Cryogenic distribution system for the ESS superconducting proton linac

J. Fydrych, P. Arnold, W. Hees, P. Tereszkowski, X.L. Wang, JG. Weisend II
European Spallation Source ESS AB, Sweden

The European Spallation Source is an accelerator-driven neutron scattering facility, currently under construction in Lund, Sweden. Its proton linac will include 43 superconducting cavity cryomodules. The total heat loads to the cavity cooling loops and their thermal shields are estimated as 3.05 kW and 10.82 kW. The cooling scheme of the cavities will base on a saturated liquid helium bath at 2 K with active thermal shielding by cold gashouse helium at 40/50 K. The required cooling powers will be provided by the accelerator cryoplant and delivered in 4.5 K and 40 K temperature levels. The 2 K temperature level will be produced at each cryomodule by isenthalpic expansion of the 4.5 K supercritical helium, previously subcooled to 2.2 K in a counterflow heat exchanger.
The cryomodules will be connected with the cryoplant by a dedicated cryogenic distribution system (CDS). The system will be composed of a cryogenic transfer line with a splitting box and a cryogenic distribution line with 43 valve boxes and an end box (Fig. 1).

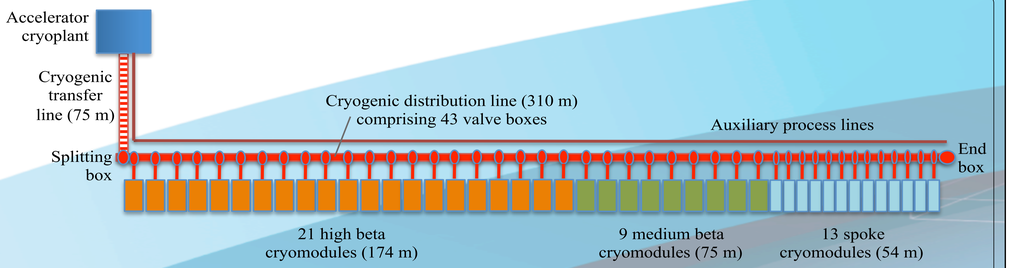

Fig. 1. Layout of the cryogenic system for the ESS linac

The valves that allow shutting off the cold circuits in the cryomodules are grouped together in special valve boxes (Fig. 2). Each valve box is equipped with cryogenic control valves CV03, CV04, CV06, CV60, CV61 and CV63, check valves VN01 and VN02, warm control valves CV05 and CV62, safety valves SV02 and SV60 as well as with pressure transmitters PT01 and PT60 and temperature sensors TT05, TT06, TT60 and TT65. The cryomodule is connected to the valve box via a branch cryoline, so-called jumper connection, which includes a vacuum barrier.
During nominal operation conditions, as well as during the cool-down and warm-up of the whole linac cryogenic system, only CV03, CV04, CV60 and CV61 will be kept open in all the valve boxes. However for bringing a single cryomodule to the ambient temperature only CV05, CV06, CV62 and CV63 must be open. Then warm helium from the HP line will flow into the cryomodule circuits and back to the ACCP via the helium recovery line.

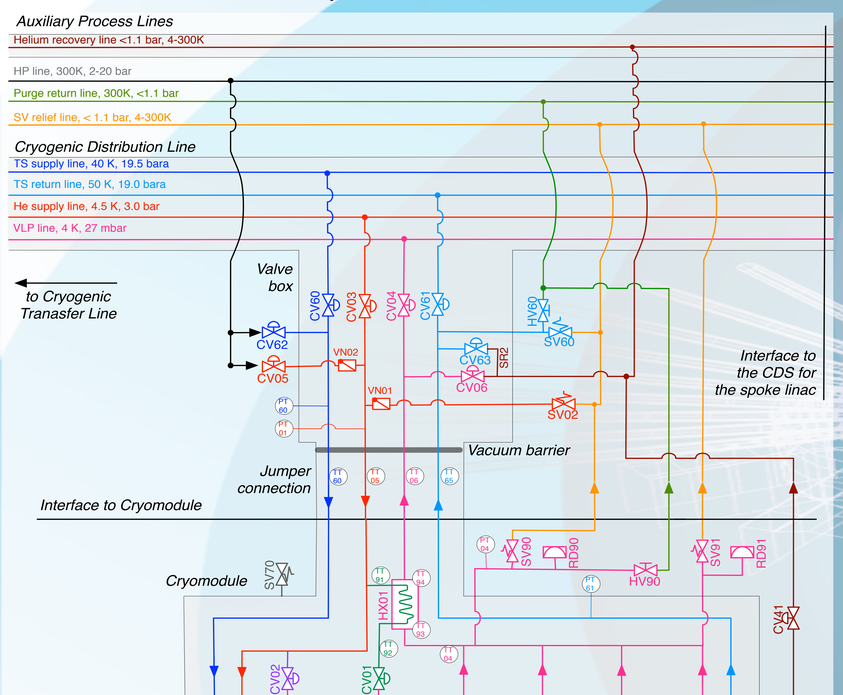

Fig. 2. Piping and instrumentation diagram for the CDL for the elliptical linac

A number of main requirements for the CDS result from the top-level requirement of 95 % availability of the ESS linac itself. It imposes that the linac equipment, and the CDS as well, must be extremely reliable throughout the expected lifetime of 40 years and must require a minimum of maintenance. Some main functional and technical requirements for the design and construction of the system are as follows:

- allow for warm-up and cool-down of a single cryomodule, while keeping the rest cryogenic temperatures,
- ensure no deterioration of thermal and mechanical properties within the operation lifetime,
- heat loads not higher than 420 W and 3.66 kW to the cold helium circuit and thermal shield,
- helium temperature in the interfaces to the cryomodules < 5.2 K at nominal operation conditions,
- vacuum insulation < 10^{-6} mbar at nominal working condition (< $5\cdot10^{-3}$ mbar at ambient with active vacuum),
- integral helium leak rate into the insulation vacuum below $5\cdot10^{-7}$ mbar·l/sec,
- tightness of the valve seats ≤ $1\cdot10^{-4}$ mbar·l/sec,
- all materials and components located in the linac tunnel resistant to the radiation dose of $5\cdot10^{5}$ Gy.

In order to check the feasibility of the CDS construction and installation in the linac tunnel in respect to the functional and technical requirements ESS has developed a detailed preliminary design of the system. Figure 3 presents the preliminary design of the CDL section with the valve box for elliptical cavity cryomodules.
The proposed design bases on modular structure. Each module is 8.26 m in length and is connected to the adjacent modules with special interconnections. The module includes a valve box with two main cryoline sections and a jumper connection. The vacuum jacket of the jumper connection is equipped with two lateral compensators, whilst the branch process lines have flexible hoses. These components are for allowing for some adjustments during joining the cryomodules to the CDS. The design and location of the external supports is strongly affected by the routing of the cryomodule waveguides that run transversely to the CDL 735 mm above the floor.
Neutron radiation in the linac tunnel has a strong impact on the CDL design, especially on material choices and on the architecture of the control and instrumentation system. Materials sensitive to this radiation are not allowed. The control valves will have pneumatic actuators and electro-pneumatic positioners with remote electronic parts situated in a radiation free area, namely in the klystron gallery, 50-100 m away from the valve boxes.

The linac CDS has been split into two subprojects, i.e. the CDS for the elliptical linac and the CDS for spoke linac. In spite of this, their schedules are composed of the same following phases:

1) agreement and project initiation;
2) preliminary design;
3) detailed design;
4) fabrication and factory testing,
5) preparation for installation,
6) transportation, installation and site testing,
7) preliminary acceptance tests.
8) final acceptance tests.

The linac CDS will almost certainly be provided as two separated in kind contributions. Negotiations with two European institutions are on-going and the partners most likely begin the design phases in the second half of 2014. The commissioning (preliminary acceptance tests) is scheduled in the end of 2018.

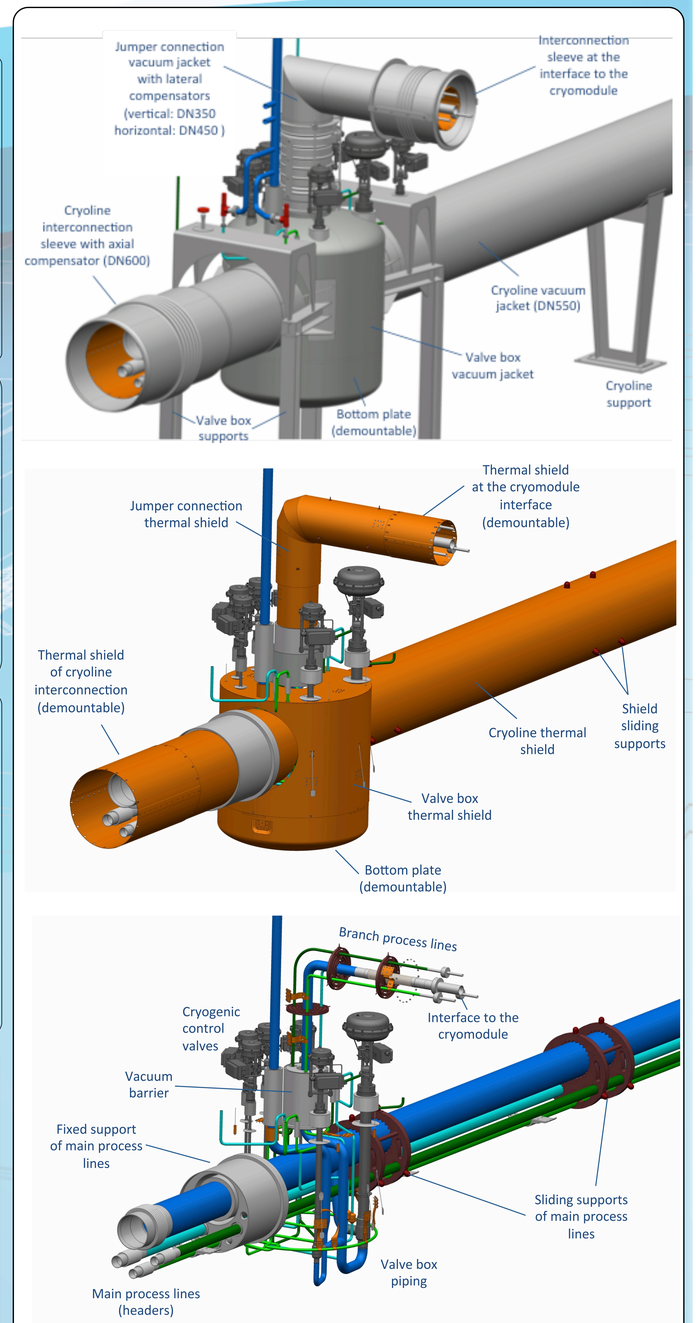

Fig. 3. Preliminary design of the CDS and valve box for the elliptical cavity cryomodule, a) vacuum jacket, b) thermal shields, c) process pipes and supporting system