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2 K SUPERFLUID HELIUM CRYOGENIC VERTICAL TEST STAND OF PAPS

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Abstract

Platform of Advanced Photon Source Technology R&D (PAPS) in the Institute of High Energy Physics (IHEP) is an ongoing project, which aimed to provide a comprehensive research and testing platform for the particle accelerator, X-ray detection and optics. As one of the important parts of the platform, cryogenic vertical test stand for the superconducting cavities is composed of three big vertical test cryostats with 2 different inner diameters, which can provide 4.5K liquid helium, 2K superfluid helium and the lowest 1.5K environments according to the cavities test requirements. The cryogenic vertical test stands also focus on current international "hot spot" fast cool down to the superconducting cavities, maximum liquid helium mass flow rate can be reached to 80 g/s. Because of the big size of the cryostats and certain scale, the finished cryogenic vertical test stand can meet several different type cavities test, such as 1.3 GHz 9cell, Spoke, elliptical, etc. And also can provide the cavities' mass vertical testing for the large scale superconducting accelerators.

INTRODUCTION

The Platform of Advanced Photon Source Technology R&D is scheduled to be put into operation in 2019 at Institute of High Energy Physics. This facility will sup-port the performance test of various type of superconducting cavity and require additional refrigerating capacity at 2K and 4.5K. The helium cryogenic system will be constructed on a capacity at 2.5kW@4.5K or 300W@2K.This system will be used for vertical test stand, horizontal test stand and a beam test stand. Flow chart of the helium cryogenic system of the PAPS is shown in Fig. 1.

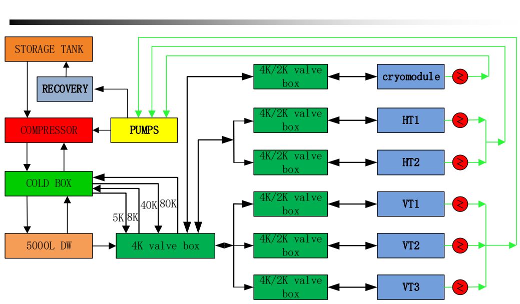

Figure 1: Flow chart of the helium cryogenic system of the PAPS.

The vertical test system have been designed for different type superconducting cavities, which is used for the operation of superconducting linear accelerator [1-3].The cryogenic vertical test stand for the superconducting cavities is composed of three big vertical test cryostats with 2 different inner diameters, which can meet several different type cavities test. Every cryostat integrates most important components such as vacuum vessel, 80K liquid nitrogen shield, liquid helium Dewar, 2K heat exchanger, J-T valve and cryogenic distribution to on equipment

METHOD OF OBTAINING 2K SUPERFLUID HELIUM

As we know there are several methods of obtaining 2K superfluid helium such as vacuum pumping, vacuum pumping accompanied with throttling process and throttling process accompanied with precooling. For higher liquid ratios of superfluid helium, we adopt throttling process accompanied with pre-cooling. The flow chart is shown in Fig. 2.

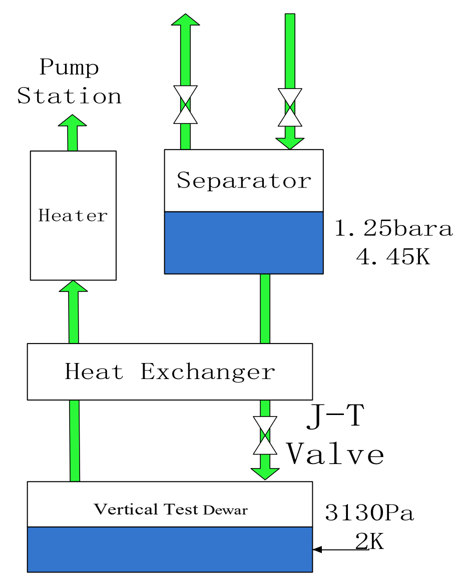

Figure 2: Flow chart of method of obtaining 2K superfluid helium.

2K J-T heat exchanger is the essential equipment for 2K cryogenic system, Vertical Test Stand-1 (VTS-1) [4] at Fermilab is used to test cavities in a 2 K liquid helium bath. The test stand includes a J-T heat exchanger consisting of a single layer of coiled finned tubing. Other test stands such as Fermilab's Vertical Magnet Test Facility (VMTF) [5] and DESY's Tesla Test Facility (TTF) Vertical Cryostat [6] have also used similar single-layer J-T heat exchangers for

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testing superconducting magnets and SCRF cavities, respectively.

Compared with direct throttling, the system adds a 2K J-T heat exchanger before throttling [7]. It make the temperature before J-T valve lower than 4.45K. Consequently, the vertical test Dewar can obtain higher liquid ratios of superfluid helium. The relation between liquid ratios and temperature before J-T valve is shown in Table 1.

Table 1: Liquid Ratios and Temperature

Temperature	4.45K	3K	2.5K	2.3K
Liquid Ratios	58.5%	82.4%	87.2%	89.2%

VERTICAL TEST DEWAR AND LAYOUT

As mentioned above, the helium cryogenic system of the PAPS will be constructed 1 cryomodule, 2 horizontal test station and 3 vertical test station for superconducting cavity (SC). Vertical test stand of construction the system will provide test of any kind SC from already existing accelerator, namely VD1, VD2 and VD3. Every cryostat integrates a cylindrical helium Dewar, vacuum vessel, a phase separator, a J-T heat exchanger, cryogenic valves, 80K liquid nitrogen shield, 2K heat exchanger, J-T valve, cryogenic distribution, flowmeter, temperature and pressure sensors on equipment

The equipment of VD1 is same with VD2 and all can operate capacity of 100W@2K. VD3 is smaller than VD1 and has a cylindrical liquid helium Dewar with inner diameter on 850mm and vertical height at 5500mm. VD1 and VD2 can meet the test of two 650 MHz 5-cell SRF cavities at the same time, the inner diameter is1250 mm and the effective liquid level height is 2500 mm. The vertical test stand can also be used to test other types of Superconducting cavities. Superconducting cavity will be hanged in vertical test Dewar and immersed into superfluid helium. Two magnet shields of the vertical test Dewar are included to reduce magnet field to 10mGs. Three-dimensional structure of vertical test cryostat is shown in Fig. 3, static heat leakage of cryostat is about 2W@2K.

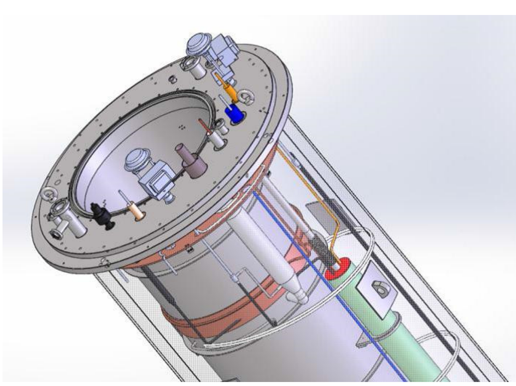

Figure 3: Three-dimensional structure of vertical test cryostat.

The cryogenic distribution valve box is the key components of the vertical test station. The cryogenic valves are installed to valve box which distributes liquid nitrogen and liquid helium to vertical Dewar. Three-dimensional structure of cryogenic distribution valve box is shown in Fig. 4.

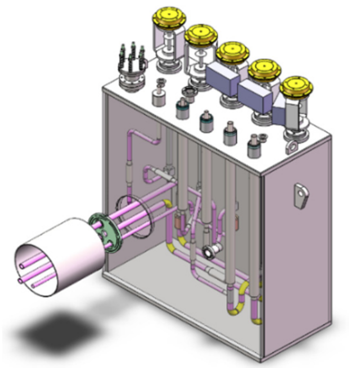

Figure 4: Three-dimensional structure of cryogenic distribution valve box.

According to the trend of SRF cavity research and development in recent years, 2K Superfluid Helium cryogenic vertical test stand of PAPS in the institute of High Energy Physics (IHEP) can provide the cavities' mass vertical testing for the large scale superconducting accelerators. The layout of three vertical test Dewar is shown in Fig. 5.

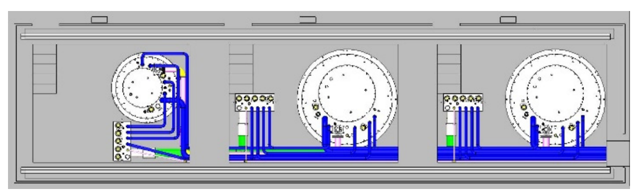

Figure 5: Layout of three vertical test Dewar of cryogenic system.

ELECTRICAL HEATER OF RETURN GAS

The temperature of helium vapour from 2K J-T exchanger is about 4K. Cold gas return will damage the vacuum pumps or compressor. So we need heating the cold gas to room temperature about 300K by the electrical heater. The calculation of electrical heater power is shown in Table 2.

Table 2: Calculation Electrical Heater Power

Items	Value	Units
P average	2975	Pa
T inlet	3.3	K
H inlet	32200.2	J/kg
T outlet	273	K
H outlet	1432989	J/kg
Mass flow rate	10	g/s
power	14007.88	W

Three-dimensional structure of electrical heater is shown in Fig. 6

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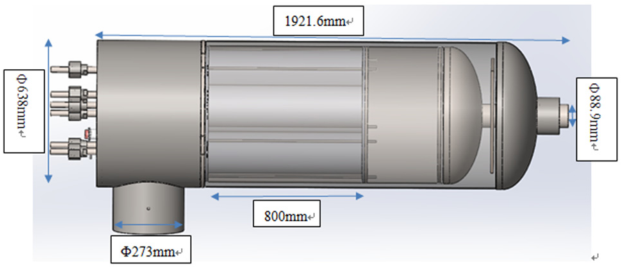

Figure 6: Three-dimensional structure electrical heater.

2K VACUUM PUMPS SYSTEM

When tested superconducting cavities need at 2K superfluid helium temperature, vacuum pump system will be work to change 4.5K mode to 2K mode. 2K vacuum pumps expensing of helium will be put into operation to provide the required maximum capacity of 19200 m^3/h. Main parameters of the vacuum pump system are shown in Table 3. The helium tank pressure is about 31mbar, pressure stability is ±10 Pa.The maximum mass flow rate can reach to 26.7 g/s. And the vacuum pumps station outlet is also connected with the helium compressor inlet, so out pressure is about at 1.2bara@300K. Therefore, in the cool-down 2K mode the outlet helium of J-T heat exchanger in cryostat will be heated from 4K to 300K by an electrical heater.

Table 3: Main Parameters of Vacuum Pump System

Helium tank pressure	3129 Pa
2K cooling capacity	120 W
Pressure stability	±10 Pa
Max mass flow	26.7 g/s
Total pumps system capacity	19200 m^3/（300K,30mbar）
Pumps station inlet temperature	300K
Pumps station outlet pressure	1.2 Bara
Noise level	<80 dB@1m
Leakage rate	1E-6 Pa·m^3/s
Vibration size	<5mm/s

Separate control systems will be set up for each group of vacuum pumps. The control system is divided into manual and automatic modes, including two parts: local and remote. When the pressure of station reach to 31 mbar, the pressure fluctuation will be controlled in ±10 Pa. Faction diagram of 2K vacuum pumps system is shown in Fig. 7.

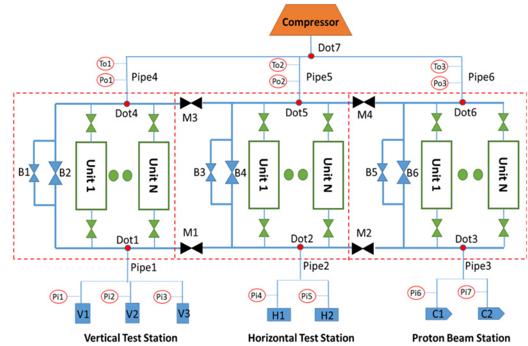

Figure 7: Faction diagram of 2K vacuum pumps system.

Three-dimensional diagram of 2K vacuum pumps system is shown in Fig. 8.

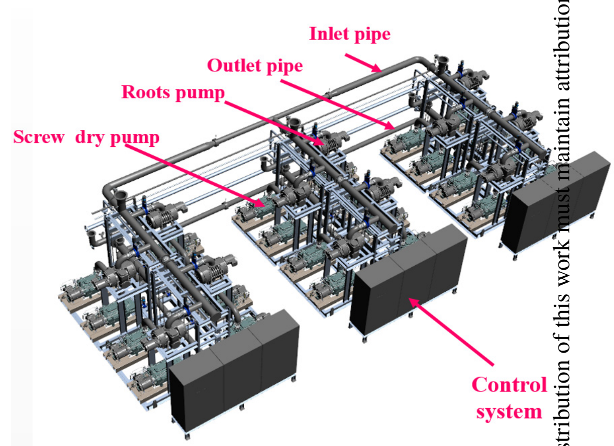

Figure 8: Three-dimensional diagram of 2K vacuum pumps system.

CONCLUSION

The SRF cavity is the key equipment of the superconducting accelerator facilities, which need vertical test under the condition of 4K liquid helium and 2K superfluid helium before installed in the cryostat. Platform of Advanced Photon Source Technology R&D (PAPS) in the institute of High Energy Physics (IHEP) will be built to support the test of SRF cavity. The scheduled commissioning of the helium cryogenic system of the PAPS will be carried out during 2020.The vertical test stand of PAPS superfluid helium cryogenic system contains three vertical test cryostats, which can meet the requirements of the test of several different type cavities test. This paper describes some essential equipment of 2K superfluid helium cryogenic vertical test stand of PAPS such as vertical test Dewar, electrical heater of return gas, 2K vacuum pumps system, etc.

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