Maintenance assessment of the SPES Front-End

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SPES FRONT END

The SPES Front-End is made up of two main components:

- The Proton Front-End (FEP), improperly called proton channel, which is the responsible for the transport of the proton beam;
- The Radioactive Front-End (FER), improperly called radioactive channel, which is responsible for the transport and acceleration of the radioactive beam.

The Front-End also collects all the auxiliary devices necessary for the operation of the entire system. Unlike what happens, for example, for the target chamber which is removed from the front-end, the set of internal components remain fixed inside the bunker and are only subjected to scheduled maintenance. In particular, the components closest to the target chamber are subject to considerable damage due to the high dose of radiation absorbed and coming from the target, which decreases, approximately, with the square of the distance from the radiating source

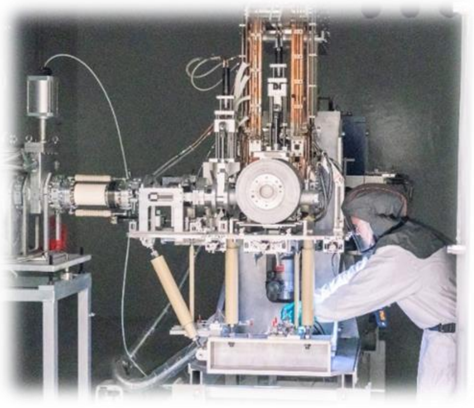

Figure 1: Maintenance experimental campaign of the SPES Front-End.

The Front-End performs the following functions:

- It guarantees support and stability to the proton channel, to the target chamber and to the equipment necessary for the transport of the radioactive beam;
- It allows the creation of a sufficiently high degree of vacuum to allow the proper operation of all the components inside and connected to it;
- it provides electrical power (for the operation of the instruments and for the target block heating) and water supply (for the components cooling);
- Allows quick coupling with parts that need to be periodically removed and replaced (e.g. the target chamber).

The methodologies for the quantitative risk assessment applied to the SPES Front-End are the semi-quantitative Hazard and Operability Analysis (HazOp) and the Layer of Protection Analysis (LOPA); from the application of these methodologies it was found that the final frequencies satisfy the order of magnitude of the target frequency for each hazard scenario.
At present the target frequency is not satisfied because the IPLs are not fully developed. In particular, there is a lack of maintenance procedures, a preventive maintenance program with periodic inspections and an operator training program. [3]

MAINTENANCE EXPERIMENTAL CAMPAIGN

In order to develop the maintenance procedures, an experimental campaign has been planned to determine average times, considering different operators and different levels of training, necessary to perform some maintenance operations.
Six operators took part in the maintenance tests, equally distributed by gender, in order to have a broad spectrum of characteristics to define the average time necessary to carry out the maintenance procedures. Preliminary tests have been defined to ensure adequate efficiency and effectiveness of the operations that must be carried out in the shortest possible time to limit the operator's exposure time.
The maintenance procedures have been collected in a template, made available to the operator.
In the template, specific for each maintenance procedure, the first part indicates the number of operators required, the conditions that must be met, the maintenance frequency of that specific component and the mandatory Personal Protective Equipment (PPE).
This is followed by a form containing the assessment of the potential risks arising from the maintenance operation. Mechanical, thermal, ergonomic and radiation hazards have been analyzed. The estimated duration of the operation, resulting from the experimental maintenance tests, and the estimated dose absorbed by the operator based on simulations using the FLUKA code are also indicated. All operations have been divided into preliminary operations relating to the phase in which the operator wears the PPE, disassembly of the component, storage of the disassembled component, assembly of the new component and

removal of the PPE. For each of these phases there is a detailed procedure that must be compulsorily followed by the operator to ensure maximum efficiency of the operation. Finally, the same template indicates the procedure to follow in the event of an emergency or accident which must be declared as soon as an anomaly is noticed that cannot be immediately resolved by the maintenance operator.

Therefore, the objectives are to determine the radiation dose to which the operator is exposed, to identify the work positions as well as to identify the criticalities in order to improve the design and therefore the maintenance operations. To do this, an analysis of the existing components was carried out to identify the most critical in terms of maintenance. The components subjected to the maintenance test are the protonic gate potentiometer, the radioactive channel limit switch and the protonic channel pneumatic motor.

In order to increase the efficiency of these operations, maintenance tests were carried out using different tools. For example, to disassemble the pneumatic motor, the Allen key and alternatively the ratchet were used in order to identify which is the most suitable work tool to perform this task. It has been shown that a new design (e.g. limit switch and potentiometer) allows to reduce maintenance times and minimizes the use of tools.

RESULTS OF THE EXPERIMENTAL CAMPAIGN

From the maintenance tests of the pneumatic motor relating to the proton channel it was possible to observe both in the disassembly and assembly tests, the times of which are represented in Fig. 2, that the maintenance times obtained using the allen key (tool A) are greater than those obtained with the ratchet (tool B).

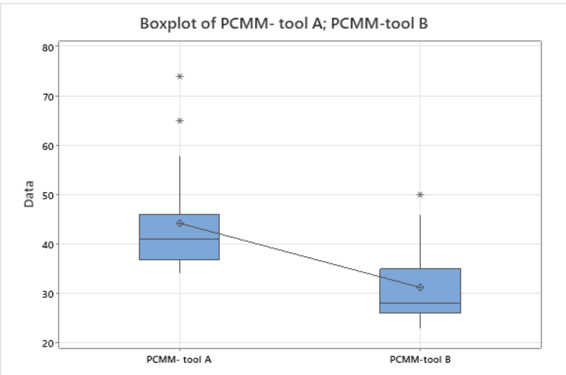

Figure 2: Boxplot Plot of the Protonic Channel Motor Mounting using different tools

In order to verify this graphical evidence from a statistical point of view, a parametric test, the Two Sample T-Test was applied. As an alternative hypothesis, it is assumed that the average times of using the allen key are greater than those obtained using the ratchet.

From the comparison, a lower p-value of $\alpha = 0.05$ was obtained for both the disassembly procedure and the assembly procedure, therefore the alternative hypothesis is accepted. There is sufficient evidence to conclude that the mean times using the Allen key are greater than those obtained using the ratchet at the significance level of 0.05; therefore, in order to ensure the optimization of the maintenance procedure, the reversible ratchet will be used. With regard to the maintenance tests of the protonic gate potentiometer and of the radioactive channel limit switch, it was possible to observe both in the disassembly and assembly tests, the times of which are represented in Fig. 3 and Fig. 4, that the times obtained using the new design, which involves disassembly by means of a clamp, are considerably shorter than the times obtained with the previous design. From the boxplots it is possible to observe that the times relative to the old design (PGOMA - tool A) have a greater variability because the previous design required the use of auxiliary tools which are not easy to handle using PPE.

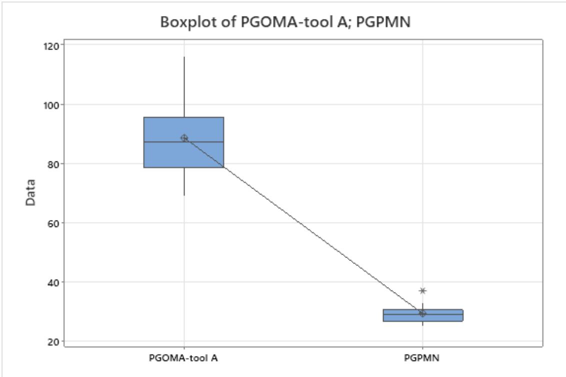

Figure 3: Boxplot of the Protonic Gate Potentiometer Mounting relative to the new design (PGPMN), and the old design (PGOMA-tool A).

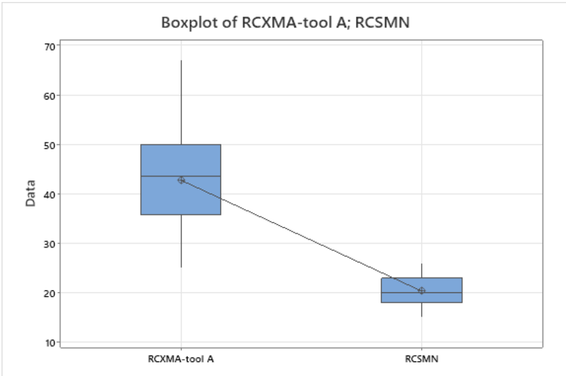

Figure 4: Boxplot of the Radioactive Channel Limit Switch Mounting relative to the new design (RCSMN), and the old design (RCXMA-tool A).

There is sufficient evidence (Two Sample T-Test) to conclude that the mean times using the old design are greater than those obtained using the clamp at the significance level of 0.05; therefore, the optimization of the design has made it possible to significantly reduce maintenance times and consequently also the dose to which the operator is exposed.

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[3] G. Lilli et al., " Risk Assessment of the SPES On-Line Front End: HAZOP and LOPA Analysis," this Annual Report.