HIGH POWER NEUTRON CONVERTER FOR LOW ENERGY PROTON/DEUTERON BEAMS: TEST FACILITY*

A.Antoshin, M.Avilov, M.Blinov, D.Bolkhovityanov, V.Golikov, K.Gubin, M.Kholopov, N.Lebedev, P. Logachev, V.Popov, S.Shiyankov, A.Tsyganov, I.Zhul
BINP, Novosibirsk, Russia,

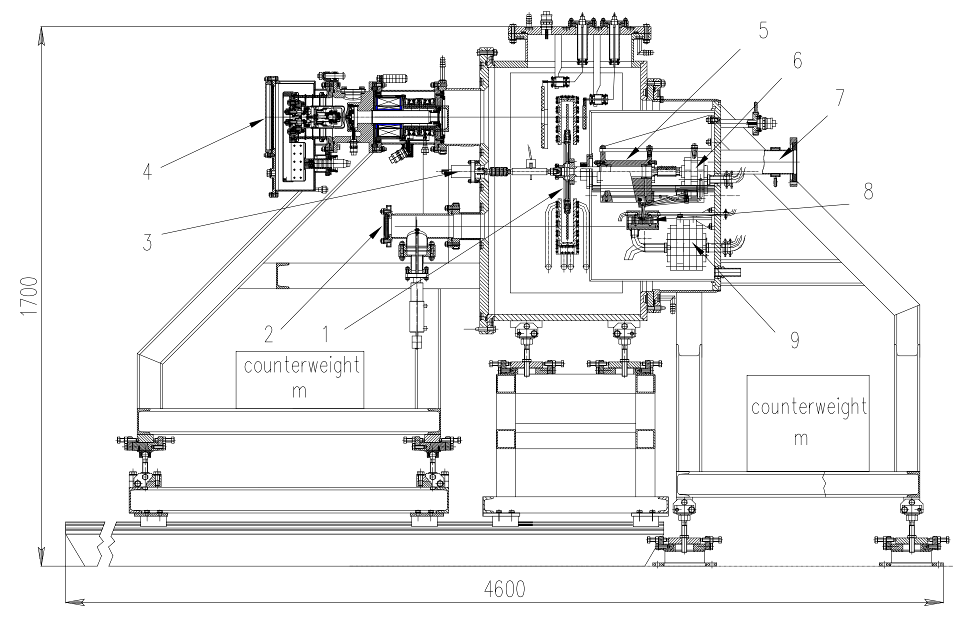

Figure 1: Test facility in assembly. 1- rotating target, 2 – windows assembly, 3 – rotation feedthrough, 4 – electron gun, 5 – suspension assembly, 6 – LM motor, 7 – pumping port, 8 – float valve, 9 – motor/pump LM couple.

Abstract

This paper presents conceptual design of test facility that is now under creation in the framework of development of high power neutron targets for SPES (INFN-LNL, Italy) and SPIRAL-II (GANIL, France). General destination of facility is to test different target systems and elements (hot converter unit, liquid metal driving gear and cooling systems) as well as experimental checking of supply, protection and control methods etc. Also, this facility must be used as a base for input quality control of targets as a whole in future. The structure, general features and experimental possibilities of facility are described.

INTRODUCTION

For SPES (INFN LNL, Italy) and SPIRAL-II (GANIL, France) projects the high temperature rotated graphite-made target was proposed as the intense source of high-energy neutrons [1]. In nominal operating conditions the target with diameter close to 1.2 m should be exposed to the proton beam with power up to 200 kW and size close to 3 cm. Normal speed of target rotation could be around 20-50 Hz. Tests of target prototype [2] for the 50 kW of beam power demonstrated suitability of this design.

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Nowadays the next stage of target development was started. It includes:

- construction and tests of full-scale converter assembly;
- development and tests of liquid metal (LM below) driving gear and cooling systems [2,3];

In the framework of this work the creation of test facility for experimental checking of these devices. From the other hand, test facility allows to work through technology of input checking for the real target assemblies.

The equipment, operation modes, and performance specification on the designing and manufacturing the experimental facility are determined by these tasks. Facility represents a complex experimental installation aimed at the solution of tasks and problems arise during the project implementation. It includes the following main systems:

- Experimental and LM volumes;

- High power electron beam source;
- System of heating and temperature stabilization;
- Control system;
- Vacuum system;
- Engineering infrastructure.

EXPERIMENTAL AND LM VOLUMES

Main experimental volume comprises (see Figure 1) the vacuum chamber with the dimensions ~ 920x900x520 mm. Basic experimental units, which are the LM driving gear (6), suspension assembly (5), rotating target (1), cooling channels, systems of protection and diagnostics, are placed inside the main volume. The chamber has the removable frontal, rear and upper walls, as well as the lateral flanges.

The electron gun (4), the window unit for optical thermometry (2), and the rotary motion feedthrough (3) provided for the diagnostic purposes, are mounted on the frontal wall.

The rear wall is intended for LM tank mounting, with the LM driving gear, suspension assembly, and motor/pump couple inside the tank. All the LM pipelines inlets, as well as pumping ports and sockets for diagnostics and heating devices of LM tank, are located on the rear wall. LM driving gear with motor and LM sliding bearings, as well as the motor/pump couple of auxiliary circuit are assembled inside the tank. About a half of the volume is filled with the LM working alloy. Alloy heating is carried out by means of a heating cable BARTEC EKM, which is sunk directly into the alloy. The heating of a rotation unit is realized via the dedicated heating cog partially sunk into metal. The rotation unit's shaft is taken out of the tank via the composite gland. Level of metal is maintained by the auxiliary circuit, whose motor/pump couple (9) is fully sunk into metal and works continuously in common with the float valve (8). Protecting iris, current sensor, capacitive sensor of shaft rotation, additional window unit, and a part of the measuring and heating sockets are positioned on the lid. Bottom of a chamber is equipped with full-size target model attachment point. Lateral flanges have the cooling channels, described in [3].

LM tank is vacuum separated from the rest of the volume by following reasons:

- normal operation conditions require ~ 10^{-2} mbar pressure for tank, however, while operating under the beam it is necessary to get ~ 10^{-4} mbar;
- the presence of vapor and, in particular, the sparks of lead on the target working area are not allowable;
- separate design enables the experiments with LM drive, in which the target of large diameter is under the atmospheric pressure.

Chamber walls are not cooled and are heat-insulated. In order to protect the split flange joints, special water cooling channels are provided in the close vicinity from these joints.

Pump tank is a heating-up chamber 350 mm high and 470 mm in diameter. 3 LM pumps located inside the chamber provide the LM circulation in circuits. 3 kW electric engines Matador DCM6F ("Control Techniques" production) are placed on the tank lid's cooled ports. Engine operation parameters are controlled by the "Control Techniques" Maxi Maestro controller. Engines connected with LM motors via the feedthrough with magnetic liquid. Besides, LM circuit pipelines are led to the tank. Tank infill/discharge assembly and 10^{-2} Torr pumping port are also available.

Two filling tanks are the heating-up volumes 400 mm high and 365 mm in diameter with LM loading ports.
Total LM weight in circuits is about 550 – 600 kg during operation.

Figure 2: Electron gun.

HIGH POWER ELECTRON BEAM SOURCE

The electron gun (Figure 2) developed and manufactured in BINP is used as a source of high intensity electron beam [4]. It can produce the beam of up to 500 mA current at 60 keV energy. The gun can operate in either continuous and pulse regime. The optical system enables angular and longitudinal beam scanning, as well as its focusing to the size of 2 mm at full operation current. All necessary electronics, including power supply, lockout-signaling device and computer control, is also developed and delivered in common with the gun. Basic gun parameters are following:

- Beam pulse minimum width at full current 10 ms;
- Maximum frequency of beam modulation 50 Hz;
- Maximum depth of beam modulation 1–500 mA;
- Beam stabilization time (at 5% level) 3 ms;
- Maximum beam escaping angle ± 7 °;
- Maximum parallel shift of beam escape ± 5 mm;
- Maximum frequency of beam scanning 2 kHz.

HEATING AND CONTROL SYSTEMS

The use of LM in the facility requires the main assemblies to be kept at the temperature of 300 – 350 ^{0}C. In order to ensure such conditions it is necessary to have a system of heating and temperature stabilization. It consists in 12 independent brunches with controlled heating power up to 3 kW each. Each brunch represents the controller with PID (Proportional Integral-Differential) control algorithm of temperature regulation which also includes the power symistor key, heating element and temperature feedback sensor.

Heating cable BARTEC EKM VA 1000 (inside the vacuum) and heating band ENGLU-400 (outdoor) are used as the heating elements. Integrated equipment of "Termodat" brand were selected as a controller and power key.

The thus completed system of heating and temperature stabilization makes possible the LM circuit temperature maintenance within a range of 300-400^{0}C with necessary time characteristics (starting and stopping modes) and the precision on the level of 3-4^{0}C.

Measurements and control the electron beam parameters are carried out by the electron gun control own system. They include: beam current and energy, its position and escaping angle, amplitude and angle of beam scanning. All data transmit to a common lockout-signaling device (LSD) system and console computer.

The current sensor located beyond the converter carries out measurement of beam current density distribution. The beam impinges the sensor via a set of diagnostic holes in the converter's plates. The sensor is performed as the graphite plate and, at the same time, aimed at the protection of chamber walls from the beam hit.

Converter temperature is measured by means of optical pyrometer Impac Electronics IS12.

Measurements of target rotation parameters include:

- Measurements of electric motor rotation parameters by means of sensors built in motor controllers (tachometer sensor of rotation speed, motor current sensor, maximum and minimum rotation speed lockout, current excess lockout);
- Target rotation speed measurement by means of optical couple sensor placed outside the main vacuum chamber;
- Target rotation speed measurement inside the vacuum chamber with the use of capacitive sensor whose capacitance could be varied by means of special lugs on the target shaft.

Heat flux removal from the installation is calorimetrically measured with the use of two thermodetectors and a flow meter.

For the *LM pressure* measurements it is suggested to use the special assembly, which design is based upon the pressure transfer to the atmosphere via the heating-up bellows.

For the *LM consumption* measurements in the circuit the ballpoint flowmeter was developed. The principle of measurement is based upon the motion of a ball made of magnetic material around the circular channel. The LM vortical motion is provided by a special vortex. Ball revolution frequency is measured with the use of inductive sensor. It consists in 2 inductively coupled coils, which coupling ratio varies when the ball passes around.

All the measured data are detected and transmitted to the console computer placed in the control room. Console is used also for the facility general control. PC connection to the equipment is realized in digital format.

The software for the control system is based upon the CX system which is now under operation at VEPP-5 accelerator complex. CX is a client-server system which uses 3-level architecture. The system enables the remote control of the experiments. CX provides both "data bus" and main features to create the operator unitized interface. CX operates under OS Linux.

CONCLUSION

Described test facility will be assembled and commissioned during 2008 year. It will have possibilities to provide wide range experiments in the framework of development of high-power beam dump devices: large experimental vacuum volumes, LM infrastructures, high-power e-beam, control and measurement etc.

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