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The Hydrogen Circulation Cold Box of CSNS Cryogenic System

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Introduction

CSNS cryogenic system offers 15 bara hydrogen as a neutron moderator at 18 ~ 22 k, and the para hydrogen concentration is 99%. Two cold boxes are adopted - hydrogen circulation cold box and accumulator cold box. The main equipments in hydrogen cold box are hydrogen circulators, H_2-He heat exchanger, ortho-para convertor, heater. Accumulator is in the accumulator cold box.

Cryogenic system provide hydrogen moderator with the aid of the equipments inside the cold boxes. Cold boxes have heat preservation effect on internal equipments and pipes, support the weight of the equipments and pipes. Reasonable structure is need to ensure the normal operation of cryogenic system. This article will discuss the engineering design of CSNS hydrogen circulation cold box and the corresponding structure analysis.

Structure design

Hydrogen temperature change impact the system volume, the pressure will fluctuation. The accumulator can supply the volume compensation within a certain range of the temperature fluctuations, keep the system pressure unchanged. The main components of the accumulator are weld bellows with limited shrinkage life, and can bear 2bar at most. When failure need to replace it, this can affect the running. Therefore, we set up two cold boxes - hydrogen circulation cold box and accumulator cold box. The two cold boxes are joint with two single transfer lines. When the accumulator is failure we can shut off inlet/outlet valves and open the bypass valve. The hydrogen circulation cold box can still working alone to maintain the normal operation of the cryogenic system. Abstract design is on the base of the hydrogen circulation process (see fig 1).

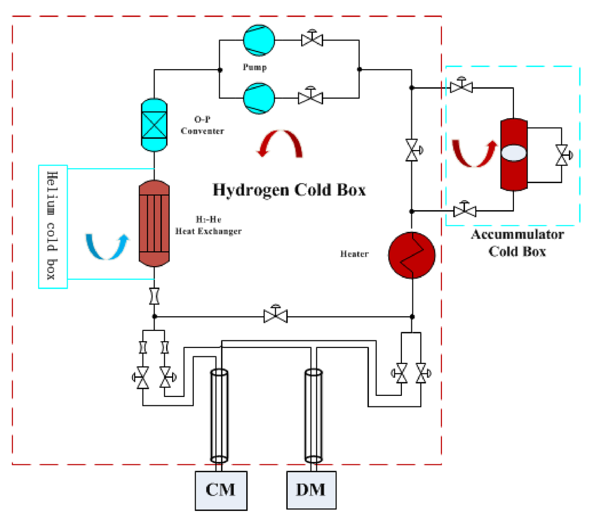
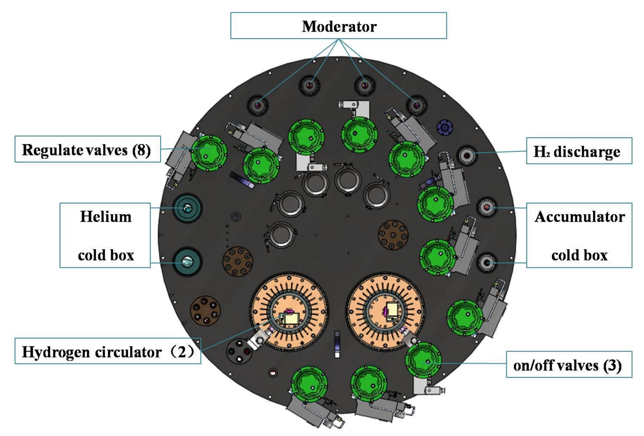


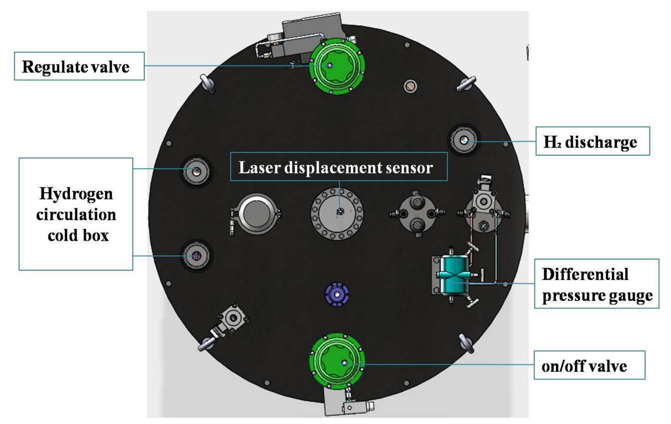
Fig1. Hydrogen circulation process

Design of the top flange is the key of the cold box, it can impact on the overall dimensions and structure. The hydrogen circulation cold box connect helium cold box and cryogenic transfer line respectively. Helium port locate at the left of the flange close to the helium cold box. Hydrogen discharge port locate at the right of the flange. Hydrogen ports for cryogenic transfer line located at the front of the flange. For the convenience of adjustment and read data, cryogenic valves are placed on the outer ring of the flange. As far as possible to shorten the length of the pipes, the valves should close to the upstream and downstream equipments. As far as possible to shorten the length of the pipes, the valves should close to the upstream and downstream equipments. In order to reduce the heat leakage , we design a support ring to weld . H_2-He heat exchanger, ortho-para convertor and heater are fixed with booms on the bottom of the flange.

The only equipment inside accumulator cold box is the accumulator. It fixed at the bottom of the flange with loose flange, which can guarantee the verticality and stability. On the top of the vacuum sleeve, we set a laser displacement sensor to measure the displacement of the bellows. Under natural state, the distance from laser launch to mirror is 200 mm. The location of hydrogen port is corresponding with hydrogen circulation cold box, on the left of the flange. The two pair ports are parallel connection with pipes. Cryogenic valves, safety valves, pressure sensor, blasting piece are placed at the top of the flange. The top flange layout is shown in fig2.



a) Hydrogen circulation cold box



b) Accumulator cold box

Fig2. Layout on top flange of the two cold boxes

Pipe design is according to the location of each device. The temperature of supercritical hydrogen is 20K. The material should ensure the safety and can sustain low temperature impact, so 316L stainless steel is chosen. When satisfy the stress and strain requirement, the pipe shape should as simple as possible; shorten the length can reduce the pressure drop and heat loss. Pipe should be flexible enough, when designing use the natural compensation to absorb the swell- shrink and displacement of the pipe. In order to reduce the heat leakage, we wind thermal insulation material outside the pipes. The multilayer insulation adopts mylar alternating with non-woven fabric combinations。

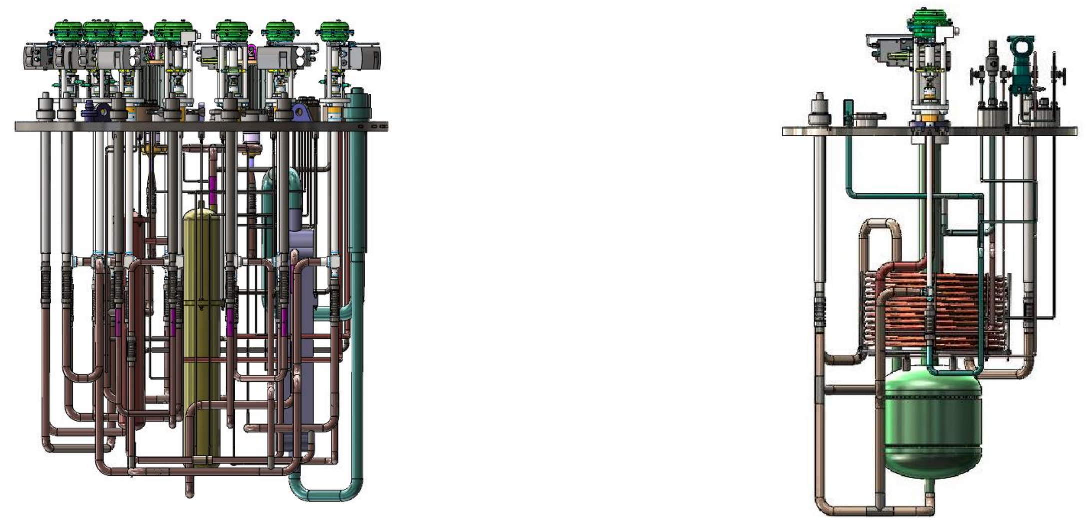


Fig3. Pipe design of the two cold boxes

The structure form of vacuum vessel is a vertical cylinder, the cylinder is supported by three anchors. The thickness of vacuum cylinder is 10mm, and the bottom flange is 40mm.The height of the cylinder is 1700mm.

Fig4. Design of the vacuum cylinder

Structure analysis

Strength analysis of the cold box including three parts-the top flange, piping system and vacuum cylinder. The maximum stress and maximum strain all satisfy our design requirement.

The heat leakage of cold box mainly includes two parts: heat radiation leakage of high vacuum multilayer insulation; the axial heat conduction of bayonet, valves and pipes fixed on the top flange. Two cold boxes are winded with multilayer insulation to reduce heat leakage, the vacuum need to reach more than 1.33×10^{-2} Pa. The general heat leakage of hydrogen cold box Q=43.95 W. The accumulator cold box Q=12.12 W. The leakage of two cold boxes meet the design requirement: both less than 100 W.

Processing

The process of cold boxes are according to the completed structure design. Pipe prefabrication according to following process: cutting, spot welding, straightening, welding, leak detection, liquid nitrogen soaking, cleaning, ultrasonic cleaning, drying and then another leak detection. We use argon arc welding, and argon as protective gas fill in the pipes. We examine the leak detection with helium mass spectrometer leak detector after complete the whole welding. The leakage standard is less than 5.0×10^{-10} Pa•m³/s. Now the assembly body of two cold boxes see as fig5.

a) Hydrogen circulation cold box b) Accumulator cold box

Fig5. The assembled two cold boxes

Conclusion

Accumulator is the vulnerable equipment of the cryogenic system. Hydrogen recycling equipments are arranged in two cold boxes, this can repair and replacement the accumulator easily. The advantages of double cold boxes also reflect on enough space for layout of equipments and pipes connection.