Helium Cryostat for Experimental Study of Natural Turbulent Convection

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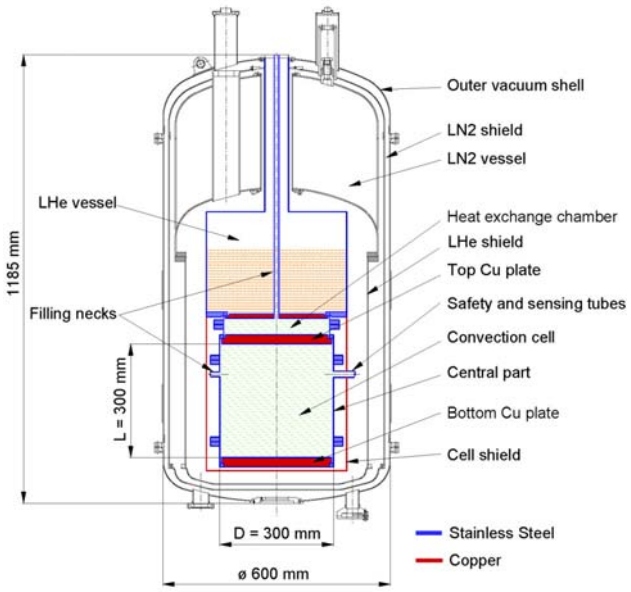
INTRODUCTION

This paper describes a helium cryostat with an experimental cell for the study of the natural turbulent convection at very high Rayleigh numbers ($10^6 < Ra < 10^{15}$) with cryogenic 4He gas (from 4.2 K to 12 K) as working fluid. The cylindrical convection cell of 300 mm in diameter and up to 300 mm in height is assembled from central, top and bottom parts. The parts are jointed by flanges which are sealed by indium wires. The central part is exchangeable and allows modification of the geometry of the cell. The cell is designed for measurement at pressures from 100 Pa to 250 kPa. The cell design minimises the parasitic heat flux into the fluid.

CRYOSTAT CONCEPTION

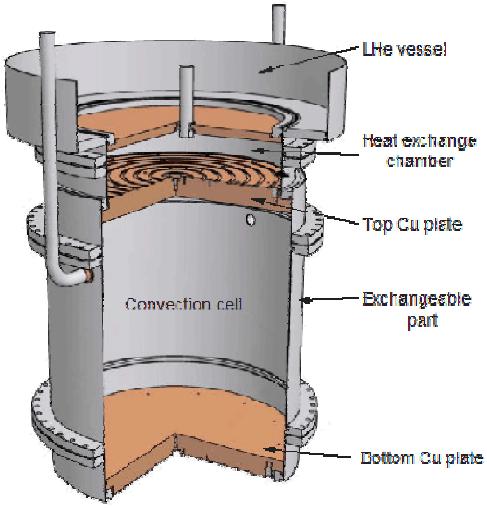


Cryostat conception is based on our long-term experience in cryostat design, especially low-loss cryostats for NMR magnets.

Parameters:

- LN2 vessel (60 litres), static evaporation rate 4.0 litre/day
- LHe vessel (28 litres), static evaporation rate 2.2 litre/day
- Convection cell (21 litres of cold helium gas)

CONVECTION CELL CONCEPTION

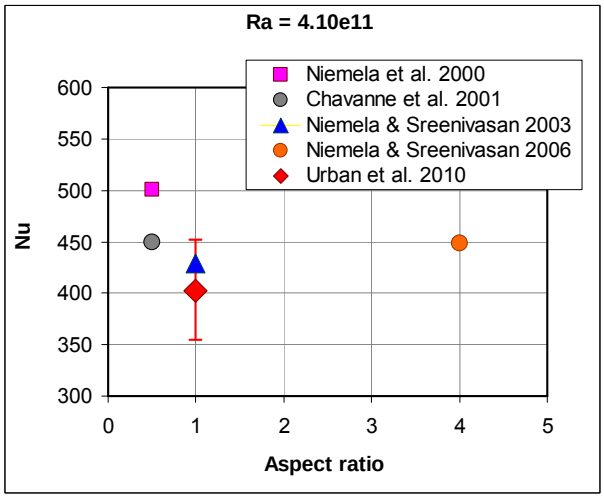


Parameters:

- *Ra* number up to about 10^{15} under Boussinesq condition $\alpha \times \Delta T \leq 0.2$
- Cylindrical experimental cell of 300 mm in diameter D and up to 300 mm in height L
- Cylindrical cell with the top and bottom plates made of high conductivity copper 1800 W/m/K (4.2 K)
- Sidewalls with low heat conductivity (to reduce substantially parasitic heat flux)
- The sidewalls are in very weak thermal contact with the copper plates
- The cell design allows to change the aspect ratio *G* = D/L from 1 to 2.5 or to implement a middle part with a modified geometry
- Operating pressures in the cell from 100 Pa to 250 kPa at temperatures from 4.2 K up to about 12 K
- Eelectrical resistance heaters, placed in grooves on the plates, heat power from 10 mW to 10 W

EXPERIMENTAL APPARATUS

RESULT OF TEST MEASUREMENT



PARASITIC HEAT FLUXES

The parasitic heat fluxes into the convection cell were minimized up to a value of 1 mW. Such a low value enables us to measure values of *Nu* number down to at least 20 (*Ra* ~ 107). At the measurement of *Nu* = 20 the parasitic heat fluxes are less than 1 % of the convective heat flux.

CONCLUSIONS

A helium cryostat with the cylindrical convection cell, 300 mm in both diameter and height, has been designed, manufactured, assembled and tested. The whole apparatus is ready for experiments on very high Rayleigh number turbulent convection, using cryogenic helium gas as a working fluid. The cell is designed for the experiment which ought to resolve the existing contradictions in various aspects of the convective flow and heat transport, especially in the scaling exponent of the *Nu*(*Ra*) power law dependence, with the advantage of the so far minimal influence of the cell structure on the convection at both low and high ends of the attainable range of *Ra* numbers.

ACKNOWLEDGMENT

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