Cryostats for Space, Superconductivity and More

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Demand for large capacity cryostats in India originates principally from the space program, research activities in high temperature superconductivity and metallurgical applications for surface treatment. The space program uses cryostats at both liquid nitrogen as well as liquid hydrogen temperatures, whereas high temperature superconductivity research and metallurgical applications utilize cryostats operating at liquid nitrogen temperatures.

The demand for large capacity cryostats encouraged Shell-N-Tube Pvt. Ltd. (CSA CSM) to custom design cryostats to suit these applications. The cryostats developed so far include three 3,000 liter capacity liquid nitrogen cryostats for high temperature superconducting fault current limiters, a 3,000 liter capacity liquid hydrogen cryostat for development of flight model discreet level sensor arrays, a 3000 liter liquid nitrogen cryostat for testing ultra high pressure helium gas storage bottles used for cryogenic stages of satellite launch vehicles and a 35,000 liter rectangular liquid nitrogen cryostat for metal treatment.

The 3,000 liter liquid hydrogen cryostat was designed to meet the specific need of calibrating discreet level sensor arrays suitable for liquid hydrogen service. A discreet level sensor array consists of multiple capacitance sensors, the capacitance of which changes abruptly due to the change of fluid phase when the liquid level crosses that sensor. It is used to monitor rapid change in cryo fluid level in the propellant tank of the cryogenic stage of rockets or in the run tank of a cryogenic test facility. This cryostat was supplied to Indian Space for the GSLV-MK III program.

Special care was taken during manufacture to prevent deformation of the vessel's large body flange. The flange allowed for removal of the vacuum jacketed top lid so that the discreet level sensor arrays could be introduced and taken out vertically during the calibration process. Eliminating the leakage of hydrogen gas through the body flange was a challenging problem. Metallic seals were tried but were found unsatisfactory. Viton o-rings, in multiple grooves, were then incorporated into the design, resulting in successful operation.

Trial for 3 Phase Superconducting Fault Current Limiter. *Image: Shell -N-Tube*

Three 3,000 liter capacity liquid nitrogen cryostats were designed and manufactured to accommodate three high temperature superconducting fault current limiting coils. Since these superconducting fault current limiters are expected to run in an unattended remote location, an automated PLC based liquid fill and level control system was integrated into the fault current limiter.

When required, the unit's differential pressure level sensors generate a feedback signal for the liquid nitrogen level in individual cryostats, causing the PLC to command LN_2 fill from a bulk liquid nitrogen tank through a set of solenoid operated valves. The main manufacturing challenge in this system was keeping system cleanliness to a high level as the fault current limiters were tested discreetly at 40kV and 130A in Shell-N-Tube's facility before delivery to the customer. The system is expected to be operational this year at a remote rural location.

A 3,000 liter liquid nitrogen cryostat for Indian Space was designed to cater to a specific need of testing the onboard helium gas storage bottle to a pressure of 400 bar at 78 K. The unit had a special design requirement, a reinforced multilayer insulated top lid to support the weight of the suspended helium gas storage bottle during testing. Body flanges were also provided to help quickly remove and introduce multiple test samples.

A very large capacity cryostat was also designed and manufactured for a steel rolling mill to simultaneously cool four 2,000 kilo steel rolls. It is a rectangular 35,000 liter cryostat with internal dimension of 7m x 2m x 2.5m. The cryostat has built-in internal liquid nitrogen spray headers that quickly and uniformly cool the steel rolls to about 60°C to improve the surface properties of the steel roll. Since this was formed as part of a continuous production process, a microcontroller-based LN_2 flow control and a temperature monitoring system were integrated into the cryostat.

Additional safety interlocks in the form of oxygen concentration in ambient air were included because of the large volume of nitrogen being handled in the cryostat. An automated purging system with air blower was also incorporated to make the unit safe for regular operation. The system has been operational for the last five years without any design or operating problem.

The main challenge in making such a large double-walled cryostat was making the outer vessel compatible for external pressure when the annular cavity is evacuated. This problem was solved by providing a counter-pressure neutral support system in the annulus to take care of ambient thrust load. **www.shell-n-tube.com** ■