USPAS Cryogenic Engineering (June 21 – July 2, 2021)

Instructors: John G. Weisend II (ESS, Sweden), Ram C. Dhuley (FNAL, USA)

Grader: Greg Tatkowski (FNAL, USA)

Class Project

A new proton linear accelerator (The Buckytron) is being built to provide high energy protons to a target that produces neutrons via the spallation process. The bulk of the accelerator consists of Niobium superconducting RF cavities operating in saturated helium baths at 1.8 K. Six cavities are contained within one cryomodule. A total of 40 cryomodules are required. In addition to the cavities, each cryomodule also contains a 40 K thermal radiation shield. Each cavity has a coaxial coupler to bring the RF energy into the cavity. Each coupler has a 20 W load at 40 K and a 1 W load at 1.8 K. Each cryomodule is 8 m in length and 0.75 m in diameter. Between each cryomodule is a 3 m long warm (300 K) section that contains magnets and beam instrumentation. When operating, the RF energy deposits 7 W into the 2 K space per cryomodule. The total deposited by the proton beam into the 1.8 K space is 10 W. The linac is contained in a 10 m diameter tunnel located 20 m below the surface.

Based on this information, design the cryogenics system for the accelerator. The cryogenic system includes: The cryomodule, the refrigeration plant or plants and the distribution system if needed to tie the refrigeration plant(s) to the cryomodules as needed. Include in this design:

1. A list of information you will need from other groups in the accelerator project
2. Definition of requirements for both the cryomodule and the cryogenics system
3. A conceptual design for the cryogenics system. This should include:
    - A conceptual design of the cryomodule including an estimated heat leak
    - A high level Piping & Instrumentation Diagram (P&ID) for the cryogenics system
    - A conceptual design for any distribution system including pipe sizes, estimated heat leaks, pressure drops and required valves
    - Number and size of cryogenic refrigeration plants. These do not have to be designed but will be procured from a commercial vendor
    - Discuss how the system will handle possible operating modes including cool down, warm up and standby (cold but no beam or RF energy present)
    - Build safety into the conceptual design; include relief valves as needed Consider impact of venting on oxygen deficiency hazards
4. Describe any prototyping or testing you feel would be required
5. Describe design alternatives considered

Assume that all subsystems associated with the superconducting RF system including the cavity design itself, power supplies, controls, and power coupler design are provided by other groups.