CRYOGENIC SYSTEM FOR THE ADS INJECTOR II IN IMP, CAS*

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Abstract

In order to meet the requirements of ADS Injector II project which is now designing and building in IMP, CAS, a liquid helium cryogenic system with 4.5K&850W cooling power is building. This paper presents the primary design and the status of this cryogenic system with deferent operation models according to the need of superconducting tests.

INTRODUCTION

In order to produce energy and transmute radioactive wastes in a possibly, cleaner and safer way, the Accelerator Driven Sub-critical (ADS) program has been officially started under the coordination of Chinese Academy of Sciences (CAS). The final aim of this program is to build a 1000 MW demo facility in 2032. The road map of this program is shown in Figure 1. There are two beam lines will be built before 2015, which respectively called ADS injector I and II with deferent design idea. The upper line is ADS injector II (RFQ + HWR) [1], will build by Institute of Modern Physics (IMP), Chinese Academy of Sciences (CAS). It has three cryomodules, two of them are on-line operation and the other one is off-line test module. Each of them includes 8 superconducting HWR cavities and 9 superconducting solenoids [2]. The superconducting solenoids are bath-cooled with saturated liquid helium near the atmospheric pressure and the superconducting cavities are bath-cooled with 2 K saturated liquid helium. For the steady operation, the pressure fluctuation of the liquid helium in the cryomodules of cavities should be less than ±0.3 mbar, while the liquid level should be kept in a small band of ±1%.

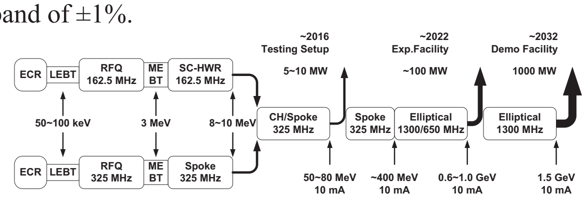

Figure 1: Road map of ADS program.

CRYOGENIC SYSTEM

The flow diagram of the cryogenic system is shown as Figure 2. It consists of a helium refrigerator, a 2000 L helium storage dewar, a purification system, three identical valve boxes, three cryomodules, four 100 m3 pure helium gas buffer tanks and several cryogenic lines. The helium refrigerator system, a standard helium refrigerator LR280 developed by LINDE, is based on 2-turbine-in-series and 1 additional JT turbine Claude cycle. It consists of a compressor module, an oil removal system, gas management panel, a cold box. An oil lubricated screw compressor (FSD 571 made by KAESER Ltd.) is used to compress 95 g/s helium gas from 105 kPa to 1.4 MPa. The oil remove system comprises a bulk oil separator, two coalescing filters mounted in series and a final activated charcoal absorber. The gas management system consists of two by-pass recycle valves (for roughly and finely adjusting, respectively) to automatically recycle excess flow from compressor discharge to suction line and two control valves to automatically adjust the helium inventory in the refrigeration system. The cold box is a vertical cylinder consisting of 5 stages of brazed aluminium plate-fin heat exchangers, two gas-bearing turbo-expanders arranged in series, one additional JT turbine, valves, one 80 K absorber and one 20 K absorber furnished to remove contaminants from the helium stream. The three valve boxes are used to distribute and control the helium flow and nitrogen flow in different operation models such as cool-down, warm-up, 4.3 K bath-cooled mode, 2 K bath-cooled mode and to protect the cryomodules against any possible damages. The cryogenic transfer lines used for delivering LHe, GHe and LN2 include a coaxial transfer line, a multi-channel transfer line and several single channel transfer lines.

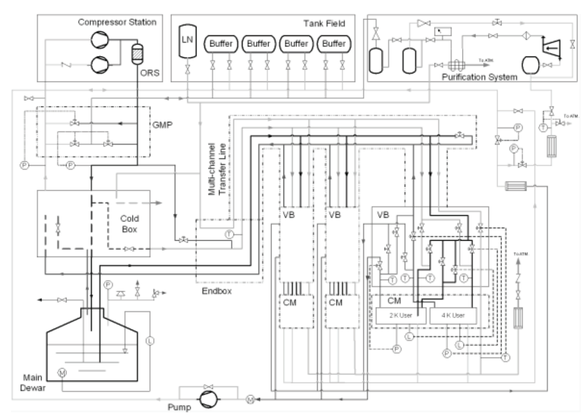

Figure 2: Flow diagram of the ADS Injector II cryogenic system.

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HELIUM GAS RECOVERY SYSTEM

In order to reduce the cost of superconducting test, a helium gas recovery system is build. This system consist of a helium gas collecting sub-system and a high pressure purifier sub-system. These sub-system include gas balloon, multi component detector, diaphragm compressor, pure high pressure tank, impure high pressure tank and LN2 tank. Figure 3 is the diagram of helium gas recovery system. The impure helium is first collected in a 50m3 gas balloon. There are two position sensors are used to protect the gasbag from over filled and to control the compressor too. As soon as the gas bag is filled with impure helium gas enough, the higher position sensor is triggered, the diaphragm compressor will run automatically to pressurize the impure helium gas go through the purifier to a 5000m3@15MPa impure helium gas tank. The multi component detector can monitor the purity of the helium gas, if the purity of helium gas reach 99.999%, the relevant valve open, pure helium gas goes into the 3000m3@15MPa pure high pressure tank, otherwise, purify cycle again.

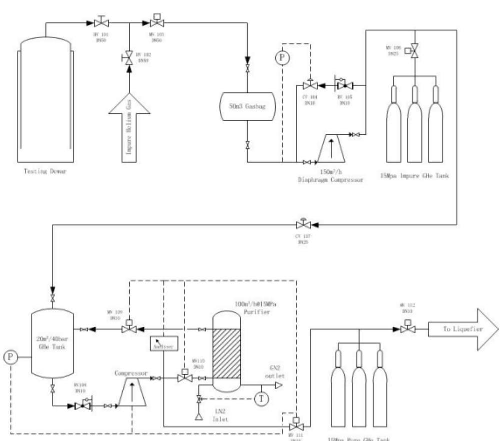

Figure 3: The diagram of helium gas recovery system.

OPERATION MODELS

According to the cooling requirements of superconducting test, this cryogenic system can supply mainly four operation models, such as 300 K ~ 80 K cool-down mode, 80 K ~ 5 K cool-down mode, warm-up mode and nominal cooling operation. For 300 K ~ 80 K cool-down mode, to control the cool-down speed, the cooling temperature is mixed from 300 K gas and 80 K gas. The mass flow rates of the cryogen are adjusted in the valve boxes. As the temperature of the return gas in this model is high, the return gas will go to the compressor suction via the by-pass valve and a heater. For 80 K ~ 5 K cool-down mode, the cool-down temperature and mass flow rate also can be controlled. The return gas will go to the cold box to recover the cooling capacity. Warm-up mode is the reverse procedure of cool-down, the suitable temperature and mass flow rate of the warm gas will be used. Under the nominal cooling operation, the superconducting solenoids are 4.3 K bath-cooled and the superconducting cavities are 2 K bath-cooled. The levels in the 4.3 K and 2 K cryomodules are adjusted by the supply valves, respectively. The pressure in the 4.3 K and 2 K cryomodules are adjusted by the return valves. Almost of the 4.3 K vapour helium will return to the cold box; other helium from current leader and coupler will return to compressor suction directly. All of the 2 K vapour helium will return to the compressor suction via an electrical heater and a pump station

ESTIMATED HEAT LOAD

The estimated heat load @ 4.5 K of the system is listed in Table 1. The total load for operating will be 335 W + 120 L/hr. allowing for margin, the equivalent load for nominal operating mode will be 850 W @ 4.5 K

Table 1: Estimated 4.5 K Heat Load

Items	**Equivalent Heat load @ 4.5 K**
Cryomodules	50 W×3 = 150 W 1.4 g/s×3 = 4.2 g/s ~ 120 L/h
Valve boxes and End box	30 W×3+10 W = 100 W
multi-channel transfer line	10 W
single channel transfer lines	45 W
2000L dewar	30 W
Total	335 W + 120 L/h ~ 700 W
With margin	**850 W**

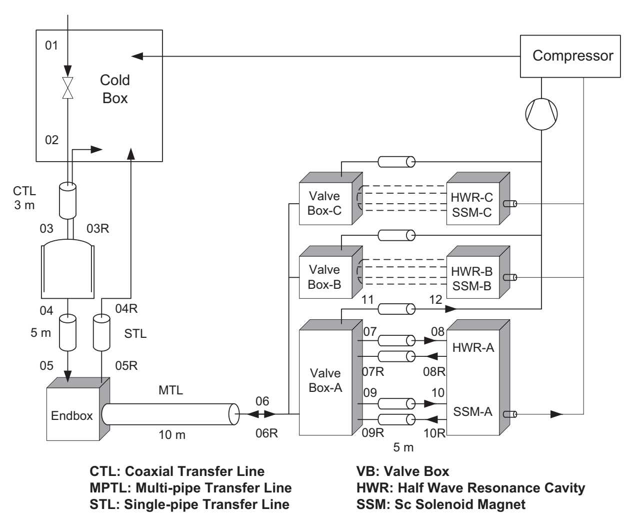

Figure 4: Simplified flow scheme of the ADS Injector II cryogenic system.

PROCESS SIMULATION

The thermodynamic analysis of the system was carried out based on the simplified flow scheme (see Figure 4) and the estimated heat loads. The simulation boundary conditions are based on the Ts-Diagram for specific mixed mode of refrigerator. The pressure, temperature, mass flow rate and cryogen quality have been calculated. The results of the static processing simulation for

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superconducting solenoids and superconducting cavities are presented by T-s diagrams in Figure 5 and Figure 6.

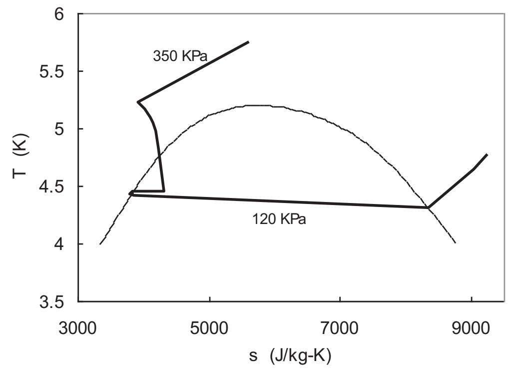

Figure 5: T-s diagram for the cooling of superconducting solenoids.

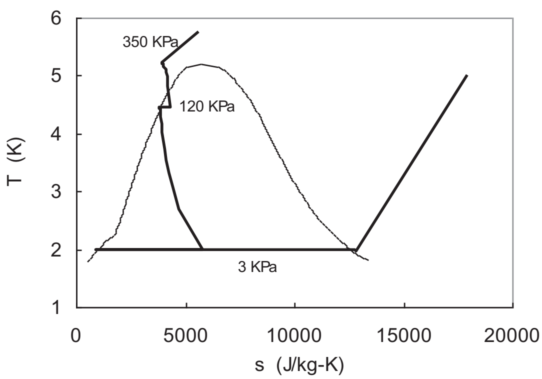

Figure 6: T-s diagram for the cooling of superconducting cavities.

SUMMARY

Basically, the cryogenic system for cooling ADS injector II System was designed by considering a various requirements of operation modes. The static and dynamic heat load of the cryomodules was estimated. The thermodynamic analysis of the cryogenic system was carried out based on the simplified flow scheme. The procurement of the components of the cryogenic system, such as refrigerator, dewar, buffer tanks have been ordered and are under fabrication in factories. The helium gas recovery and purification system are also built. All the cryogenic system will be completed in 2013.

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