Abstract:
Accurate measurements of the helium flowrate and of the temperature on ITER magnets is of fundamental importance to make sure that the magnets operate under well controlled and reliable conditions, and to allow suitable flow distribution in the magnets through the helium piping. Therefore, temperature and flow rate measurements shall be reliable and accurate. In this paper, we present the full thermometric chain as well as the Venturi flow meter installed on ITER magnets and their helium piping.

The thermometric chain is described from the sensor and its attachment on pipe or structure, to the electronic conditioning of the signals and the shielding system. The thermometric block design is based on the developed one by CERN for the LHC, which has been further optimized thanks to thermal simulations carried out by CEA. The ITER specifications are challenging in terms of accuracy and call for severe environmental constraints, in particular regarding the distance between the sensors and the electronic measuring system. A focus will be made on this device, which has been recently developed by CEA: based on a lock-in measurement and amplification of small signals, and providing web interface and software to monitor and record temperatures, this measuring device provides a reliable, accurate, electromagnetically immune, and fast (up to 100 Hz bandwidth) system for resistive temperature sensors between a few ohms to 100 kΩ.

The full mass flow chain is not yet defined but the flowmeters required are completely designed, manufacturing is on-going. The behavior of the gas has been studied in detailed thanks to CFX software to obtain the same differential pressure for all types of flowmeters. Measurement uncertainties have been estimated and the influence of input parameters investigated. Then mechanical calculations have been done to guarantee the mechanical strength required for pressure equipment operating in nuclear environment. On the other hand, different technologies of absolute and differential pressure sensors have been tested under magnetic field to identify equipment compatible with ITER environment.

Operation of ITER magnets: 277 Venturi flowmeters required (6 types of Venturi)

- 6 sizes of flowmeters to control the flow rates inside the magnets and the current leads
  - Reference: 0.1 to 1 kg/s, Near 300 K: 3 to 4 bars
  - DN100: 1 to 10 kg/s, Near 300 K: 3 to 4 bars
  - DN150: 3 to 30 kg/s, 4.2 to 6 K: 4 to 10 bars
  - DN200: 15 to 60 kg/s, 4.2 to 6 K: 4 to 10 bars
  - DN250: 40 to 400 kg/s, 4.2 to 6 K: 4 to 10 bars

Design follows standard NF EN ISO 5167-4

General design of the Venturi

Design of the flowmeters

- Fluid modelling used (CFX) to obtain the same differential pressure for all flowmeters
- Uncertainties: probable error on density and on mass flow rate
- Mechanical calculation to size pressure vessels
  - Load cases considered (cold flowmeters):
    - Pressure and connecting pipework
    - Fault condition at operational temperature
    - Fault condition at operational temperature and seismic loads

Different technology of pressure sensors tested under magnetic field to identify equipment compatible with ITER environment

- Piezo electric
- Capacitive
- Resistive gauge
- Optical

Two phases foreseen: a first type of sensors before nuclear radiation and a second one after

Conclusions:
Thermometric chains: After one year of experience dedicated to the validation of the thermometric measuring chain for ITER, we are confident that the chosen components and method used (sensor located in vacuum and thermally anchored through a method pioneered by CERN), as well as the electronic board chosen, allow temperature measurements compatible with ITER’s specifications. Production of the pre-series has started to insure first 2016 deliveries to ITER Organization and to its Domestic Agencies. After validation of a complete nominal thermometric chain coming from the pre-series, the series production will start.

Flowmeters: The design phase is currently completely finished. Different aspects have been examined, as fluid modelling, uncertainties calculation and mechanical calculation has fulfilled all ITER’s requirements and especially the classification of the flowmeters as pressure vessels in nuclear environment. The production phase has been started. In parallel, different technology of pressure sensors have been tested under magnetic field to identify equipment compatible with ITER environment.