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PELLET TARGET CRYOSTAT TEST RESULTS

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ABSTRACT

A cryostat cooled with liquid helium receives a stream of gaseous hydrogen, which liquefies in a copper condenser. The liquid hydrogen is injected through a condenser nozzle into a droplet production chamber, where it is broken up into uniformly sized micro–spheres by a piezo–electric generator. The chain of hydrogen spherical pellets with diameter about 70 μm has been derived and registered during testing run.

INTRODUCTION

The present nuclear target is very important and delicate part of experimental facilities using on internal beam of accelerators. To obtain new interesting and high accuracy results in experiments on internal beam of particles, we should use nuclear targets of small thickness and definite space position. Hydrogen and deuterium are most convenient as target materials.

The main purpose of performed stage of tests was determination of hydrodynamic and thermal parameters ensuring a stable mode of production of liquid hydrogen jet and its break–up to a chain of spherical pellets. The scheme of the facility on which tests were performed is presented on Fig.1. The main part of the facility is a vertical cylindrical cryostat (1) with OD of 400 mm, height of 1000 mm, and capacity of helium bath about 10 liters. Main units of cryostat supplying liquid hydrogen drops production are the system of heat exchangers and the system of formation of a jet and production of pellets. Both systems are enclosed in an outer vacuum chamber, evacuated to 10^{-7} mbar for the purpose of thermal insulation.

1. SYSTEM OF HEAT EXCHANGERS

The system of heat exchangers (SHE) is intended to obtain stable stream of liquid H_2 at given values of temperature and pressure. It includes 2 heat exchangers (2, 8 on Fig.1) and condenser (3) of flow, which supply liquid to the jet and also 2 heat exchangers (7, 10) of flow that should keep designed pressure in the droplet production chamber (DPC).

During formation of H_2 droplets with diameter of 70 mkm, SHE liquefied normal hydrogen up to 0.1 L/h. The temperature of liquid leaving the system was in the range from 15 to 20 K, and the pressure was in the range from 200 to 700 mbar. Gaseous H_2 purity of 99,9999 volume % was directed at the system from a standard balloon (11). Pressure level in the input collector was kept near 1.5 bars by means of pressure controller (12). The H_2 stream supplying liquid in condenser after passing through MASTER FLOW controller (13) was cooling down by liquid N_2 to 100 K in the first heat exchanger (8).

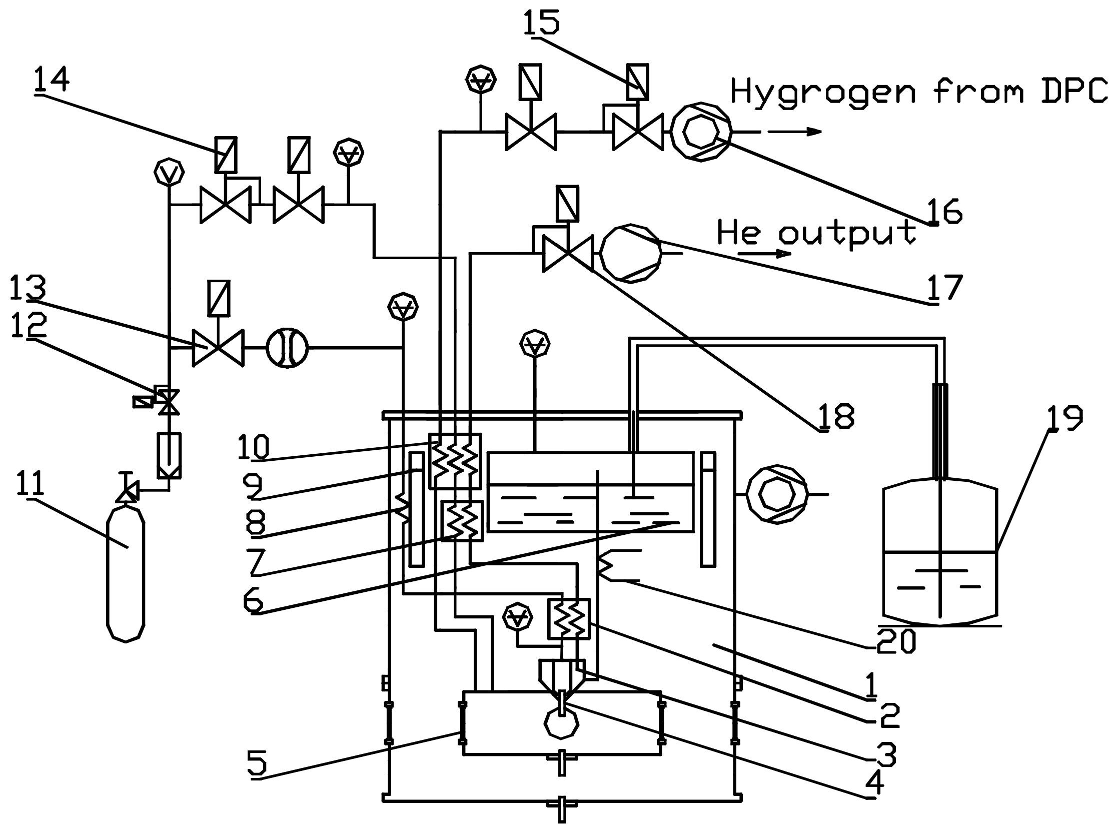

Fig.1.Scheme of pellet target set–up

This heat exchanger was produced from copper tube with a diameter 4×0.5 mm wounded outside on lateral wall of a N_2 bath (9). Further, H_2 stream was cooling by gaseous He down to 21–22 K in a coaxial–tube heat exchanger (2). It was made of thin–walled stainless steel tubes with a diameter of 3 and 5 mm and length of 1.5 m. H_2 moved inside internal tube, and He did in opposite direction through space between tubes. The heat load of the heat exchanger did not exceed several watts. The flow of H_2 leaving the heat exchanger passed to a top of the condenser vertical channel (3) of 3 mm diameter. Gas was liquefied and flew down to a nozzle input (4) at the condenser bottom. Condensation heat was moved up by a stream of gaseous He passing in opposite direction over an outside wall. The flow of He was entered a cross section appropriate to an output of liquid hydrogen stream from the condenser. That was made to sub cool a jet before its input in the DPC. The cooling flow formed at the vapor space of helium bath (6) by pumping the diaphragm pump MZ 2 (17). The stream was controlled by means of the valve (18). Temperature of helium was controlled by means of resistive heater (20) and temperature sensor of silicon diode type, mounted inside the entering tube. He leaving the condenser passed through the heat exchangers (2), (7) and (10). A design and size of heat exchanger (7) are the same as of (2). In heat exchanger (10) besides He a flow of H_2 pumped out from DPC by pump (16) in order to cool down an opposite hydrogen stream. The designed pressure in DPC was keeping with error less than 5% by means of a piezo gauge and controller (15), operating at room temperature. The temperature and pressure sensors were mounted in the most important places of H_2 and He hydraulic systems (Fig.1). To reduce a temperature measurement error of flows entering the condenser, silicon diodes DT–471 were mounted directly inside feed tubes. Sensors specifically calibrated with an absolute accuracy of 0.02 K at 20 K carried out the temperature measurement.

2. SYSTEM Of A JET FORMATION AND PRODUCTION OF DROPLETS

The view of system is shown on fig.2. For formation of H_2 jet, a cylindrical nozzle made from OFHS copper with ID of 2 mm and length of 60 mm was used. A diaphragm produced from the sapphire with calibrated orifice 60–mkm was tightly expanded into internal channel of nozzle.

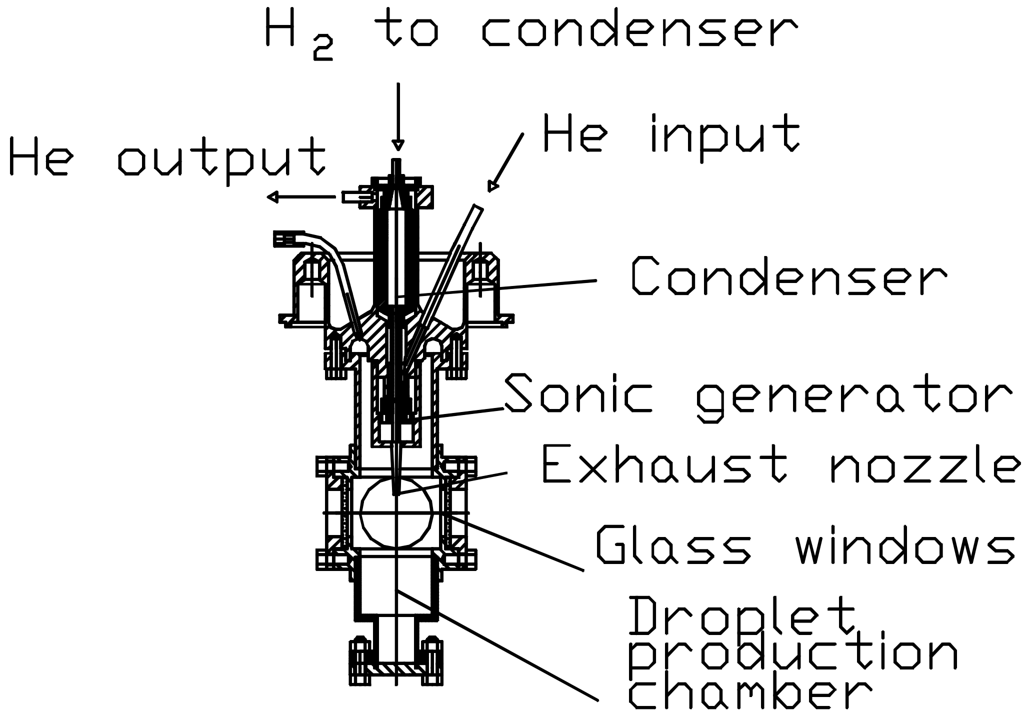

Fig.2.System of a jet formation and production of droplets.

The hollow cylinder ultrasonic piezo–electric generator with resonance frequency 3 kHz was mounted coaxially on the nozzle outside surface. Unit of an output nozzle with generator was mounted in DPC, which was vacuum–tight attached to the bottom of condenser unit. To provide conditions close to isothermal ones walls of the chamber were made of OFHS copper. For control of pressure and keep it near triple point temperature of H_2, there were two holes in the top flange of the chamber. One is to feed flow of H_2 passed through heat exchanger (10) and (7), another to pump out gas from DPC. The observation and photography of jet leaving nozzle and produced pellets was carried out by means of the camera Zenit. For this purpose 4 optical windows were located on DPC wall oriented at 90^0 relative to each other. They were oriented corresponding to windows on outside enclose of the cryostat.

3. TESTS RESULTS

The cold capacity of used He stream was equal 2 W at 18 K. It permitted to liquefy up to 0.1 liter H_2 per hour. In order to provide continuum regime the liquid hydrogen flow velocity was kept rather low, not exceeding several meters per second that corresponded to number Re from 500 to 2700. These regimes were characterized by rather low values of flow rate coefficient, less than 0.4. It means that sub cooling of liquid hydrogen in the nozzle seems was not enough. Results of tests (Fig.3) have shown that character of flow and the form of the jet depend in strong degree on temperature of the nozzle and on pressure, which was keeping in DPC. In our case the optimum temperature corresponding to the stable mono–dispersed flow regime (Fig.3d) was about 18 K. Due to low value of H_2 surface tension it could see a shattering of droplets. At higher temperatures the regime transformed gradually in vapor–liquid one (Fig.3a), at lower temperatures the jet was frozen. Figs. 3b and 3c demonstrate a vapor–liquid jet regimes corresponding to intermediate temperature between vapor–liquid and mono–dispersed one.

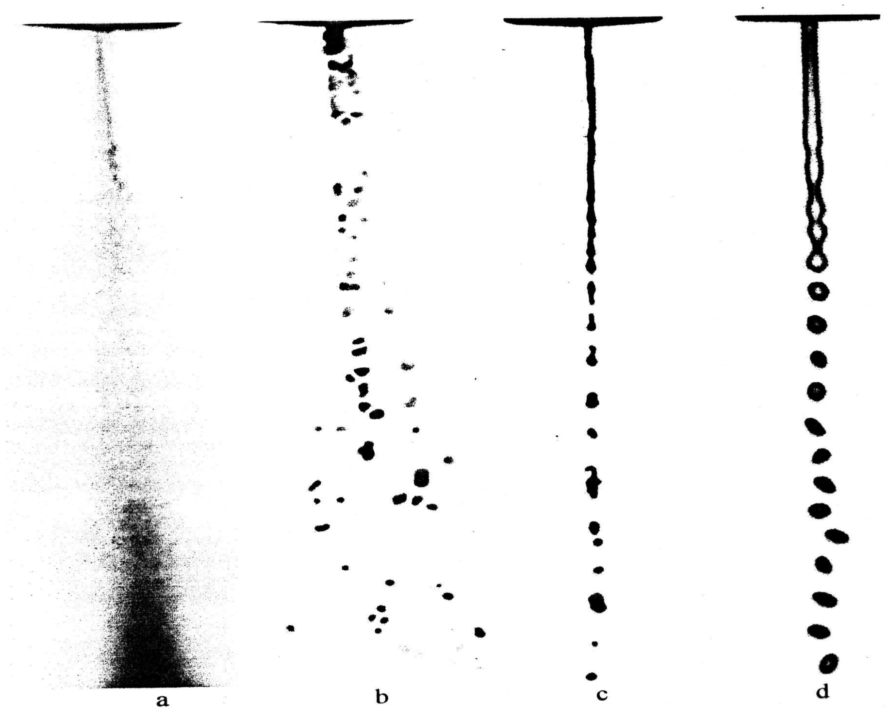

Fig.3. Views of hydrogen jet

The previous vacuum injection studies of water have shown that besides form of a nozzle tip the jet form and stability depends strongly on pressure in a vacuum chamber. The deviation of the jet from initial vertical direction was rather small at pressure close to triple point value. At lower pressure, the deviation grew. Direction and the value of deviation in this case are unpredictable. Take in consideration it the pressure in DPC during the H_2 pellet production, was keeping in the range of 80–100 mbar, that corresponds approximately to the triple point value or was a little bit higher. In cases when the pressure was lowered down to 30–50 mbar, the H_2 jet frozen in the chamber.