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A LOW EVAPORATION TARGET FOR LIQUID HYDROGEN, DEUTERIUM OR HELIUM

V. MONTELATICI

Laboratori Nazionali di Frascati – CNEN

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A liquid hydrogen, deuterium or helium target, insulated by vacuum and low temperature radiation shields, is described.

Its future is a low evaporation rate of liquid hydrogen $\approx 10^{-2}$lt·hr^{-1}.

Deuterium is condensed by a single current heat exchange at a final pressure of about 0.4 atm using nitrogen and hydrogen as refrigerating liquids.

A valve system permits to empty and fill rapidly the liquid volume exposed to γ-ray beam.

Using liquid helium the evaporation reaches values less than 2×10^{-1}lt·hr^{-1} of liquid.

1. Introduction

In the experimental studies of the γ-ray beam and nuclear interactions, better conditions are realized when the irradiated sample is as dense as possible, and has a known geometry with respect to some fixed reference frame.

Hydrogen and deuterium are frequently employed for nuclear studies; their N.T.P. densities are 8.9×10^{-2} and 7.5×10^{-1} g·lt^{-1} respectively, while at the N.B.P. they are 70.8 g·lt^{-1} and 164 g·lt^{-1}. The boiling point is 20.4° K for hydrogen and 23.6° K for deuterium.

Clearly it is convenient to work with hydrogen isotopes in the liquid state. This involves the construction of special containers, cryostats, which must reduce all types of heat transfer to liquid gases in order to work for long periods and to avoid boiling of the liquid.

The cryostat described in this paper is an improvement of a preceding one[1]) and is similar to others existing in some laboratories[2,3]).

It has the following characteristics:

1) easy change of the cell without damage of the structure of the cryostat;
2) greater exposed volume of the cell to γ-ray beam;
3) low evaporation rate of liquid;
4) filling with either hydrogen or deuterium;
5) cell free from tubes or other materials except its walls.

2. Description

The different parts of the cryostat are divided into four sections: (1) at room temperature (300° K), (2) at low temperature (77° K), (3) at very low temperature (20° K), and (4) connections.

Fig. 1 shows the drawing; all parts are made of stainless steel except the heat exchanger and some parts of the valves which are made with brass and teflon.

2.1. ROOM TEMPERATURE SECTION

This includes the external tanks made of three parts joined by screws; the vacuum is secured by means of two "O" rings.

In the lower part there is a mylar window (0.19 mm thickness) cemented with araldite to the external wall.

A diffusion vacuum pump, having a capacity of 300 lt·sec^{-1} is placed under the device; and a freon refrigerated baffle is incorporated in it.

On the top of the external tank are placed the control vacuum gauge and the tube terminals connecting the different parts of the cryostat.

2.2. LOW TEMPERATURE SECTION

This includes the 30 lt capacity nitrogen tank and the copper radiation shield which surrounds the lower hydrogen tank and the cell.

The lower part of the radiation shield is cut away on the side to permit the passage of low-energy particles. Only a thin aluminium foil is placed around the hole.

Between the nitrogen and external tank is a multiple layer radiation shield. There are about 20 foils/cm. The foils are made with aluminated mylar (0.012 mm thickness).

Four nylon wires connected to the nitrogen tank prevent changes of the target position due to temperature gradient changes of the tubes.

2.3. VERY LOW TEMPERATURE SECTION

This includes the 6 lt capacity hydrogen tank, the 0.6 lt capacity deuterium tank and the cell the shape of which depends on the type of experiment to be performed.

The cell is fixed to the deuterium tank and this to the hydrogen tank with brass screws; an indium gasket assures the vacuum tightness.

The cell is fixed with respect to the copper radiation shield with four connecting nylon wires.

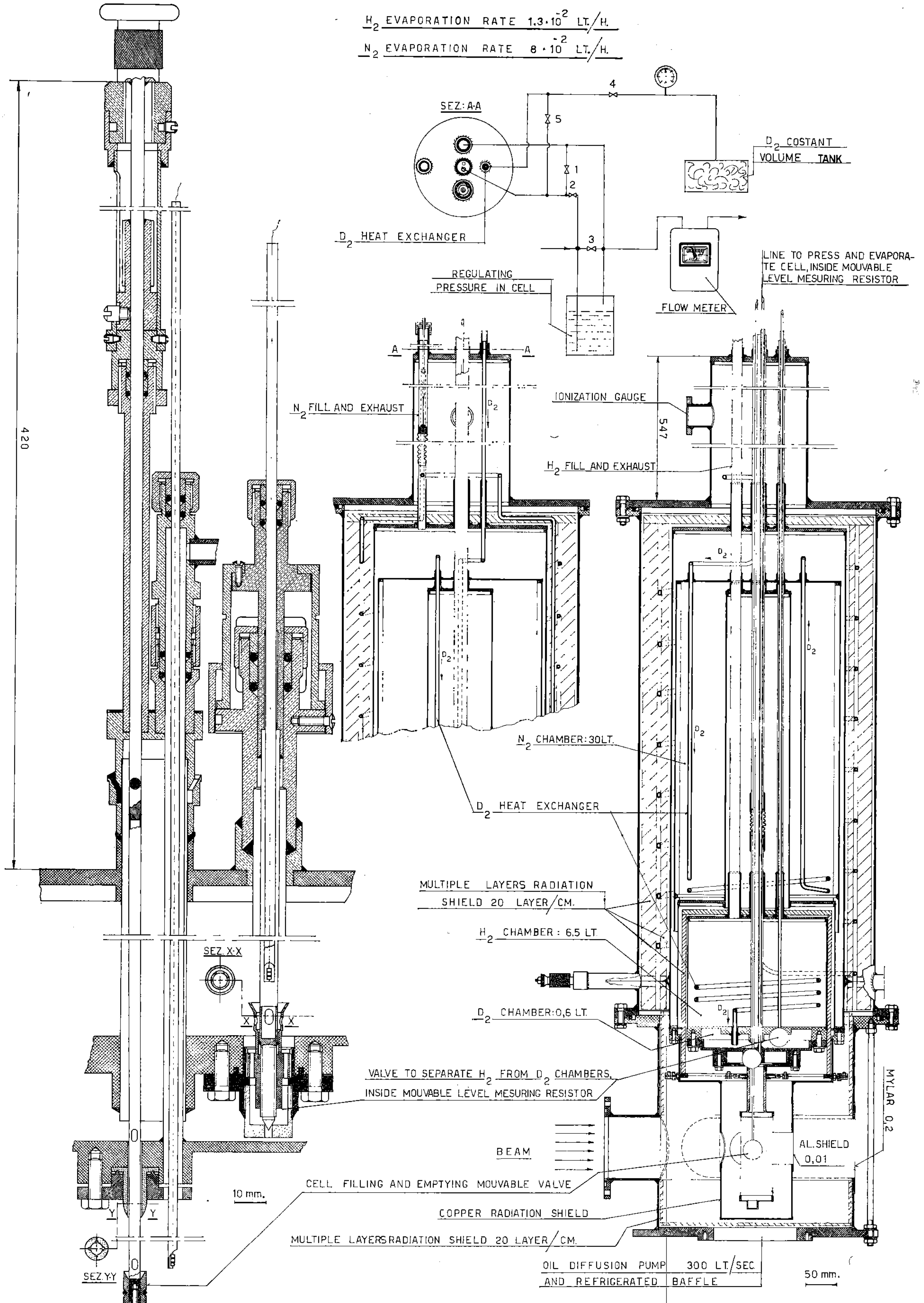

Fig. 1. Sketch of liquid hydrogen, deuterium or helium target.

Between the hydrogen and nitrogen tanks an aluminated mylar multiple layer radiation shield is placed.

2.4. Connections

Five tubes pass through the two tanks and are welded on the top of the external tank, they are:

a) the filling and evaporating nitrogen tube (inner diameter 1 cm and 0.2 mm thickness); it is closed when the tank is full with a non return valve. This tube bypasses a refrigerating coil placed inside the multiple layer radiation shield. After filling the nitrogen tank the tube is closed with a valve and the cold nitrogen gas is forced to pass through the coil.

The end of the coil is placed at the top of the tube inside the cryostat.

b) the heat exchanger to liquefy the deuterium (inner diameter 6 mm and 0.3 mm thickness). Its copper part in the liquid nitrogen bath is 150 cm long and that in the liquid hydrogen bath is 350 cm long; its end is inside the deuterium tank.

c) the filling and evaporating hydrogen tube (inner diameter 15 mm and 0.2 mm thickness).

From this tube an external evaporating line conveys hydrogen gas outside the building through an oil bubler to avoid any return and condensation of moisture.

d) The central tube (inner diameter 20 mm and 0.2 mm thickness) goes from the top of the target to the deuterium tank. Inside it there are two tubes: the cell filling and emptying valve and a tube which communicates directly between the cell and the external control valves. Inside this second tube there is a moveable tube supporting at its lower end a carbon resistor to measure the liquid hydrogen level in the cell. The filling and empting valve, (A), is a tube (inner diameter 0.35 cm) which slides a fixed distance, so that its lower end touches the cell bottom or is immersed a few millimeters in the cell. On the tube two holes are worked in such a way that when the valve is in the lower position, the lower hole is near the cell bottom and the upper hole is in the deuterium tank; the tube over the upper hole is closed.

A stainless steel piece is on the lower end of the valve and it is surrounded with a tantalium ring. By photographing the γ-ray beam one knows the cell center position with respect to the beam. The valve slides in a teflon piece shaped to fit the stainless steel piece. Putting the stainless steel piece a few millimeter from the teflon tongue, the liquid hydrogen supplies the cell through some longitudinal holes in it. The cell is sealed off from the deuterium tank by fixing the teflon tongue in the dovetail stainless steel piece. At the top of the tube valve there is a screw which holds the two pieces together strongly.

e) Deuterium and hydrogen tank separating valve. This consists of a tube (inner diameter 6 mm and 0.35 mm thickness) which is inside another tube. The second tube has its end in the top of the hydrogen tank.

The valve has a threaded stainless steel screw with a polished needle end; at its external top it has a ring-nut. Turning the nut, the needle end closes a hole in a brass piece.

This valve, (B), separates by a vacuum tight seal the hydrogen from the deuterium tank. Inside the valve tube another one (2 mm in diameter) can slide. At its lower end a carbon resistor is placed. It is used to measure the liquid hydrogen level in this tank.

To measure the liquid level a 100 ohm nominal carbon resistor, placed in an arm of a Wheatstone bridge, is used. The bridge is balanced when the measuring carbon is immersed in the liquid. Taking it out of the liquid a sufficient variation of its resistance occurs to see a large deviation of the reading. It is possible to detect 2 ÷ 3 mm in the liquid level changes.

3. Operation

The operations using the target are divided in three sections and we shall refer to fig. 1.

3.1. Initial setting up

The vacuum pump is switched on, after about 4 days, the dynamic vacuum is approximatively 5×10^{-5} mmHg. Now the valves number 1 and 3 are closed and the valves number 2 and 5 and (B) opened; the (A) valve is lowered. After hydrogen gas is passed through the filling and emptying tube to clean moisture from the cryostat. The number 4 valve is always closed.

3.2. Nitrogen and hydrogen filling

The valve number 5 is closed and the valves number 1, 2 and 3 opened after nitrogen is filled. At the same time, hydrogen gas is supplied to the hydrogen tank to compensate the refrigerating effects. After 24 hours the nitrogen tank is refilled and by a transfer tube the hydrogen is dropped into its tank.

After the tanks are filled the dynamic vacuum reaches 10^{-6} mmHg or less. To work with the γ-ray beam the (A) valve is raised, but not closed with the external screw, to permit the continuous cell refilling.

3.3. Filling and emptying cell

To empty the cell the valves numbers 1, 3, 5 are closed and the (A) valve lowered together the carbon resistor tube. A current is passed, dissipating two watt in the carbon resistor, to raise the pressure in the cell and force the liquid into the upper tank through the holes of the (A) valve.

About ten minutes are necessary to empty a cell, 300 cc in volume.

Then the cell is closed tightly be screwing the external control of the valve (A) and the valves number 1, 2, 5 are opened. To fill the cell the (A) valve is lowered. In a few minutes it is filled.

3.4. TARGET USE WITH DEUTERIUM

Before filling the cryostat with liquid gases the (B) valve and the valves number 1, 2, 5 are closed. The deuterium line is evacuated. After cleaning the deuterium tank, heat exchanger and cell by vacuum, the valve number 4 is opened and the nitrogen and hydrogen is filled in the two tanks.

During the hydrogen filling the deuterium gas is condensed and liquified in its tank to a 0.3 $\div$ 0.4 atm. pressure.

The same procedure as for hydrogen is used to empty the cell.

4. Performance

The observed evaporation rate was less than 10^{-2} $\mathrm{lt \cdot h^{-1}}$ of liquid hydrogen and 8×10^{-2} $\mathrm{lt \cdot h^{-1}}$ of liquid nitrogen. Without the multiple layer radiation shield and the refrigerating coil we observed an evaporation rate of about 7×10^{-1} $\mathrm{lt \cdot h^{-1}}$ of liquid nitrogen.

The cryostat has been tested with liquid helium. It reaches an evaporation rate of less than 2×10^{-1} $\mathrm{lt \cdot h^{-1}}$ of liquid helium. We think that it is possible to reach lower evaporation by eliminating a few tubes from the lower tank.

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