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Cool-down and transient operation with the Nelium cycle

FCC Week Amsterdam // 2018

Agenda

1. Cost of neon for the FCC-hh
2. Transient operation
3. Cool-down of magnets with the Nelium cycle

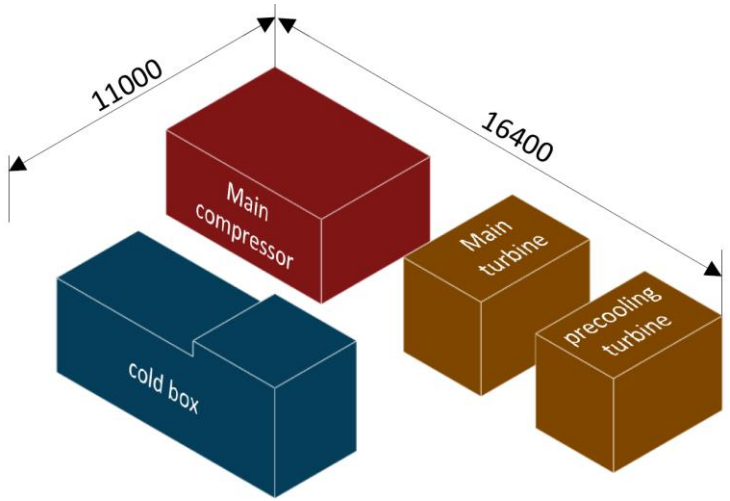
Neon – a prohibitively expensive refrigerant?

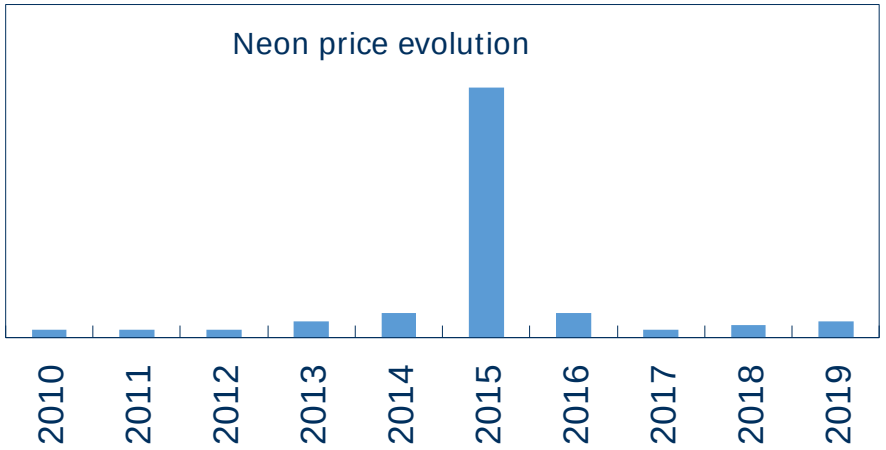
Characteristics of the concept

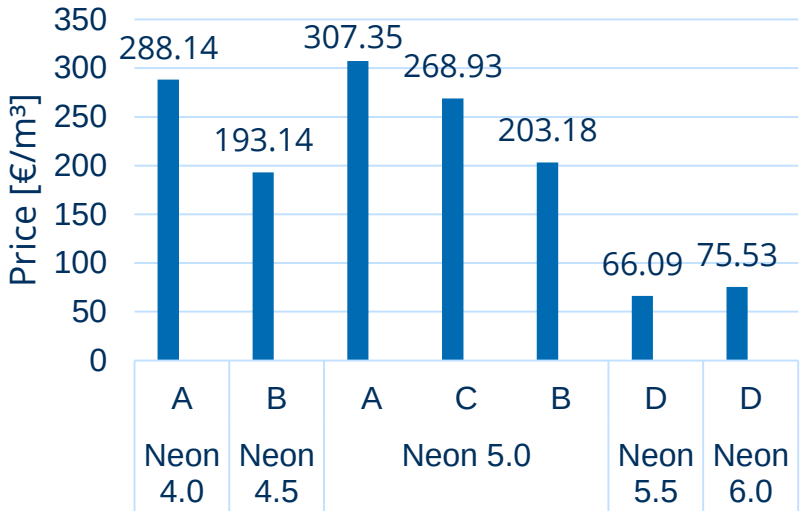
- High pressure
- Compact size
- No liquid

Required Neon for initial filling: 144 kg Neon

≈ 100 k€ for all of FCC –hh







Transient operation

Heat loads at 40 to 60 K:

Permanent:

Thermal shields	70 kW
Circulator	110 kW

During beam circulation:

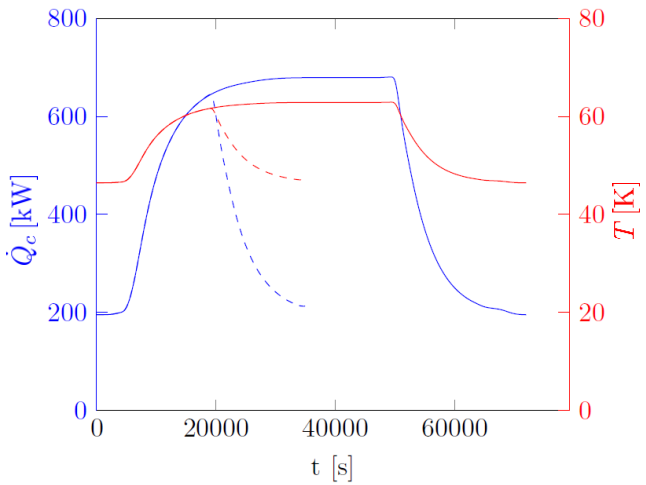
Synchroton radiation	500 kW

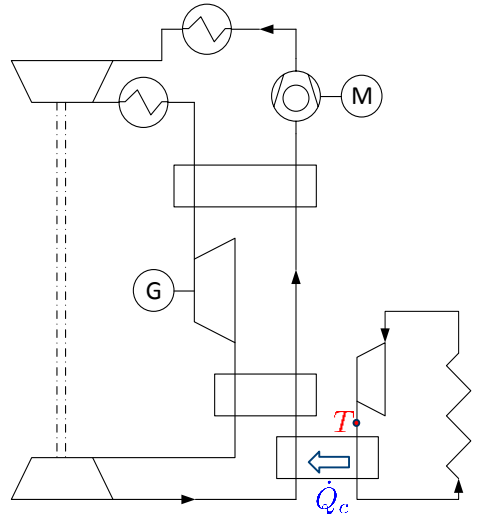
High variation of heat load

Change over times ~1 hour

Constant mass flow through BS + TS

Temperature and load profiles by H. Rodriguez:





Strategies for capacity control

Unloading of cycle

-removal of mass from the system

-pressure and temperature ratios constant

-additional mass has to be cooled

-buffers are needed

Variation of speed

-slow down of main compressor

-pressure and temperature ratios decrease

-reaction times: minutes

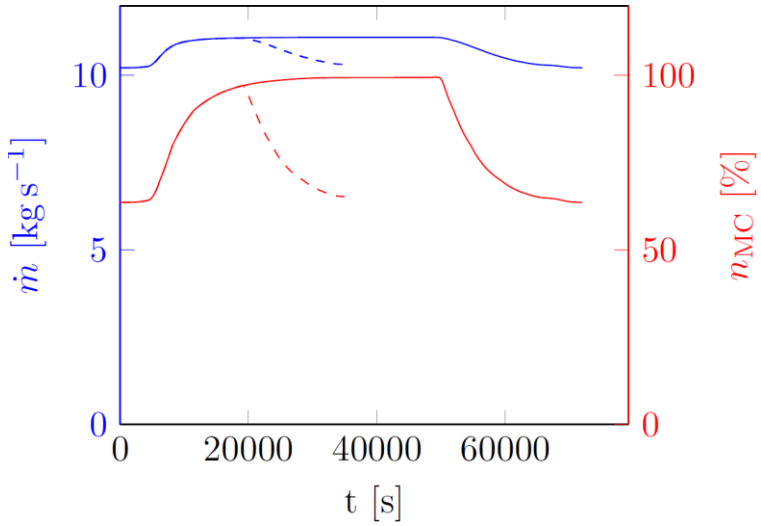
-change of velocity triangles

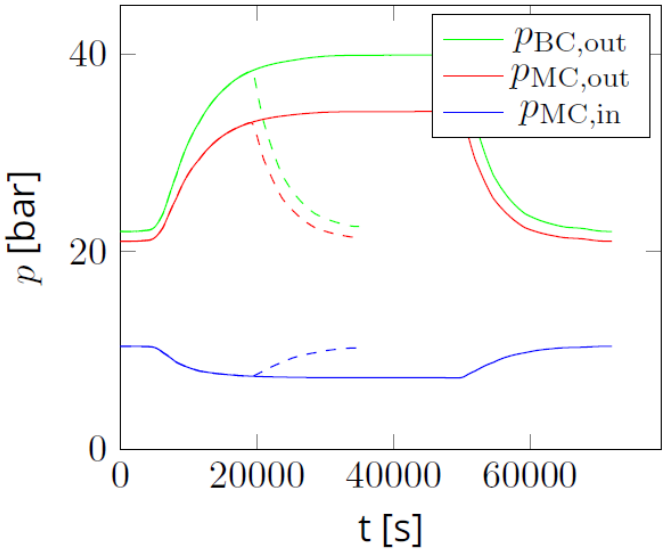
Capacity control strategy

Reduce compressor speed to 64 %

Nearly constant mass flow

Required buffer size: 6.25 m³ → 23 kg Nelium “dead mass”



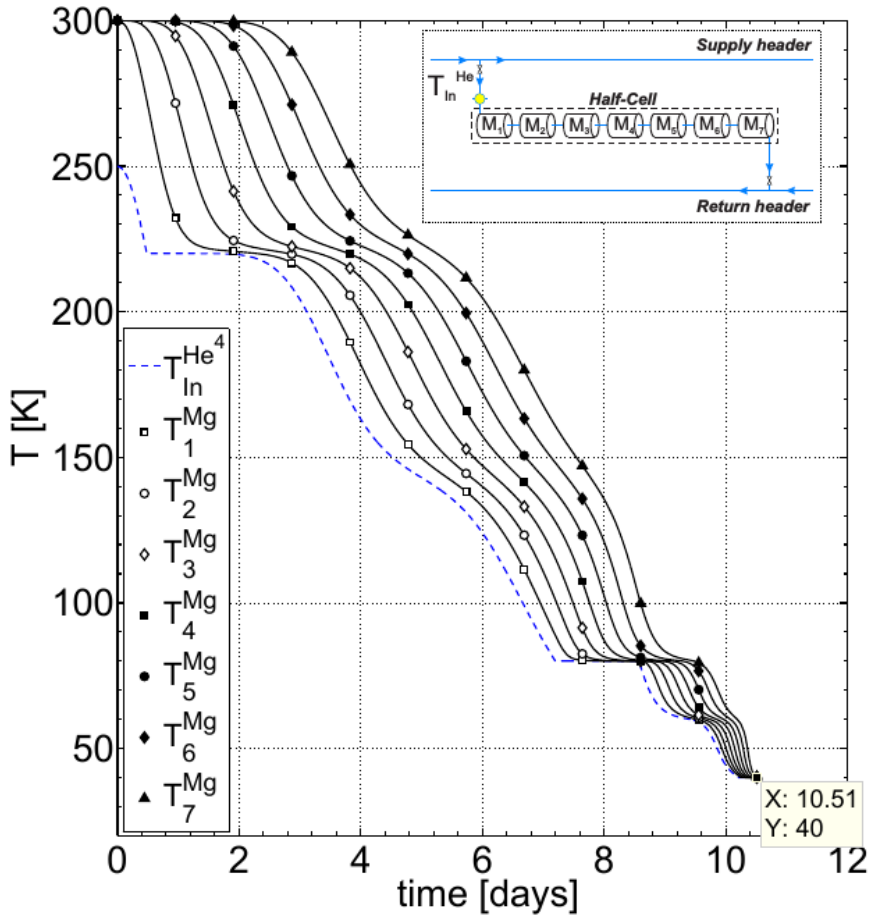


Cool-down of magnets with the Nelium cycle

Theory: cooling capacity ~T_C

Requirements:

Temperature level [K]	$\dot{Q}_{0,\mathrm{spec}}[\mathrm{kW}]$
250	2500
200	2000
150	1500
100	1000
40	570



Cool-down of magnets with the Nelium cycle

$$\dot{Q} \approx P_{\mathrm{T}}$$

Increase turbine power

$$P_T = \dot{m}\ \Delta h$$

$$\dot{m} = A_N\ w\ \rho_N \qquad \Delta h = c_{\mathrm{p}}\ T_{\mathrm{in}} \left[1 - \left(\frac{p_{\mathrm{out}}}{p_{\mathrm{in}}}\right)^{\frac{\kappa-1}{\kappa}}\right]$$

$$w = \sqrt{2\Delta h_N} = \sqrt{2\Delta h\,(1-r)}$$

Turbine	Main turbine	Pre-cooling turbine
	MTC 200	MTG 120
Nominal power [kW]	825	240
Max. power [kW]	2000	650
Nominal speed [rpm]	24 000	21000
Max. speed [rpm]	43000	60000

nozzle area; inlet temperature; total pressure ratio

$$P_{\mathrm{T}} = 5.6\ A_{\mathrm{N}}\ \mu\ p_{\mathrm{in}} \left(\frac{\bar{R}}{M} T_{\mathrm{in}}\right)^{0.5} \sqrt{F^2 - F^{2.\bar{6}}} \left[1 - \left(\frac{p_{\mathrm{out}}}{p_{\mathrm{in}}}\right)^{0.4}\right]$$

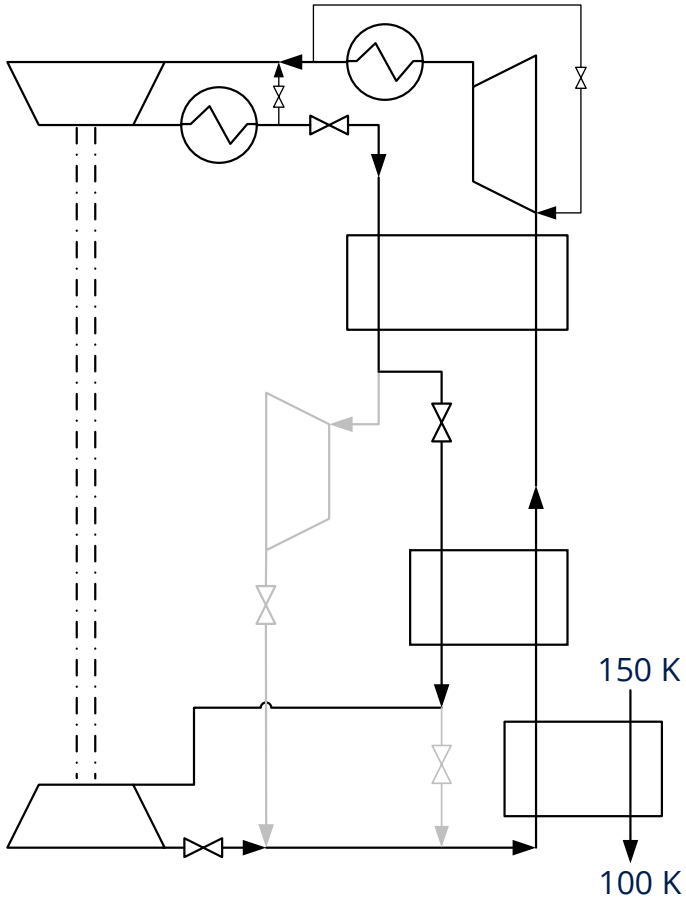
inlet pressure; nozzle pressure ratio

Cool-down operation

Cool-down at 100 K

Main turbine sufficient

	Design	Cool-down
T_{in} [K]	65.2	152
T_{out} [K]	39	98
Q [kW]	680	1000
E [kW]	3454	1433
P_{el} [kW]	8217	3830
η_{ex}	42 %	37 %

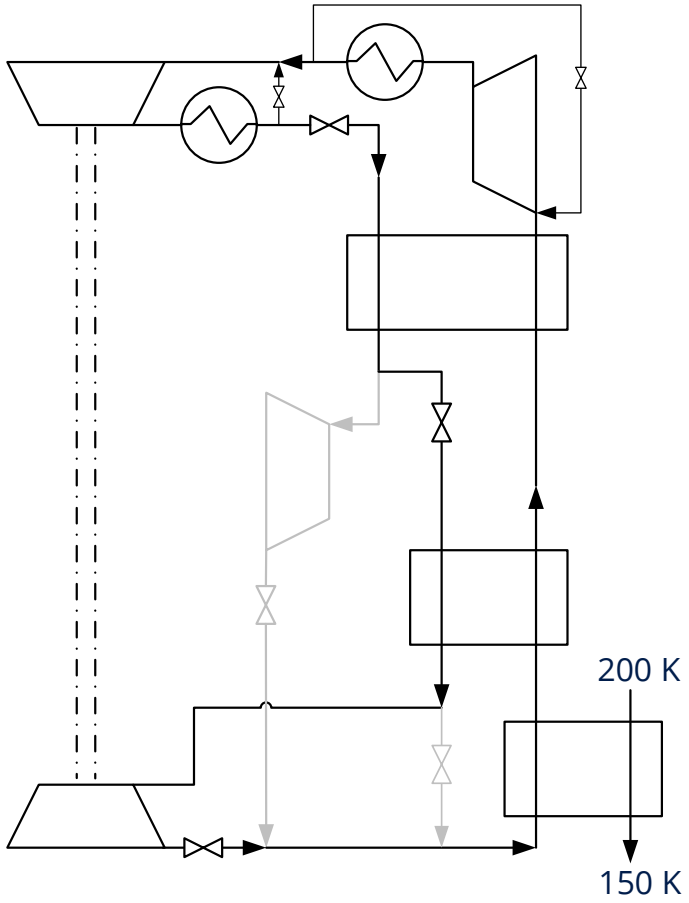


Cool-down operation

Cool-down at 150 K

Main turbine sufficient

	Design	Cool-down
T_{in} [K]	65.2	202
T_{out} [K]	39	142
Q [kW]	680	1500
E [kW]	3454	1089
P_{el} [kW]	8217	4862
η_{ex}	42 %	22 %

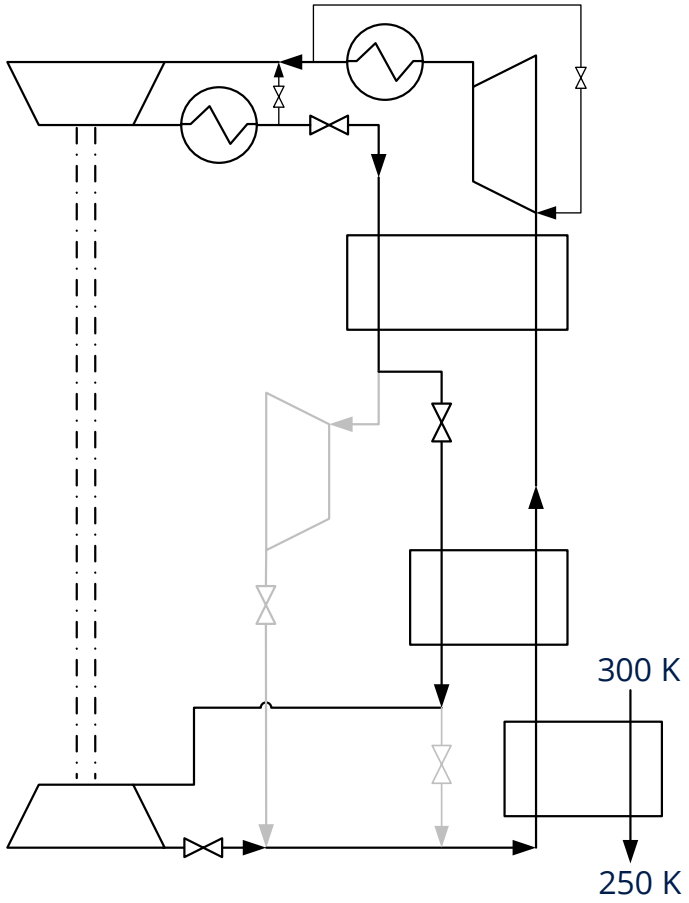


Cool-down operation

Cool-down at 200 K

Main turbine sufficient

	Design	Cool-down
T_{in} [K]	65.2	282
T_{out} [K]	39	186
Q [kW]	680	2000
E [kW]	3454	524
P_{el} [kW]	8217	2721
η_{ex}	42 %	19 %

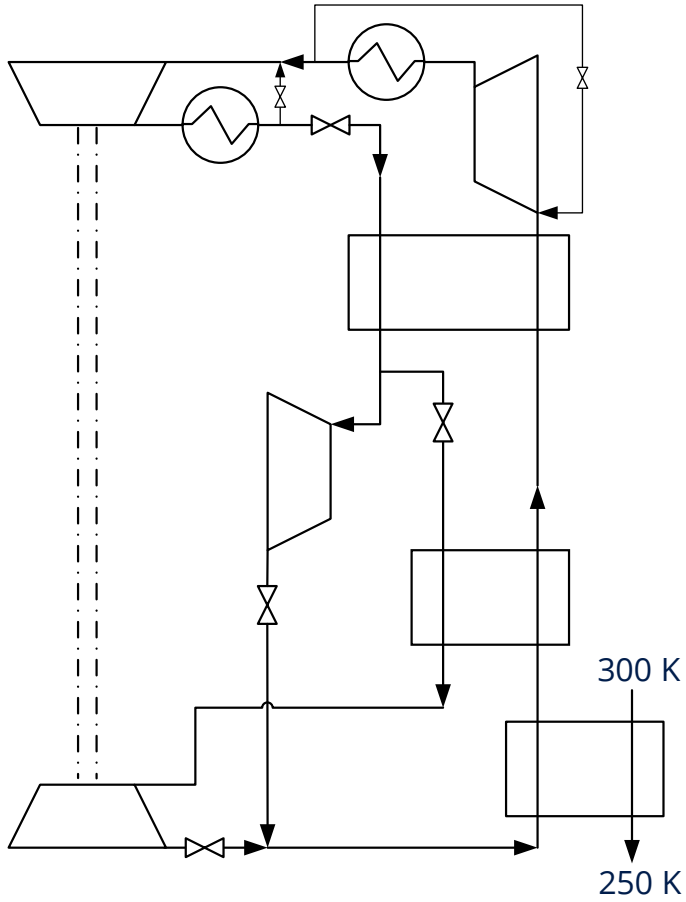


Cool-down operation

Cool-down at 250 K

Parallel operation of turbines

	Design	Cool-down
T_{in} [K]	65.2	300
T_{out} [K]	39	218
Q [kW]	680	2500
E [kW]	3454	235
P_{el} [kW]	8217	2344
η_{ex}	42 %	9.6 %



Summary

- The cost of neon is not a contraint at the current market situation
- Transient loads can be covered by adjusting main compressor speed
  - Minor buffering still required
- Cool-down with Nelium is feasible with existing turbines
  - higher capacity than requested can be supplied

TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Thank you for your attention!