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C2Po1E-02: Irradiation tests of 3/2-way piezo valves at CERN

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Most cryogenic regulating valves used in CERN cryogenic facilities rely on the Siemens Sipart™ intelligent valve actuator and for future deployment in the Large Hadron Collider (LHC) High Luminosity (HL-LHC) upgrade it is necessary to better understand the effects of particle radiation on the operation of these control valve actuators. When used in radiation environments, the Siemens™ intelligent valve actuator is split into two parts: the control module containing electronic circuits which is located in a radiation-free area and the pneumatic unit with both the miniature valves and the feedback position potentiometer mounted on the control valve stem, which is exposed to particle radiation when installed in a high energy accelerator.
Concerning cryogenic ON/OFF valves, currently solenoid-pneumatic switch valves are being used in the LHC. For the HL-LHC upgrade, the use of Hoerbiger™ piezo-pneumatic switch valves, containing the same piezo ceramic bending element as Siemens Sipart™ intelligent valve actuator, was investigated. Piezo valves require very low current for activation, and no energy to maintain the active state. This minimizes power losses, eliminates voltage drops, and reduces the required cable cross-section. As for the process control equipment design, more channels are supported, providing enhanced flexibility. These features are particularly advantageous in systems where control equipment is located at a significant distance.
The HL-LHC cryogenic upgrade will expose the valve actuators and pneumatic switch, as well as all the LHC-tunnel instrumentation, to a high level of radiation that is expected to reach up to 100 kGy. To date, all reported radiation tests were performed by using gamma rays that may underestimate the effects if the devices are prone to radiation displacement damage.
To investigate the radiation effects, two campaigns were carried out. The first radiation test was performed in CERN's IRRAD proton facility where the primary proton beam with a momentum of 24 GeV/c is extracted from the CERN PS accelerator ring. Such heavy particle irradiation, apart from radiation damage, provokes the activation of materials complicating the handling of irradiated components. The radiation test was performed on the components that had previously failed in tests, specifically the 3/2-way piezo miniature valves. The test set-up was made of ten piezo miniature valves mounted on a movable table that permits inserting the devices under test into the beam. The control equipment was located outside the irradiation area, and it was composed of a voltage generator opening and closing the micro valves, control valves and instrumentation to measure the inlet flow as well as the pressures at the inlet and control ports of the miniature valves. Signal cables, 20 meters in length, and flexible pipes with a 4-mm internal diameter were used to connect the control system to the devices under test.
The second campaign, for testing the Hoerbiger™ piezo-pneumatic switch for ON/OFF valves, was conducted at CERN's Cobalt-60 (CC60) gamma-ray facility to study accumulated radiation dose effects. The valves were exposed to a dose rate of 8 kGy per day for two weeks, reaching a total dose of 105 kGy. In total, six valves were tested, with four featuring 3D-printed cases: two made from Accura 25 and two from Ultem material. The remaining two valves retained the company's proprietary polyarylate material. The Hoerbiger™ electronics, including radiation sensitive microcontrollers and integrated circuits, were replaced with CERN developed electronics using only passive components and achieving the same functionality. All valves were disassembled and rebuilt, placing CERN electronics. 3D-printed cases were placed on four valves before testing. Like the IRRAD campaign, control equipment was located outside the irradiation area.
This paper presents the test setup and examines the effects of hadron radiation and gamma rays on the performance of 3/2-way valves under various operating conditions, providing insights into their reliability in radiation environments.

Author: CASAS-CUBILLOS, Juan (CERN)

Co-authors: CHATZIPAPAS, Nikolaos (CERN); ROSTAD, Eivind (CERN); TRIKOUPIS, Nikolaos (CERN)

Presenter: CHATZIPAPAS, Nikolaos (CERN)

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