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Thermo-hydraulic test of the moderator cell of LH_2 cold neutron source at BNC

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Abstract

Thermo-hydraulic experiment was carried out in order to test the performance of the direct cooled liquid hydrogen moderator cell to be installed at the research reactor of the Budapest Neutron Center (BNC). Two electric heaters up to 300 W each imitated the nuclear heat release in the liquid hydrogen as well as in the construction material. The test moderator cell was also equipped with temperature gauges to measure the hydrogen temperature at different positions as well as the inlet and outlet temperatures of cooling He gas. The hydrogen pressure in the connected buffer volume was also controlled. At 140 W expected total heat load the moderator cell was filled with liquid hydrogen within 4 h. The heat load and hydrogen pressure characteristics of the moderator cell are also presented.

Keywords: Cold neutrons; Neutron sources; Neutron instruments

1. Introduction

The Cold Neutron Source (CNS) implementation project at the Budapest Research Reactor is close to completion. Before assembling and commissioning the CNS, we tested the heat-removal capacity of the direct cooled liquid hydrogen moderator cell [1]. Checking of the cooling performance of double-walled moderator cell as cold He gas cooled heat exchanger was especially important because the size of cell and therefore the expected heat load has been slightly increased compared to the original project parameters (see Table 1).

2. Tests and results

Two electric heaters were mounted into the full-size test moderator cell in order to imitate the nuclear heat release in the liquid hydrogen and in the cell walls, and both could be regulated up to 300 W. The test cell was equipped with temperature gauges to measure the hydrogen temperature at three positions in the middle, at median level near the wall and close to the top of the cell. Also, the inlet and outlet temperatures and pressures of cooling He gas as well as the hydrogen pressure were controlled. The test cell was mounted into a high vacuum case and connected to a hydrogen buffer volume and to the KGU-150/4.5 He refrigerator system operating at PNPI, Gatchina and providing up to 600 W cooling power at 15 K temperature.

At the beginning of the experiment the test was cooled down from ambient temperature until completely filled with liquid hydrogen without electric heat load. The stationary state was reached in 2 h and identified by the hydrogen temperatures inside the cell and the pressure of the hydrogen gas remaining in the buffer volume. The electric heat load was increased in 10–20 W steps. The effect of heat load in the hydrogen and in the cell walls was investigated separately as well as combined in 1 : 2 proportion, which is close to the ratio of expected radiation heat loads, respectively.

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Table 1

Parameter	Project value	First test	Second test
Working medium	H_2	H_2	H_2
Volume of moderator cell (l)	0.35	0.44	0.44
Heat load in LH_2 (W)	23 (49[a])	50	100
Heat load in the cell walls (W)	40 (93[a])	100	200
Total heat load (W)	83 (142[a])	150	300
Additional heat load (W)		7–10	7–10
Hydrogen buffer volume (m^3)	0.5	0.48	0.24
Pressure in the vacuum case (Torr)	1.0×10^{-5}	1.0×10^{-4}	1.0×10^{-4}
Pressure in warm H_2 loop (MPa)	0.22	0.25	0.35
Pressure in cold H_2 loop (MPa)	0.15	0.17	0.28
Hydrogen boiling point (K)	21.8	22.2	24.24
Hydrogen temperature (K)	20.2	21	21.9
Cold helium parameters			
Mass flow (g/s)	10.0	~8	~14
Pressure (MPa)	0.15	0.14	0.195
Inlet temperature (K)	14.0	13.5	11.8
Outlet temperature (K)	15.0	17.0	16.0
Resistance of the loop (kPa)	14.0	10	16.0

[a]expected values.

The parasitic heat load on the test set-up was estimated by determining the evaporation rate of liquid hydrogen (measuring the change of pressure in the buffer volume) after the He cooling was switched off. It was found that the parasitic heat amounts to about 7–10 W.

Two series of test experiments were carried out. The first one with parameters of hydrogen system (buffer volume, warm loop pressure) close to the project values was used to the cooling capacity of our CNS system under construction. The second one with modified parameters (smaller buffer volume and slightly increased pressure in warm loop) was aimed at determining the potential heat exchanging performance of the double-walled moderator cell construction. The results of the test experiments are summarized in Table 1. The expected heat load values of the realized moderator cell as alterations to the project values are denoted by [a].

3. Conclusions

The thermo-hydraulic test experiments of LH_2 moderator cell resulted in the following conclusions.

- The construction of direct cooled LH_2 moderator cell makes it possible to remove up to 150 W heat load at the original design parameters assuring a sufficiently large safety margin.
- The heat removal can be increased up to 300 W with increased He flow rate at lowered temperature and smaller H_2 buffer volume.
- The direct cooled LH_2 moderator cell with minor improvements (lowered weight of cell, increased heat exchanger surface) can be applied as a source of cold neutrons at medium-class research reactors.

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References

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