TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Mechanical Science and Engineering, Bitzer Chair of Refrigeration, Cryogenics and Compressor Technology — **C1PoG-01**

Neon helium mixtures as a refrigerant for the FCC beam screen cooling: comparison of cycle design options

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Motivation

The Future Circular Collider for hadron-hadron collisions (FCC-hh) is planned to achieve a center of mass energy of 100 TeV. These energies cause a high synchrotron radiation in the arcs of the accelerator of 6 MW. A beam screen in the temperature range 40 to 60 K is introduced to compensate this heat load. Since synchrotron radiation was only a minor effect so far, a properly designed cooling for the beam screen has become a new challenge.

The Nelium concept

The state of the art approach for cryogenic refrigeration is a Brayton cycle with a screw compressor and helium as the working fluid. These compressors have a low isothermal efficiency (≈55%). Centrifugal compressors achieve high efficiencies (≈70%) but require several stages for the compression of helium. By adding neon, the number of stages required can be lowered significantly.

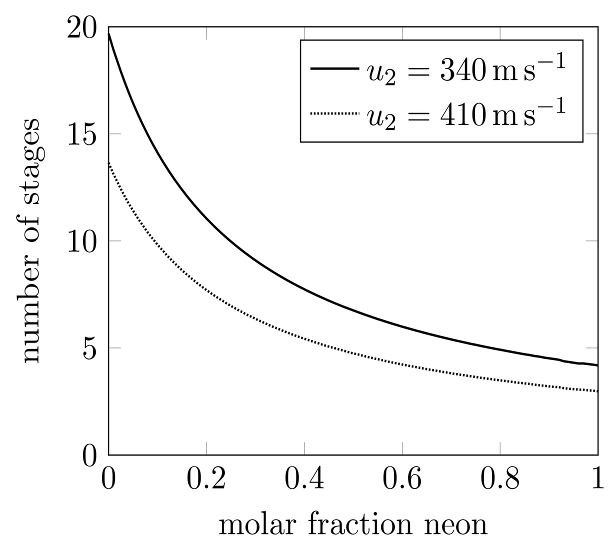

Figure 1: Required number of stages for isentropic compression and re-cooling after every stage

General cycle concept

The refrigeration system consists of a primary Nelium cycle for refrigeration and a secondary cycle with pure helium for distribution of cooling power. With this configuration, activation of neon can be avoided and the pressure levels can be reduced.

Primary cycle

Three different cycles were examined. All are of the turbo-Brayton type and use the brake compressor as a booster (2). Option A is without the second main heat exchanger (6) and without the pre-cooling turbine (5). Option B is without the pre-cooling turbine. Option C features the complete cycle.

Figure 3 shows that the higher the neon content, the higher is the influence of the pre-cooling turbine and the lower the one of the additional heat exchanger. Option C with a neon content of 25 mol-% has a Carnot efficiency of 57%. For comparison: a pure helium cycle with a screw compressor would have a Carnot efficiency of 44%.

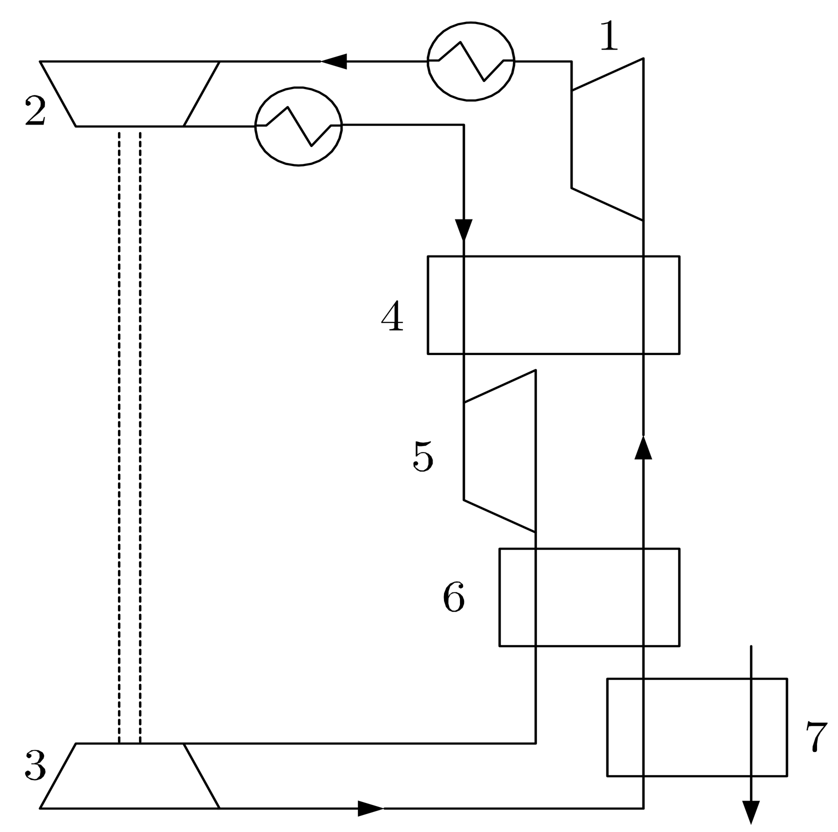

Figure 2: Proposed primary cycle (complete setup): 1 main compressor, 2 brake compressor, 3 expansion urbine, 4 primary main heat exchanger, 5 pre-cooling turbine, 6 secondary main heat exchanger, 7 load heat exchanger; option A: without (5) and (6), option B: without (5)

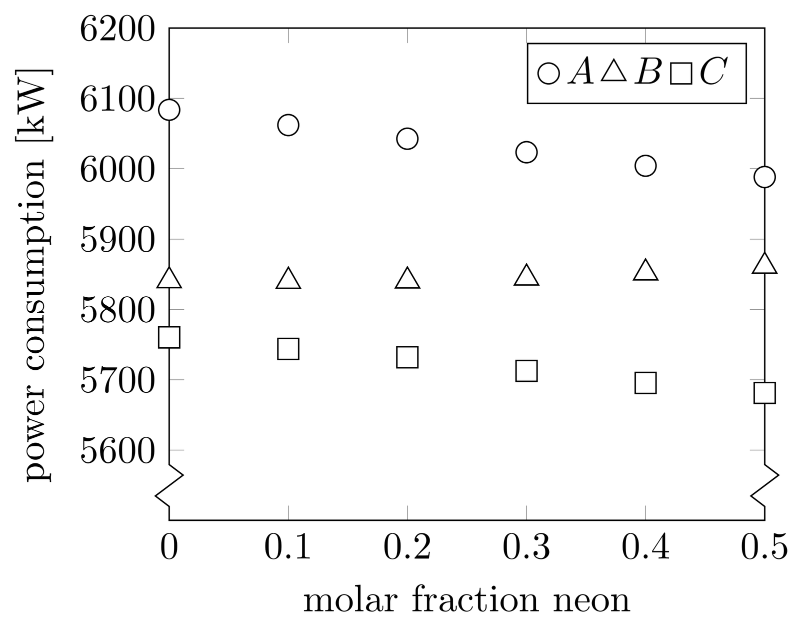

Figure 3: Power consumption for refrigeration

Secondary cycle

Circulation of the helium in the secondary cycle can be achieved with a cold or warm compressor. For the pressure drop in the beam screens of 7.8 bar, the warm compressor increases the overall power consumption by 47%, whereas the cold compressor uses only additional 35%.

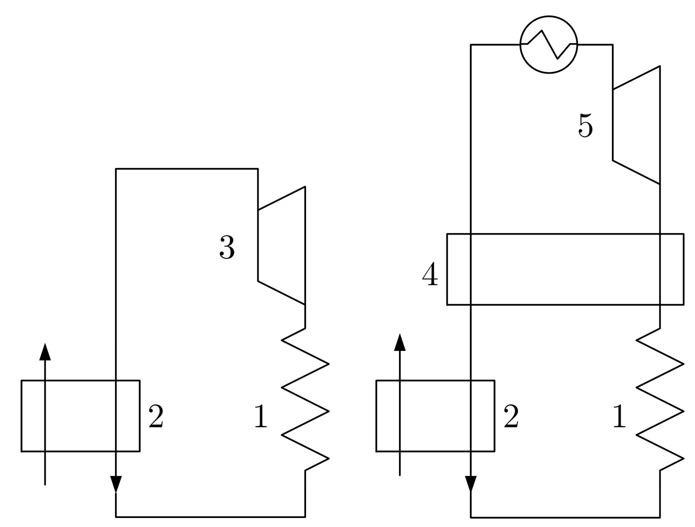

Figure 4: Proposed secondary cycles: left: cold circulation compressor, right: warm circulation compressor; 1 beam screen, 2 load heat exchanger, 3 cold compressor, 4 warm compressor, 5

Main compressor

The pressure ratio over the main compressor is 6. A centrifugal compressor for pure helium with a circumferential speed of 340 m/s requires 20 stages. This number can be lowered to 14 by increasing the speed to 410 m/s. By adding 25 mol-% neon, the number of stages can be reduced by a factor of two.

Conclusion

By applying centrifugal compressors instead of screw compressors the efficiency can be increased significantly. The number of stages that is necessary for the compressor can be reduced by using a mixture of neon and helium.

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