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INSTRUMENTATION SYSTEM FOR PULSED NEUTRON GENERATOR. Part 2: STRUCTURE AND ASSEMBLIES*.

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*) Part 1: Electronic control and data acquisition
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Abstract

The paper presents structure of the pulsed neutron generator at the Institute of Nuclear Physics after a modernisation of the main systems. The ion source, the vacuum system, the thermostatic system, the water cooling system, etc, are concisely described. A set of diagrams is enclosed.

1. Introduction

The fast neutron pulse generator and the experimental set-up for the measurement of the thermal neutron decay time in the sample are described. The fast neutron pulse generator is a linear accelerator of deuterium ions with the tritium target generating fast (14 MeV) neutron pulse according to the incoming accelerated deuterium pulse. This is followed by a dedicated setup for measurements of the time decay of the thermal neutron flux in the sample. For a proper operation of the linear accelerator several associated systems must work. There are: the vacuum system, the ion source, the water cooling system, the main supply and the H.V. supply. A sample temperature thermostatic system must work to keep a constant temperature of the measurement. All systems and the auxiliary equipment are situated in the experimental hall. The arrangement of their main parts is shown in Fig 1. This arrangement and the construction of the main parts and auxiliary systems are briefly described in the report. The associated electronic control and data acquisition system were described in [1].

2. The linear accelerator

The linear accelerator is designed for accelerating the deuterium ions in the range of 0-200 keV. It consists of three isolated metal cylinders in tandem forming electrostatic acceleration and beam focusing arrangement situated in vacuum tube [2]. Deuterium ions generated in the ion source are pushed off by the extraction pulsed or constant voltage trough a small hole and are accelerated and focused (by changing the ratio of consecutive accelerating voltages) by cylinders and leave the accelerating section. Further, the accelerated ions travel trough a stright section of the ion guide (approximately 2 m long) until they reach the target plate. The stright section of the ion guide (vacuum tight) contains a flat vacuum-tight shutter and is surrounded by the pairs of magnetic coils focusing and displacing the beam.

The X-Y displacing air-tight mechanical device allows precise adjustment of the last rigid part of the accelerator tube against the ionic beam at the end of this tube. Ionic beam position and size /approximately 10 mm in diameter/ limiting ring is mounted. The beam displacing and focusing magnetic coil system is mounted on this last rigid part of the ion guide.

The last section of the ion guide, comprising the target, approximately 1 m long, is connected to the rigid section with a flexible vacuum tight joint and suspended on inclinable fastening so, that the far end with target plate can be freely inclined (~ 30 mm). This allows the focused stright beam to reach any point on the target plate without change of the geometrical relation between beam position and sample arrangement. In this way the whole surface of the target can be exploited without unsealing the vacuum system and without change of geometrical relations. As shown by latest investigations and measurements this plays an essential role in the accuracy of measurements, especially with the newly elaborated method of a detection of the inhomogeneity of the sample.

3. The ion source

The arrangement of the ion source is schematicaly shown in Fig 2. It consists of the heavy water electrolyser, the drying columns, the system of mechanical valves, the palladium thermal valve, the conducting pipe, the special quartz bulbe with the ion cloud former and the extracting electrode. The quartz bulbe is sorrounded by a coil of the H.F. generator. The deuterium gas from the electrolyser of heavy water passes trough the drying column (to remove any moisture) and reaches the outer side of the palladium valve. The palladium valve, placed in a glass tube surrounded by a heater coil, when heated allows to pass the deuterium to the ion source bulbe. At the beginning of the accelerator work the air content in the system is pushed-off by the deuterium coming through valve which is then closed for the air and only deuterium can enter into the source bulbe.

The ion source is shown in detail in Fig 3. Ionisation of the deuterium in the bulbe is achieved by H.F electromagnetic field (~ 50 MHz) from H.F generator. The ions are spacially formed at the output hole of the quartz bulbe connected with the input hole to the accelerator and are periodically pushed-off by the positive extracting voltage pulses of amplitude up to 5 kV, and then accelerated. The intensity and colour of the glowing gas in the bulbe, containing an important information of the ion source working conditions, are transmitted directly to the control desk through the optical fibre.

4. The vacuum system and tritium gas security

The vacuum of the order 10^{-6} Tr in the acceleration tube of an approximate volume of 100 dm^3, necessary for a proper operation of the accelerator, is obtained by using two stage pumping system. It consists of the rotary pump (type BL 30) and the turbomolecular pump (Alcatel type 5150) [3] with associated valves and electronic systems. Additional small rotary pump connected to the target section of the accelerator is used for a preliminary vacuuming of this section after the target change. During the target change operation, the target section is cut-off from the main vacuum volume by a special vacuum valve system. The vacuum in the main accelerator volume is measured by a combined Pirani-Penning vacuummeter [4](Alcatel type Micro-Pascal). Schematic viev of the vacuum system is shown in Fig 4. Seeing that there is possible tritium contamination of pumped-out gas a special long air-tight tube with fan leading to the building roof is connected to the rotary pump output. During the target change operation a fan, which sucks the air from the surroundings of the tritium target, is also connected to this tube.

5. The sample camera

The sample camera is destined for keeping the sample during the experiment. It is essentially built of thick borated paraffin flat walls forming near a cube shape with the internal dimensions approximately 50 x 50 x 50 cm. The side view of the camera is shown in Fig 5. Inside the camera a sample moving table supporting the sample is situated which allows precise positioning of the sample against the tritium target (manually controlled). One of the side walls of the sample camera is movable and can be shifted on rails during the sample positioning procedure. The whole sample camera is situated on a truck moving on rails (on the floor) towards and from the target. An additional mechanical adjustment system is mounted between the camera and the truck and allows a precise adjustment of the sample position opposite the target. In this way the sample can be accurately positioned opposite the target.

Two He^3 cylindrical shape thermal neutron detectors „are looking" to the sample through round windows on lower and upper sides of the cadmium shell of the sample. The lower detector is steady mounted and the upper one is adjustable according to the sample height. The target enters the sample camera through an oval hole at the front side.

The inlet and outlet of the air that stabilises the temperature of the sample are in the bottom of the camera.

6. The sample temperature thermostatic systems

The sample temperature thermostatic system consists of two entirely independent systems:

1. The experimental hall constant temperature thermostatic system stabilises the room and sample temperature at 20 ± 0.4 °C. This system stabilises the air temperature in the experimental hall using two powerful airconditioning units with cooling and heating possibilities. They are controlled by additional separate adjustable temperature controllers, which are experimentally tuned to maintain the temperature of the air inside the sample camera at 20 ± 0.4 °C. Two additional fans are mixing the air in the room to distribute uniformly the air with constant temperature inside the experimental hall. Thick concrete walls of the experimental hall, the foamed polyestyrene roof, and walls (0.15 m) made of borated paraffine (approximately 150 kg) and the sample of ~1 dm^3 are the passive elements of the temperature stabilisation system. Approximately up to 2 days are needed to achieve the stabilised temperature of the experimental hall at the required value. The next samples are maintained in

the stabilised temperature experimental hall approximately 1 day before the experiment. The air temperature inside the sample camera is measured, recorded and the signal is delivered to the automatic control system of the experimental conditions.

2. The experimental camera variable temperature termostatic system (see Fig 6) stabilises the internal temperature of the sample camera and the sample in the range of 5–60 °C ± 0.2 °C.

In some experiments the measurements should be carried-out at different sample temperatures therefore, an additional sample temperature stabilising system in the range of 5 – 60 ºC has been developed. The system stabilises the temperature of the inner part of the sample camera. The sample camera has been modified to meet the new requirements. Due to a poor mechanical resistance of paraffin for the temperatures exceeding 30 °C an additional semihermetic temperature isolation box made of foamed polystyrene is put inside the paraffine box. Due to a poor thermal conductivity of the paraffin an additional air gap, approximately 1 cm width, is made between the inside thermal box and outer walls of the paraffin box. This air gap forming an air shell is opened at the bottom and the top so the chimney for warm air is made allowing the warm air to leave and the cooled air to let in. Two flexible air pipes connected to the bottom of the foamed polystyrene box are connected to the active part of the temperature stabilising system. The sample temperature is measured with an Pt 100 miniature device connected thermally to the metal shell of the sample container (usually a thick cadmium shell). The active part of the system is formed by a combination of fan, fluid-radiator cooler type VBF-100 and space-distributed heater net subsequently positioned in an air-tight square tube channel. A seasoning camera of the approximately 400 x 400 x 400 mm inner size is mechanically connected to the active system. This camera is destined for a stabilisation of the „next sample" temperature. The active system, the sample camera and the seasoning camera with the flexible air pipes form a closed air-tight serial circuit with air temperature stabilisation forced air circulation system. A fluid cooling unit with microprocessor controll type PCV-5, [5] located in the accelerator room is connected with pipes to the fluid-radiator cooler delivering necessary quantity of cooling agent. The microprocessor controlled programable PID autotuning device type SHINKO FCR-100 [6] controls the heater power via an pulse width modulator and optotriac power unit. The active unit is situated nearby the sample camera in the experimental room. Preliminary measurements have shown that sample temperature is practically stabilised in this way with a long temperature stability in the range of 5 – 60 °C with ±0.1 °C accuracy and stability.

7. Water cooling system

Two devices of the pulsed neutron generator, the tritium target assembly and the turbomolecular vacuum pump, have to be cooled with distilled water in a closed circulation system and should be independent of water-pipe network.

Tritium target cooling is very important. Excessive overheating of the target by the deuteron beam can release a radioactive tritium gas and also damage the expensive target.

The turbomolecular pump Alcatel type 5150 requires cooling water flow from 0.2 to 1 litre per minute with the water temperature between 10 and 20 ºC. The optimum cooling water temperature is about 16 ºC because this significantly prolongs the pump life time.

The water cooling system for the tritium target assembly and the turbomolecular pump is shown in Fig 7. It consists of the open tank for distilled water of volume approximately 1 m^3, the closed hydrophore tank of volume 0.3 m^3, the water pump connected to the pressure relay, the water cooler, two flow indicators, and valves. Both outputs of the flow indicators are connected to the alarm system in the data acquisition room.

8. Final remarks

The main systems of the pulsed neutron generator have been modernised. All of them work successfuly. The paper reports the present status of the pulsed neutron generator. Pulsed neutron measurements in different temperatures will be undertaken in the nearest future, so the modified sample camera and the sample thermostatic system were checked. The set of enclosed diagrams should be helpful for operators for the operation, maintenance and troubleshooting of the neutron generator.

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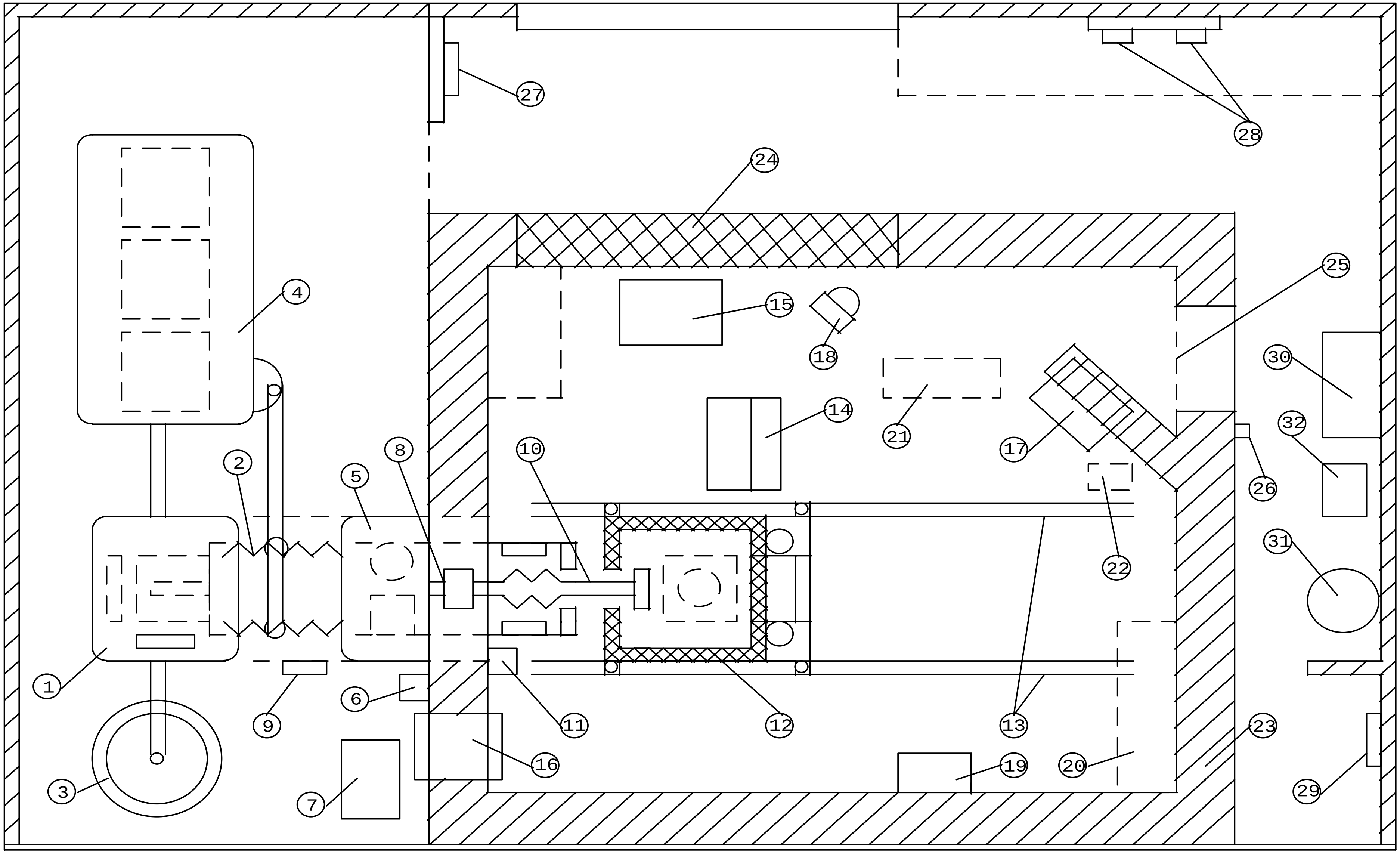


Fig 1. The Pulsed Neutron Generator and experimental hall - scheme

1. Accelerator head with the ion source the and H.F. generator
2. Accelerating tube
3. 220/220 VAC transformer with the H.V. insulation
4. H.V. insulated dome comprising H.V. supplies and auxiliary devices
5. Turbomolecular vacuum pump and rotary vacuum pump
6. Water cooler for the turbomolecular pump
7. Fluid cooler
8. Vacuum valve, X-Y displacement and quadrupole lens
9. Electronic control of the turbomolecular
10. Ion guide and target
11. Rotary vacuum pump
12. Sample camera with thermostatic system
13. Truck rails
14. Electronic rack
15. Long detector (neutron monitor)
16. Airconditioning unit I
17. Airconditioning unit II
18. Fan

19-22. Auxiliary equipment

23. Concrete walls
24. Movable gate
25. Curtain
26. Pilot lamp

27-29. Mains switches

30. Open water tank
31. Closed hydrophore tank
32. Water pump

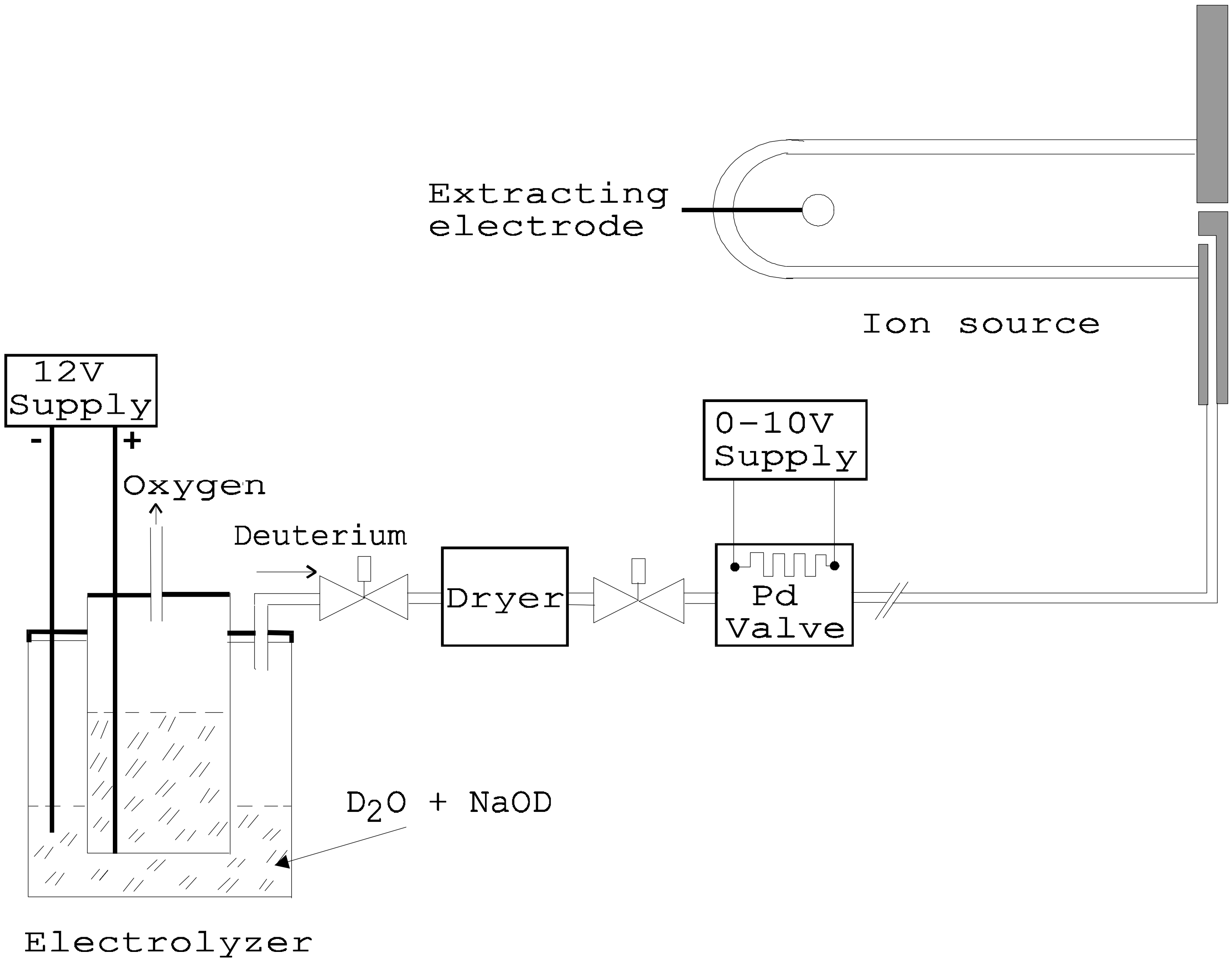


Fig 2. The deuterium supply of the ion source

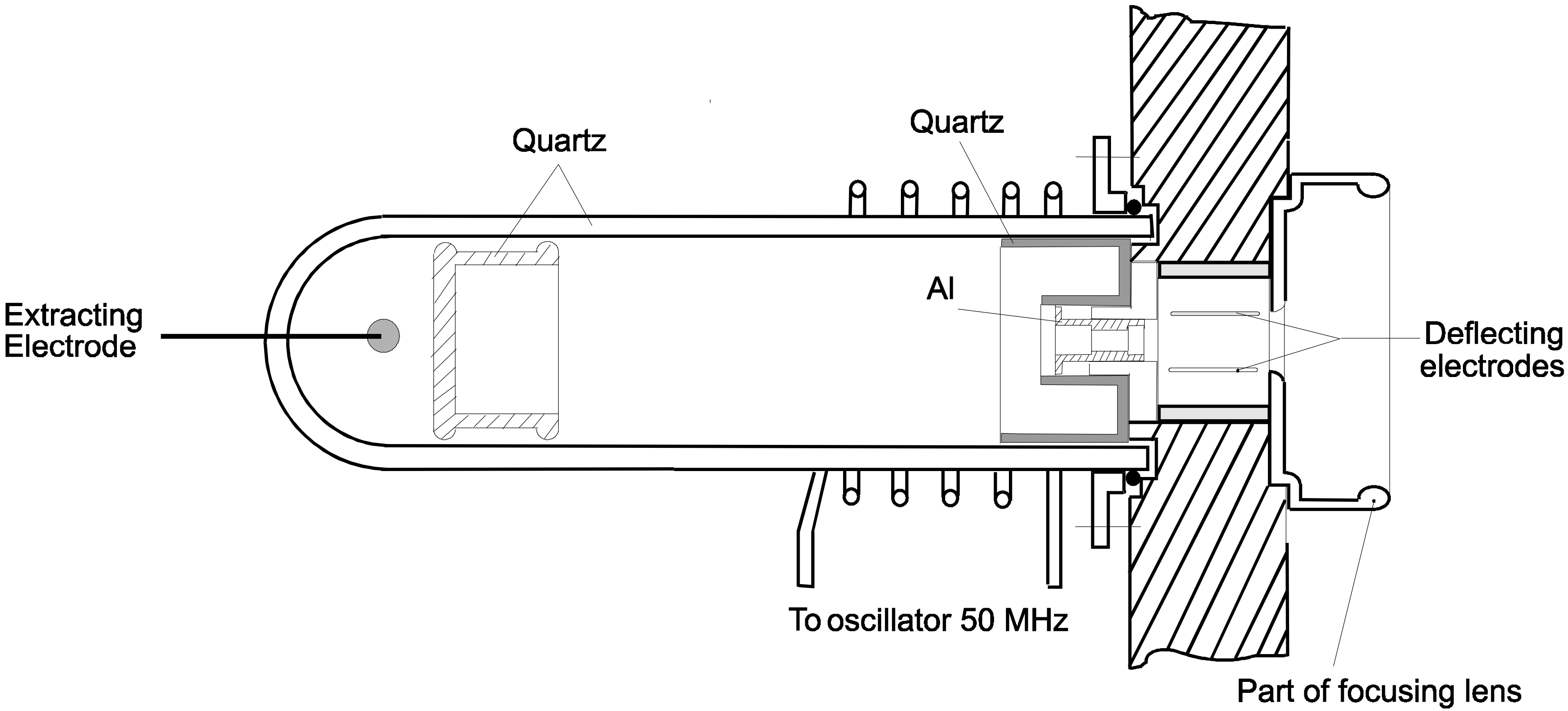


Fig 3. The ion source

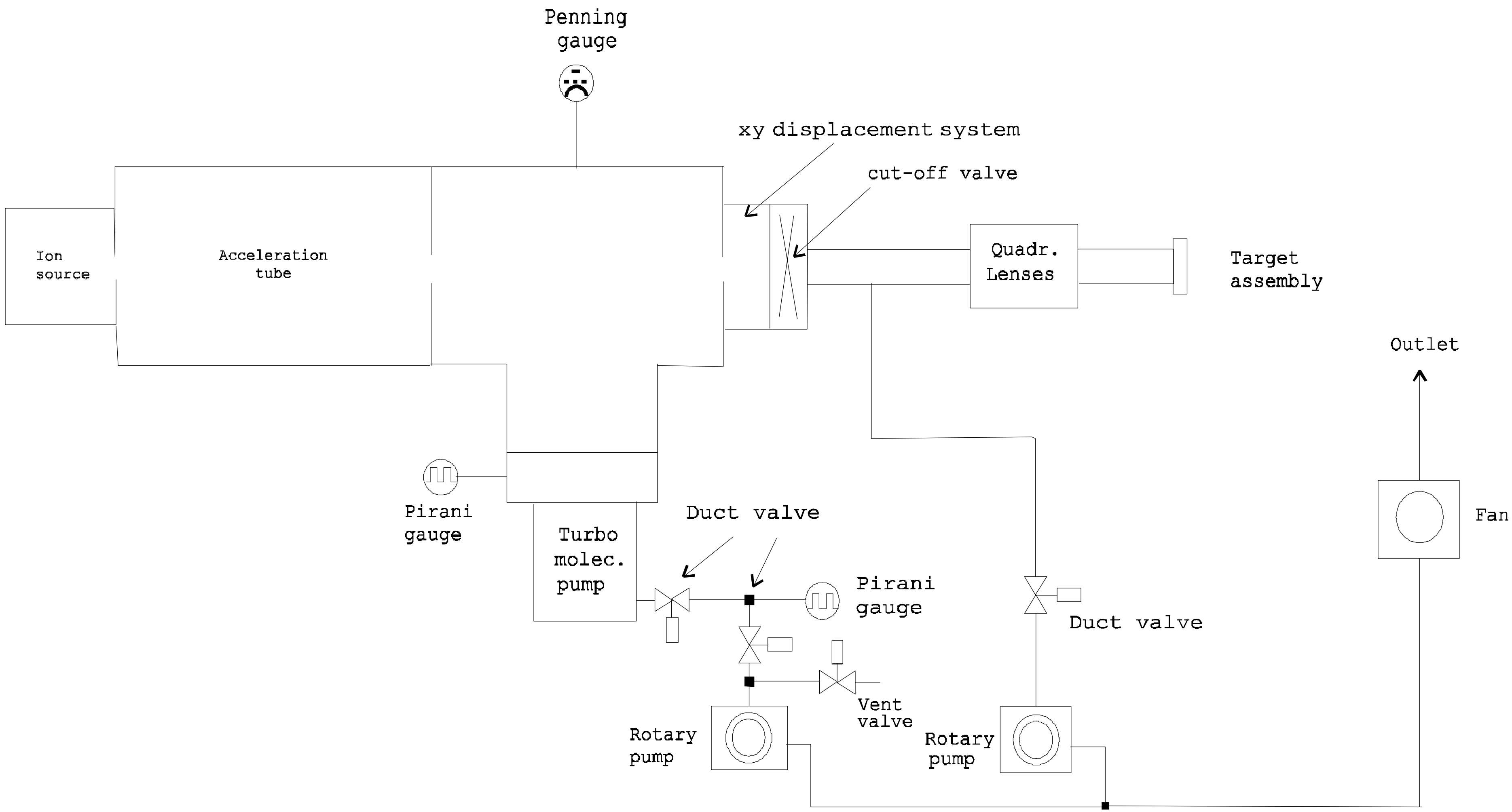
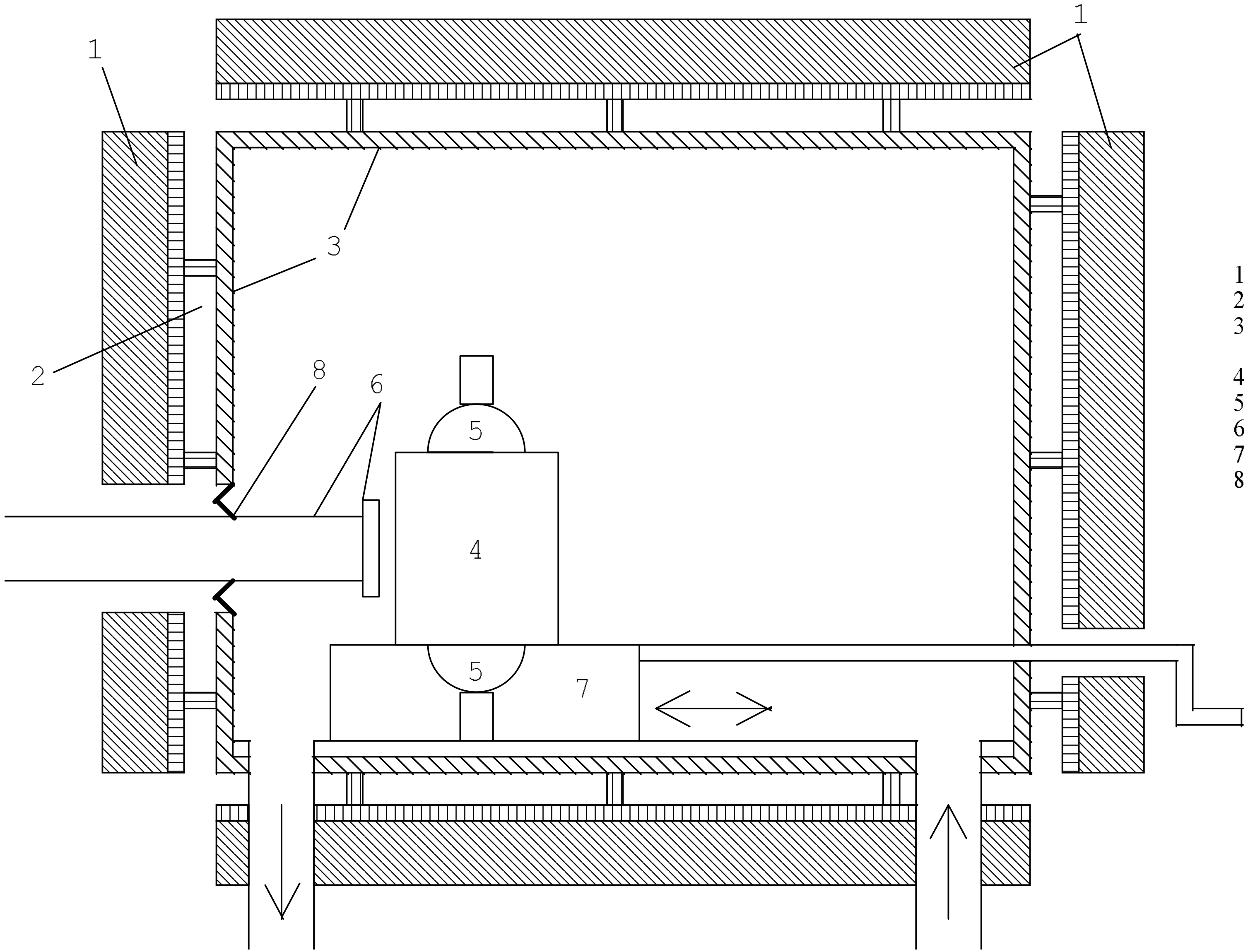


Fig 4. Vacuum system of the neutron generator



1. Borated paraffin
2. Ventillation air gap
3. Aluminium sheet with a thermal insulator cover
4. Sample
5. Detector
6. Ion guide and target
7. Moving table
8. Elastic gasket

Fig 5. The modified sample camera

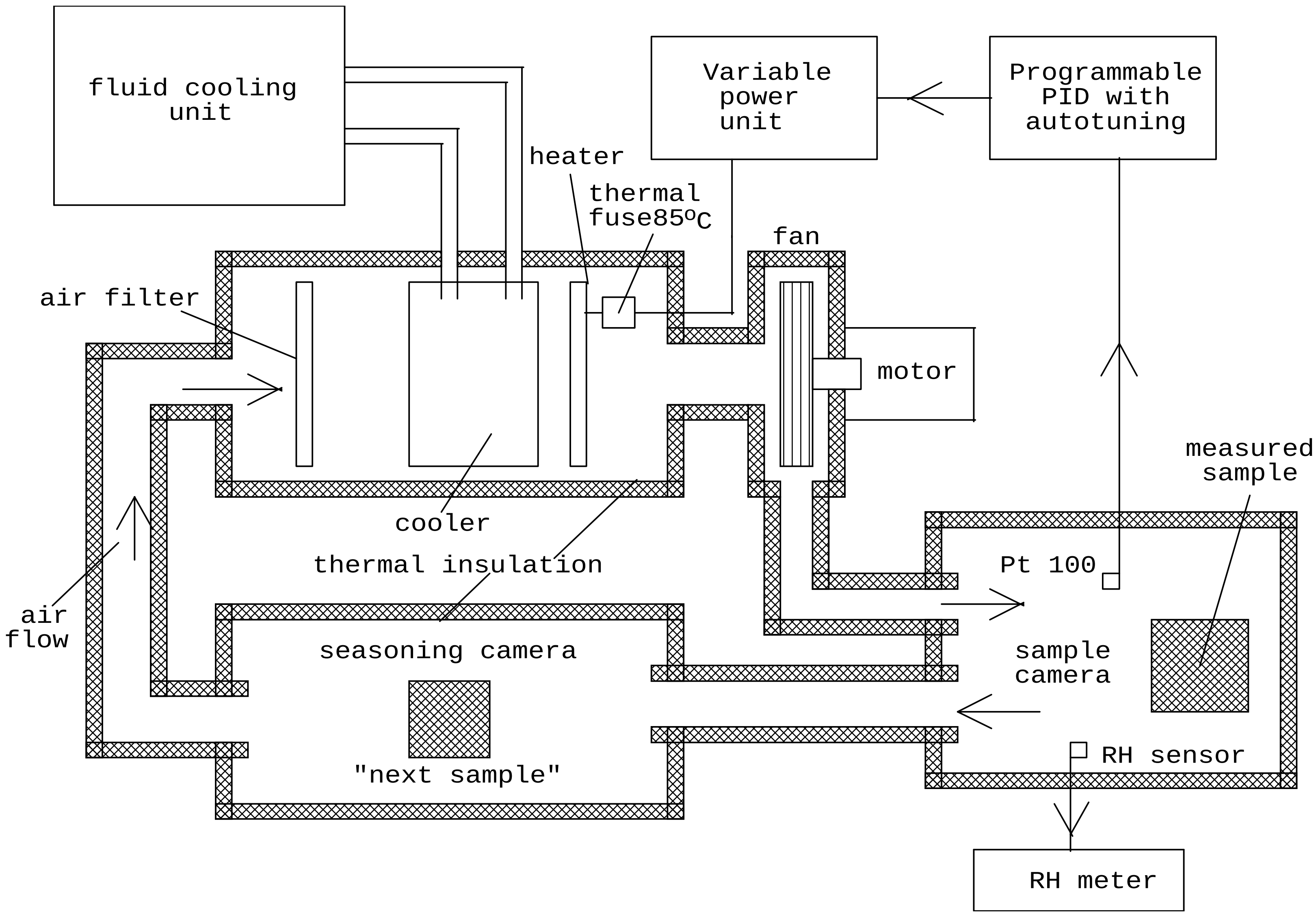


Fig 6. Sample thermostatic system

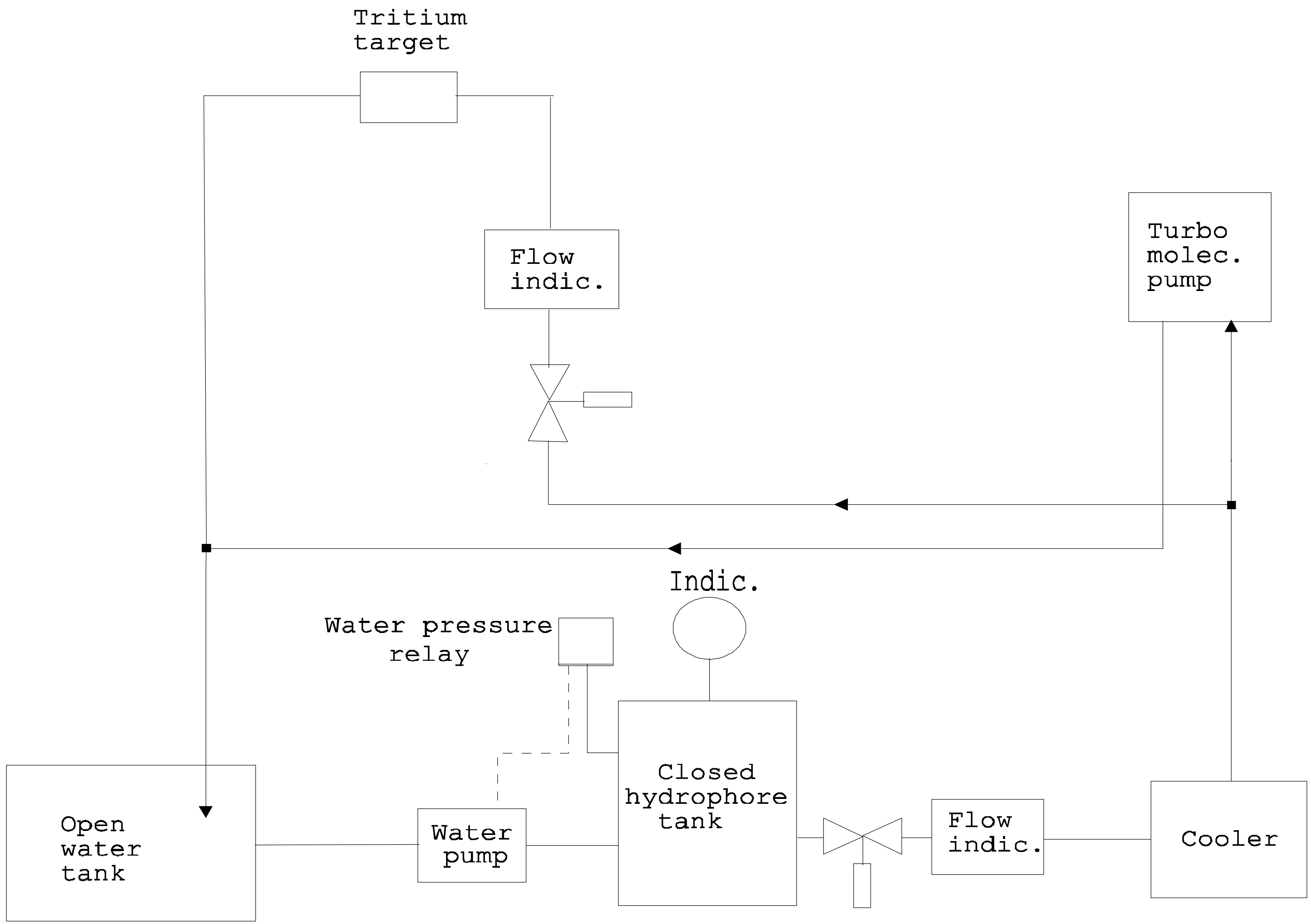


Fig 7. Water cooling system