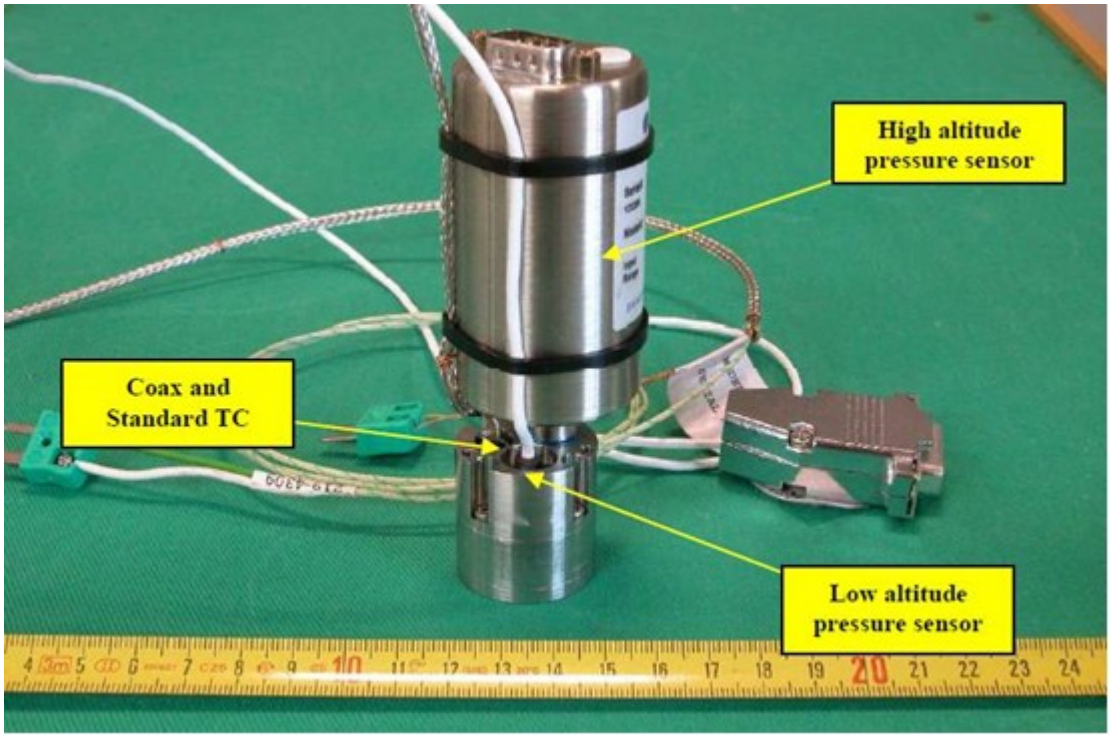

Fig. 2 Example of unit: EXPERT baseline Sensor Unit (1 thermocouples, 2 pressure sensors)

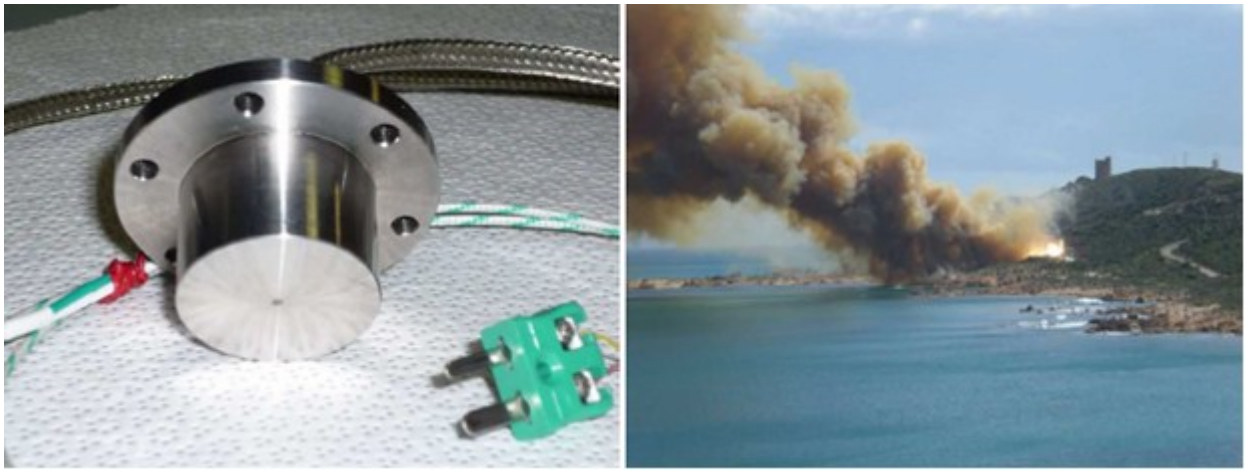

Fig. 3 Example of unit: heat flux units used for VEGA Zefiro 9 solid propellant thruster

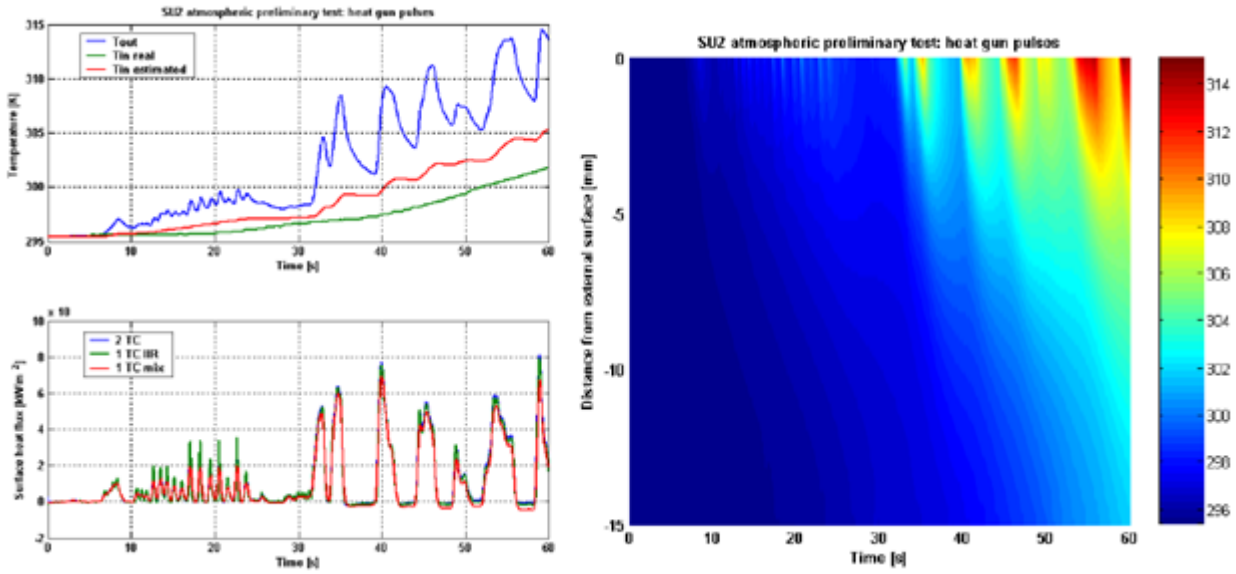

Fig. 4 Example of calibration run: temperature and surface heat flux history (left) – internal temperature history (right)

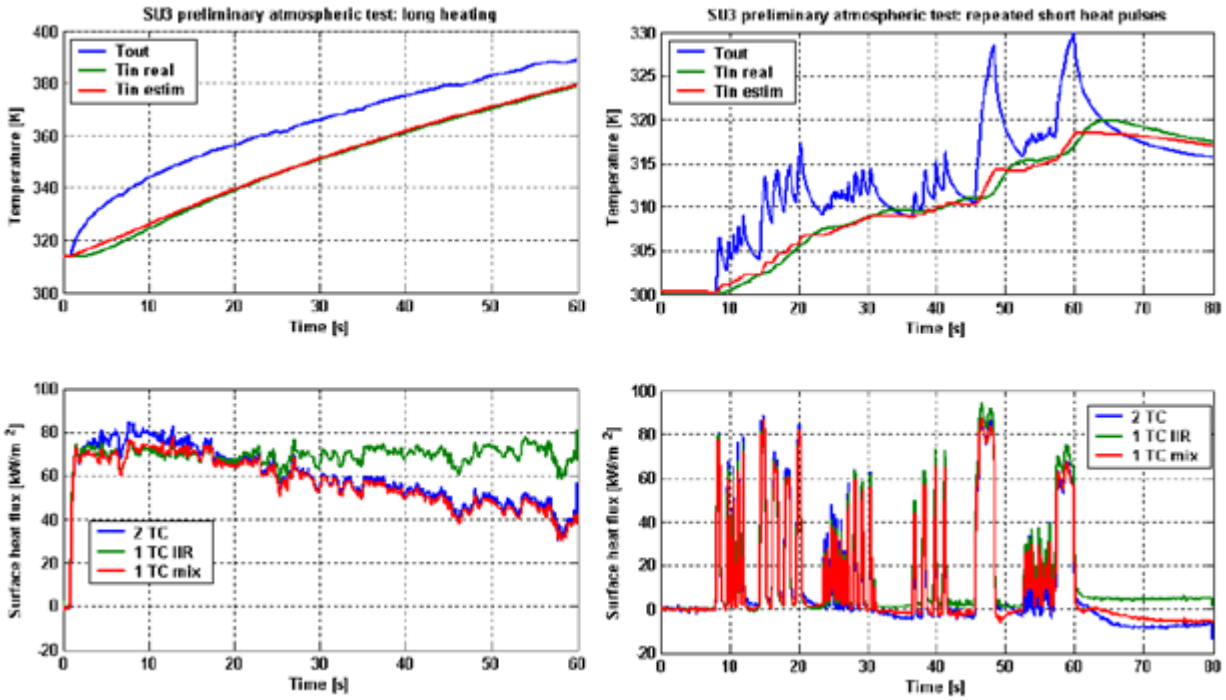

Fig. 5 Example of calibration runs: long and short duration heat pulses

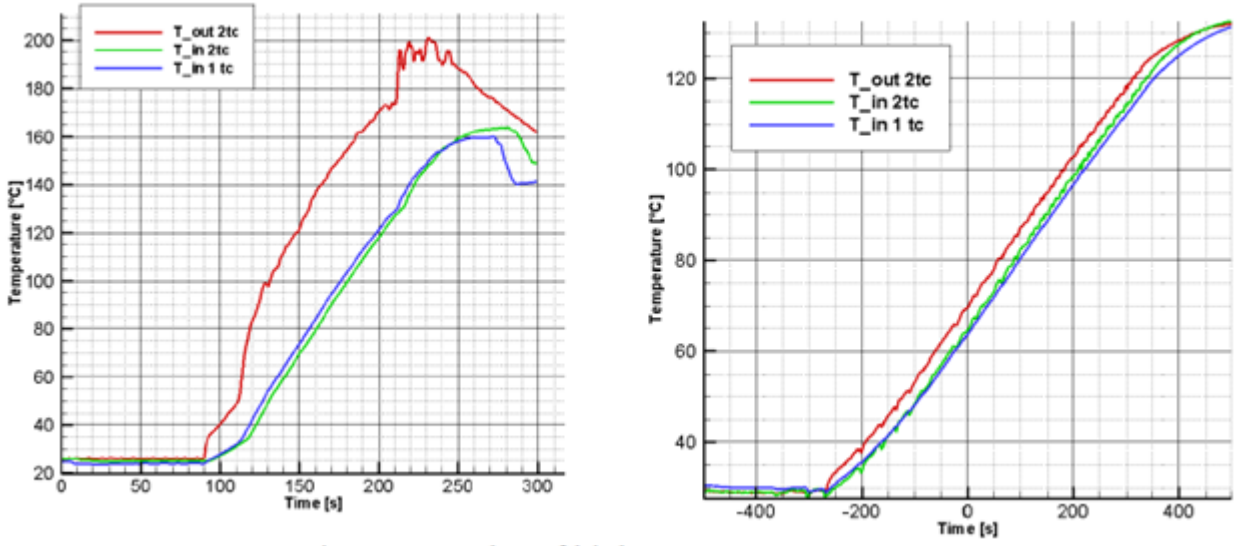

Fig. 6 Examples of higher temperature tests.

The commercial sensors typically used to manufacture the sensor units are Kulite pressure sensors (up to 140 bar compensated up to 232 °C), and MEDTHERM coaxial thermocouples (response time in the microseconds range). The unit is manufactured out of stainless steel or copper; if needed sealing is performed with high temperature glues or potting.

The proposed sensors have successfully achieved all the qualification test levels.

Application:

The sensor are meant to be used in harsh environment including high vibration (>1400 g), high temperature (> 1300 K), humid environments. The typical bandwidth is in the range of several tens of kHz with dedicated signal conditioning electronics with certified bandwidth of 20 kHz.

Current domain of application has been rocket launchers, atmospheric re-entry or on-ground rocket and conventional engine tests.

Potential further domains of applications can be all those where measurement of pressure, temperature and heat flux with bandwidth up to at least 20 kHz are needed in harsh environments.