Increasing the particle energies to reveal more secrets of matter, the Large Hadron Collider (LHC) is about to reach its limits. For future experiments colliders of a new magnitude are necessary, with large heat load from the ambiance expected, caused by the sheer size of the machine.

Heat loads unavoidable to drive the beam screen cooling system.

The necessary exergy consumption corresponds to the need of electrical power for a successful cooling and constitutes the major part of the operational costs.

The exergetic efficiency of the beam screen cooling system (without Nelium cycle) is the ratio of the exergy of the extracted heat loads and the exergy input.

Cold circulation:

\[ \eta_{\text{cold circ}} = \left( \frac{P_{\text{in}} + Q_{\text{ex}}}{P_{\text{in}}} \right) \]

Warm circulation:

\[ \eta_{\text{warm circ}} = \left( \frac{P_{\text{in}} + Q_{\text{ex}}}{P_{\text{in}}} \right) \]

For the two schemes the exergy of the extracted heat loads is the same. Depending on the performances of the circulator and of the internal heat exchanger, the total pressure loss is the main influence quantity for the cycle efficiency.

For the warm circulation scheme the power has to be extracted at cryogenic temperature level. The terminal temperature difference of the internal heat exchanger though allows a certain heat energy to “pass” – this heat has to be extracted by the Nelium cycle.

The necessary exergy consumption of the beam screen cooling system is a closed loop, connected to the Nelium refrigerator by two heat exchangers.

The exergetic advantage of large headers and short magnet strings is accompanied by an increasing effort of capital costs, controlling effort and possible downtime due to component failure.

1) Larger headers require more space increasing the necessary size of the distribution line, the amount of needed material, the heat loads and the civil engineering costs.

2) A larger amount of auxiliary equipment (e.g. control valves, sensors, ...) complicates the controlling and increases the error proneness and therefore the downtime of the entire cryogenic system.

3) Other applications and cryogenic infrastructure already are supposed to follow the pattern of half-cells of a length of corresponding to seven magnets in series (~107 m). Adjusting the beam screen cooling cycle units to this pattern simplifies the assembly, the maintenance and the organisation, paying for these conveniences with increased operational costs.

4) The sector dimensions, the beam screen design and the heat loads are determined and define the overall pressure loss.

5) The sector dimensions, the beam screen design and the heat loads are determined and define the three different lengths of magnet strings.

6) The compression losses are higher for the cold circulator, because of the cryogenic temperature level, the compression heat is dependant on the main exergy loss of the warm circulation cycle is caused by the terminal temperature difference of the internal heat exchanger. The exergetic losses of the beam screen cooling cycle are much lower if a cold circulator is used.

7) Also the total exergy consumption including the Nelium cycle is larger for the warm circulation cycle for the given pressure drop. From the progress of the total exergetic effort curves, the stronger dependency of the cold circulation scheme on the pressure drop can be recognised.

Conclusions

The energetic advantage of large headers and short magnet strings is accompanied by an increasing effort of capital costs, controlling effort and possible downtime due to component failure.

- Larger headers require more space increasing the necessary size of the distribution line, the amount of needed material, the heat loads and the civil engineering costs.
- A larger amount of auxiliary equipment (e.g. control valves, sensors, ...) complicates the controlling and increases the error proneness and therefore the downtime of the entire cryogenic system.
- Other applications and cryogenic infrastructure already are supposed to follow the pattern of half-cells of a length of corresponding to seven magnets in series (~107 m). Adjusting the beam screen cooling cycle units to this pattern simplifies the assembly, the maintenance and the organisation, paying for these conveniences with increased operational costs.

Technical advantages of the warm circulator, for example easier handling, less error proneness and the possibility of multipurpose use (e.g. during cool down and warm up) and a possible better performance during transient modes could make it a better choice, despite of the higher operational costs.

The investigation of the performances of different circulator concepts including the impact on the Nelium cycle is the next step in the development of a reliable and efficient BSC system.