Qualification of 0-60 mbar pressure transducers for the LHC HiLumi environment

ICEC ICMC

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Abstract

The LHC HiLumi upgrade requires the procurement of 0-60 mbar absolute pressure sensors with an absolute accuracy of +/- 0.3 mbar and a radiation Total Integrated Dose (TID) that may reach 100 kGy. Such a low-pressure range is usually measured through the deformation of a relatively large diaphragm and the sole passive sensors available commercially use magnetic coupling for the measurement of the deformation. Additionally, ABB provided CERN with their low-pressure measuring cell that is based on a piezo resistive bridge measuring the diaphragm deformation.

Introduction

The sensors under test are a Valydine AP10 and an ABB, both passive devices. The ABB measuring cell, if we understand correctly, is used in their commercial 266AST sensor series. Apart of the radiation, the ABB 266 AST series perfectly matches the HL-LHC accuracy requirements

Pressure sensors under test: Validyne AP 10 and ABB passive cell. Both have a 60 mbar range.

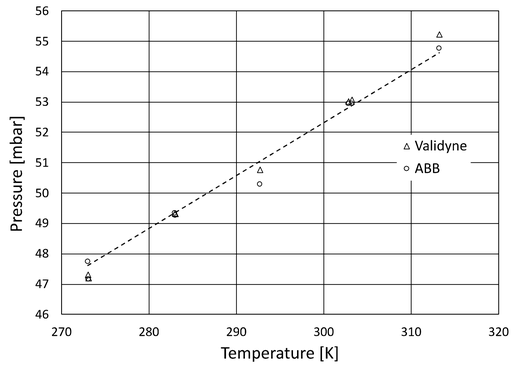
The accuracy target is selected to match or surpass the temperature measurements that show a reproducibility of ± 0.005 K, it means ± 0.3 mbar with respect to a saturated bath of 18 mbar with a corresponding temperature of 1.827 K. Equivalent ABB measuring cells are presently used in the Crabs cavity test facility located in the SPS accelarator, various measuring ranges are installed and they are either 60 mbar or 4 bar.

CONCLUSION

This paper presents the radiation hardness observed by two different type of sensors with a maximum range of 60 mbar. The Validyne® AP10 pressure sensors have demonstrated adequate radiation hardness till TID doses up to 160 kGy, this dose exceeds the HL-LHC requirement. It is planned to integrate the signal conditioning within CERN's custom-made radiation tolerant electronics [2]. For this purpose, an audio transformer with central taping, a 5 kHz excitation wave and signal rms amplitude measurement will be integrated in a readout card, this system has fixed gain avoiding the appearance of sudden signal excursions.

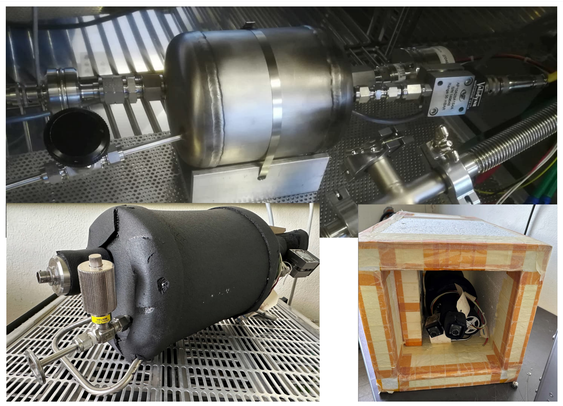
Test Set-Up

The qualification of a device for operation in a radiation environment usually require the comparison to a reference device that is either non affected by the radiation or that is moved outside the radiation field. The reference pressure selected in this test is a closed and leak-tight chamber. Its internal pressure is varied by modifying the gas temperature, in such conditions the pressure can be expected to be changed by at least 10%, by assuming that the pressure is dictated by the law of perfect gases (pressure proportional to the absolute temperature)



Measured pressure versus leak-tight temperature.

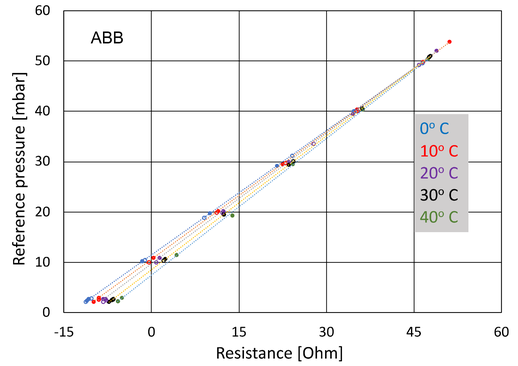
The temperature sensor is located inside the sealed chamber also exposed to the radiation field; it is a platinum 100 ohm sensor not expected to change at the expected TID.
To avoid leaks due to synthetic material degradation, the pipes are joined by metallic compression fittings and the gas filling port uses a bellow sealed valve. The sealed chamber has a synthetic insulation, and it is placed inside a cubicle made with 50 mm thick extruded polystyrene insulation plates.
The measurement apparatus is controlled by using a LabView application that monitors the ABB bridge and that acquires the Validyne sensor signal either through a Validyne® CD15 signal conditioner or by using a transformer coupling excited by a 5 kHz sinusoid.

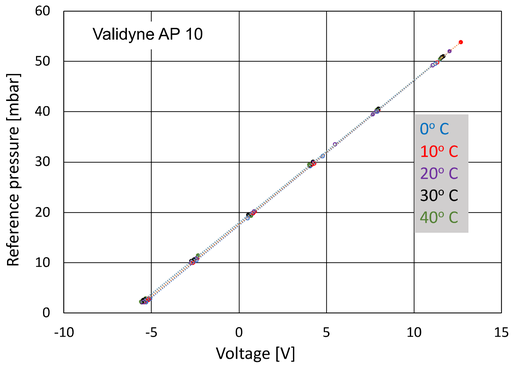


Leak-tight chamber

Individual sensor calibration

The pressure sensors are calibrated inside a climate chamber to obtain an approximation function that is capable of compensating variations of the sensor temperature.



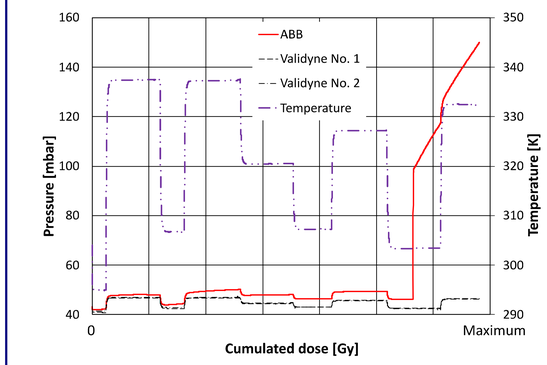


Output signal versus pressure calibration, dependency on sensor temperature

Both type of sensors have a good linearity with respect to the applied pressure and by using temperature corrections they meet the LHC Hi-Lumi requirements.
For the ABB sensor, the spread with respect to the sensor temperature increases when decreasing the pressure and the +/- 0.3 mbar accuracy target requires a temperature correction even for an ambient temperature variation as small as 1 K.
The Validyne AP 10 sensor response has a very good linearity and is insensitive to ambient temperature effects. However, for the AP 10, the connecting cable is part of the complex sensor impedance and therefore the signal amplitude depends on the cable impedance loading. When using a Validyne CD15 signal conditioner, two 10-turn rotary potentiometers to adjust gain and zeroing are used to compensate for cable loading effects. Over the long term (i.e. during irradiation tests) we have observed sudden zeroing permanent offsets that most probably are due to the electronic unit, therefore for some tests the conditioner was replaced with a set of individual instruments and no sudden offset was observed.

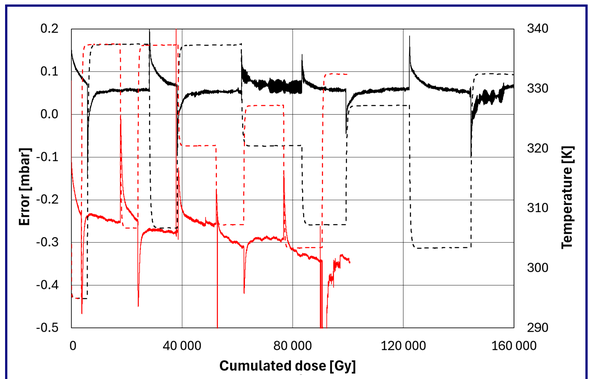
Radiation Tests

The pressure sensors were irradiated in the CC60 irradiation room of CERN's CALLAB facility. The irradiation is started by raising from the bottom of a shaft a Co-60 source, the radiation dose rate depends on the distance between the source and the sample. The test duration was about a month in order to reach the target Total Integrated Dose (TID) of 100 kGy that correspond to the radiation that the sensor may reach at its location in the HL-LHC accelerator.



Sealed chamber pressure measurement as a fonction of temperature and cumulated dose (TID)

For one Valydine sensor (#1) sudden measurement offsets were observed, they are attributed a change in either the gain or zeroing of the signal conditioning units. No such measurement offsets were observed when testing with discrete components (center taping transformer, 5 kHz sinus generator and RMS signal amplitude measurement)



Measurement error (solid line) and sealed chamber temperature (dashed line) versus cumulated dose. Data in red and black are respectively for Validyne sensors # 1 and # 2. The temperature reading is synchronous and identical for both red and black trends

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