Cryogen Free Cryostat

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ABSTRACT: The advanced neutron facilities at low temperature below 1k are mainly based on helium refrigerator inserts and dilution that are used with orange cryostat (OC) or similar type of system. Recently global helium supplied problem causes the increased cost of liquid helium that has been raised the concerns about the affordability of cryostat. In this model the design and results are mainly based on the top loading cryostat which are cryogen free. The dilution refrigerator insert which are used in this model will provide sample environment for neutron scattering experiment that is seen between the temperature ranges from 36 mK to 293 mK. The refrigerator insert are operated in the continuous regimen. The cooling time and orange cryostat which are insert are always similar to each other. The performance criteria that are created are based on the base temperature, rate of compatible and the cooling power which are present in the specification of the standard dilution refrigerator. This system will offers many types of operating parameters that are similar to orange cryostat but does not cause any complications of cryogens. In this model the first scientific result are obtained which are in the low temperature based neuron scattering experiment with the system are also discussed.

1. INTRODUCTION

The neutron scattering experiment at low temperature below 1k will provides the helium and dilution where the refrigerator that are inserts in the orange cryostat which is top loading. Sample environment has been increased in its demand from the last decade and has exceeded eighty low temperature of experiment per year. The cryogenic equipment always needs the significant resources that can develop many types of problems which includes health, safety issues and also the considerable cost in required cryogen. Cryo cooler technology offers the new system where the cryogen consumption or completely eliminated or reduced. This system also have an advantage of less space convention, simplicity and also improved safety for the users. The successful representative that are found in the family cooler of cryo which is seen in the pulse type of tube refrigerator.

The incomparable character is absence of cold based moving parts which mainly used for reducing the vibrations and noises that are generated by cooler. The cold head and its reliability are also increase because there is no high precision of seals are demanded and it can be operated without the inspection over the services. The first scientific results and operational experience are obtained by experiment which is named as neuron beam that are at low based temperature which are provided by dilution refrigerator that accommodate 25 mm in diameter in cryogen free top loading cryostat. This will gives
the sample type environment at the temperature that ranges from 2K to 293 K at high cooling power 0.19 W @ 2.0K. In cryostat the dilution refrigerator insert are loaded which allows the neutron distraction measurements at the level of temperature of 40mK. This system are improved and developed by Oxford collaborative project and by the ISIS.

2. Design of the system.

The model of this design is depends upon the idea of the top loading cryogen system along with the helium condensation loop which are successfully analysed in the first prototype. The design of the second prototype shows the major changes which are used in the experiment that are presented in this model has been the replacement of top loading cryostat and the inclusion of pulse tube refrigerator that provides higher efficiency at a very high-level flow rates that are mainly favoured by the beam line of operation. The neutron scattering experiment uses modern dilution based refrigerator that are based on the designs that includes sintered silver heat exchanger, little quantity of scattering experiment also needs low temperature along with the combination of high cooling power which uses the influential cryogen of free dilution that builds around PTR type of cryo cooler. For this condition dilution insert are used with the cryostat VTI. This system will required cooling power which produces VTI heat type of exchanger. Cool down procedure mainly consists of three important phases. In phase one insert of pre cooling with helium heat exchanger in the refrigerator vacuum jacket with the room temperature down to the 2.0K. After the VTI has been warmed for up to 4K it will exchange pumped gas for approximately in one hour. If the vacuum jacket achieved the good vacuum then the VTI is swapped off and the dilution refrigerator will begin the condensation of helium which are circulated around the automated regime.

![Figure 1](image.png)

**Figure 1.** Cooling of cryostat down to base temperature: (a) Time dependence of VTI exchanger temperature; (b) Time dependence with the mixing chamber temperature
3. Operation of the system
Base temperature of the refrigerator cooling system is shown at the figure 1. It will represent the temperature behaviour at the VTI type of exchanger and the dependence of the mixing chamber temperature related to time. Fully automated technique is used for operating the refrigerator. The total cool down of dilution insert will start after inserting in the VTI which is typical to the conventional cryogen based top loading cryostat.
In primary over night the temperature will make the system to run which stable the performance. In figure 2 it represents the heat exchanger time requirement and mixing chamber. The solidity are enlightened by the absence of time where the changes of liquid level in nitrogen and helium vessels which are existing in the cryostat conventional operation. In the central part stage, drop in the temperature are caused by the switching of nitrogen beam off. Then crossing some time, the beam of nitrogen will appear back and the mixing chamber temperature then will return to its previous values. So the estimation of the power of heating neutron beam are at the close of few microwatts.

![Figure 2. Mixing chamber temperature at the time dependence. (a) VTI exchanger temperature at the time dependence; (b) Time requirement of mixing chamber temperature.](image)

Point A – beam of neutron in switch off condition. Point B - attain neutron beam to previous condition (Current 42 μA accelerator neutron beam).

4. Experimental Outcomes
The experiment of neutron scattering at small level temperature environment sample by the cryostat are created. In figure 3 the diffraction pattern is obtained and derived from the powder sample of Sr2Ir0.5Rh0.5O4. The limited type of insulators are supposed to present at the magnetic order of 0.7k. There will be increase concentration in 5d oxide because of the stages of matter that show which are parallel to the energy scale of U. The magnetic interaction and the spin order coupling competition are seen. Lab results will offers the quality neutron powder diffraction that have the capability to show the magnetic ordering. The order phase at the level of 0.7k. Hence the dilution refrigerator is mandatory to calm the sample at the low level of temperature. The polycrystalline is the high quality sample which is sealed within the tinny based wall vanadium where the (He) gas is added at the warmth exchanger media. This type of method shows the effective way for the compulsary temperature symmetry which
crosses the vanadium and sample. The statistics in this research will establish the good coverage and angular quality. The temperature at high point are very stable at temperature base which remains in 0.2 mK during the whole measurements.

The internal progress database are mostly proposed progressively substituting all the predictable cryogenic system at the use of free system that are mainly depend on the pulse tube refrigerator (PTR). Here the examination and the model displays the scientific result and experience operation that obtained by beam line experiment at low temperatures in the sample environment. The refrigerator quartered in recently established in top loading based cryogen free cryostat.

![Figure 3](image)

**Figure 3.** Powder diffraction taken from Sr2Ir0.5Rh0.5O4 sample. Dilution refrigerator insert -34 mK Measurements were taken at the base temperature.

The model also demonstrate the long-time steadiness with the base temperature of 37mK. Upper resolution data are found in the experiment. The operating parameters are mostly similar to standard orange cryostat but without any complications. Cryostat is the device which allows the maintenance of the cryogenic environment as long as required. There are different type of cryostat are available but everyone cryostat has the different advantage and disadvantage when comparing to other. In nineteen century the orange cryostat are mostly used in the workhorse of the scattering of neutron services. This is based on top loading of helium bath cryostat along through the nitrogen that are cooked infrared radiation shield at the temperature of 1.5k. The infrared Shield are designed for highly conductive copper which helps to cover the high emissivity of the aluminium foil.

5. Conclusion

In neutron scattering instruments cryogen free technology are compactness and reliability will occupy the new niche of the cooler components. The mostly used application of CCR are depends on the cryogenic beryllium filters. A blocks of beryllium will only transmits the low energy of neutrons but produces scatters neutrons at the high energy level. The transmission of the neutrons that are filtered is found on the wavelength outside the cut off mostly on the scattering of the phonon. These are removed by the filter below the 100k and this type of removing energy will help to gain the scattering from the thermal which are excited phonons.
The advantage of the cryogen free system includes operation simplicity, reduced or complete elimination of the liquid cryogen top ups, safer mechanism, significant reduction in the resources, high level of thermodynamics efficiency, reduces in system sizes and operational mechanism, this system are much more environment friendly and conventional among other types of cryogenics. Some disadvantage are it will limit the cooling power of CCR. It also increase the demand for cooling water supplies and electricity. It may generate noise, vibrations and disturbance in the magnetic field. This creates difficulty radically improved by the non-appearance of cooling parts which are found in the PTR.

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