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MECHANICAL DESIGN OF THE RF CAVITY FOR TERA/PIMMS MEDICAL SYNCHROTRON

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Abstract

In the medical synchrotron, the required accelerating process is obtained with an alternating electrical field at an insulating gap. The revolution frequency varies between 0.4 to 3 MHz, depending on the instantaneous energy of the particles, with a repetition rate of about 1 Hz. The voltage has to be of the order of 5 kV peak at the gap. This is obtained within a RF cavity consisting of two $\lambda/4$ lines operating in push-pull. Since, for practical reasons, the total length should not exceed 1.5 m the line must be heavily loaded with a high μ magnetic material and also with a capacitance at the gap side. Tuning at the accelerator instantaneous frequency is obtained by DC bias of the magnetic material, whereas the resonance at the lowest frequency is obtained mainly by setting the value of the gap capacitance. The electro-mechanical arrangement has been designed and is described in the following.

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INTRODUCTION

The basic structure is from LNS-CEA [1] who has built a first prototype. The laboratory tests have been done by TERA at CERN [2]. These tests showed that the system is able to reach the specifications requested by the medical synchrotron in terms of voltage (5kV peak) and of frequency swing (0.4-3MHz).

The body of the actual cavity needs to be modified and completed in order to make the system operational and safe, and to make simple the assembly and the maintenance. A new arrangement of the RF gap and of the vacuum chamber has been developed. The polarisation bars have been repositioned to avoid breakdowns. The HV circuit and the RF coupling have been improved. Care has been devoted to the ground shielding and on the choice of the RF contacts. What remains unchanged from the LNS-CEA structure are just the magnetic material and the copper cooling disk package.

The description of the whole system is clarified following the picture in Figure 1. The assembly can be divided into 5 groups:

- The internal part, comprising the ceramic gap, the vacuum pipe and a copper envelope, called RF line.
- The magnetic elements with the copper cooling disk package and the bias circuit.
- The external part, comprising the base, the end and lateral plates and the cover.
- The connections to the RF amplifier.
- The water cooling circuitry.

1. THE INTERNAL PART, COMPRISING THE CERAMIC GAP, THE VACUUM PIPE AND A COPPER ENVELOPE, CALLED RF LINE

The RF ceramic gap, see Figure 2, and the vacuum pipe are recuperated from CERN. The pipe has to be cut to the required length. Two stainless steel bellows are put close to the gap, to avoid mechanical stresses in the ceramic. A capacitive divider allows direct measurement of the RF voltage at the gap.
The RF current is composed of an active and reactive part. The active part is dissipated mainly in the magnetic disks, the reactive part would go to the ground through the vacuum pipe. To avoid heating the bellows, the vacuum pipe is by-passed by a copper envelope. This can be seen as the internal conductor of a $\lambda/4$ transmission line. In the following, this conductor is called RF line. The RF current follows its path to ground through this line. At the short, the RF line is cantilevered by elastic RF contacts which insure electrical contact between copper and front-end aluminium plates. At the gap level, two ceramic bars, screwed into the bottom of the cavity, keep

the line in the right position. Sliding RF contacts allow thermal dilatations between the ceramic gap and the RF line. The contact is kept in the right position by a brass collar.

2. THE MAGNETIC ELEMENTS WITH THE COPPER COOLING DISK PACKAGE AND THE BIAS CIRCUIT

The material is an amorphous magnetic alloy (on a Co-basis) called "VITROVAC®"[3]. It consists of a 25 µm thick ribbon, wound in the shape of a toroidal core. Each turn is electrically insulated by the next one by a 0.2 µm thick insulating coat.
The material is enclosed inside a "C" form metallic box, insulated by a kapton film. An independent module is made sandwiching a copper ring, cooled by flowing water, with two magnetic cores, see Figure 3. Six of these modules are aligned around the two $\lambda/4$ RF lines, for a total of 12 modules. In the design space has been provided for 2 additional modules. Two manifolds carry the input and output cooling water.
The magnetic modules stay on two fixed rails. They are biased by four loops in the figure of eight configuration, as is commonly used to put to zero the induced voltage in the bias circuit, see Figure 4. The diameter of these bars is 4 mm, since the maximum bias current is just a few tens of amperes. Four polypropylene thin insulating plates sustain the bars by means of a metallic feed-through to avoid breakdowns.

3. THE EXTERNAL PART, COMPRISING THE BASE, THE END AND LATERAL PLATES AND THE COVER

The cavity body structure has to be easy to access and simple to assembly and maintain. The base is a 10 mm thick aluminium plate, on which are screwed two 40 mm thick aluminium end plates. These end plates represent the reference for the assembly of the other pieces. On them are clamped, at the short circuit side, the two RF lines, with the vacuum pipe inside. The lateral plates are screwed onto the end plates. The back lateral side is closed by just one plate, with two holes for the DC tuning circuitry and two holes for the HV cables. On this plate the low-pass filter for the HV will be installed with the water cooling circuitry. The front side is closed by two plates. These plates can be mounted and dismounted independently from each other. The bottom one can be dismounted allowing an easy access to the bottom of the cavity. The top one is in the form of a comb for the access of the water cooling tubes. The cover plate is an L-shape plate, which allows inside inspection pivoting around an horizontal axis, passing by two points on top of the back end plate. The RF magnetic field generates a longitudinal current. The path of this current is ensured by tight RF contacts.

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[3] Provided by VACUUMSHMELZE GMBH, Grüner Weg 37, D-63450 Hanau.

4. THE CONNECTIONS TO THE RF AMPLIFIER

On the brass collar two conducting strips are screwed to make the connection, via a DC blocking capacitor, to the anode of the power tubes. Screened DC high voltage cables are inserted from the back. They run parallel to the RF line from the end plates to the strips, then follow the strips by-passing the blocking capacitors down to the tubes.

5. THE WATER COOLING CIRCUITRY

The water cooling circuit is separated from the main cooling circuit in order to work independently from the other items and from external constraints. It is needed to cool the 24 (26) magnetic modules and the two RF amplifier power tubes. The maximum requests are 35 l/min for the 26 modules and 35 l/min for each power tube for a total of 105 l/min. This flux is enough to dissipate up to 35 kW from the magnetic modules (about 1.35 kW per disk) and a maximum of 35 kW for each tube. Due to RF power tubes specifications, the inlet pressure should not exceed 5 bars. The scheme of the cooling circuit is presented in Figure 5. The fine regulation of the water distribution is done on a panel fixed on the rear plate of the cavity.

CONCLUSION

The design of the basic structure is completed and is ready to be detailed for the execution stage. It is a matter of a unique specimen that has not been studied in view of a commercial production. Being a prototype, many details, although important, have not been represented because they need to be finalised at the assembly stage.

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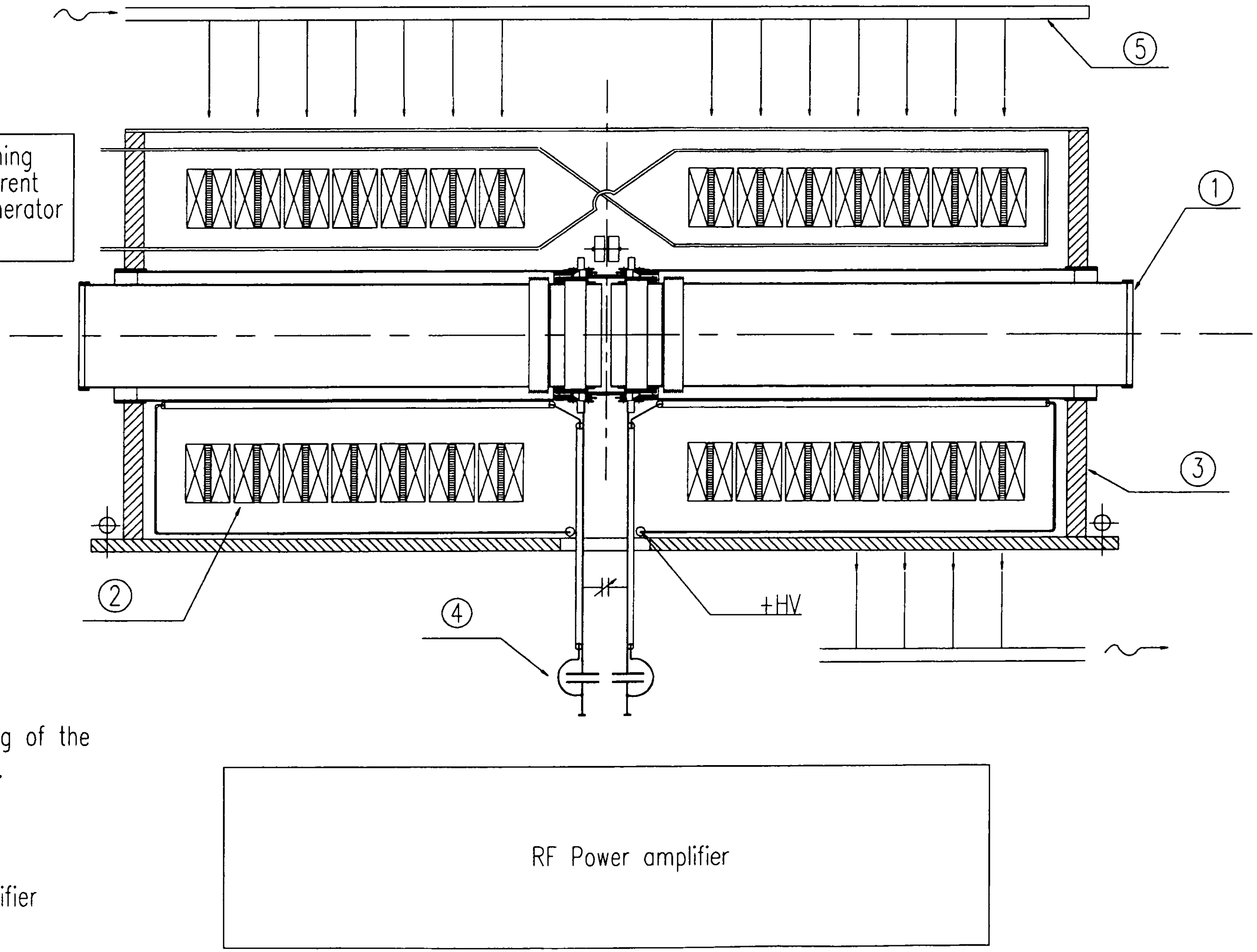

Figure 1. Schematic drawing of the RF cavity (internal section).
1 Internal part
2 Magnetic modules
3 External part
4 Connections to the amplifier
5 Cooling water circuitry

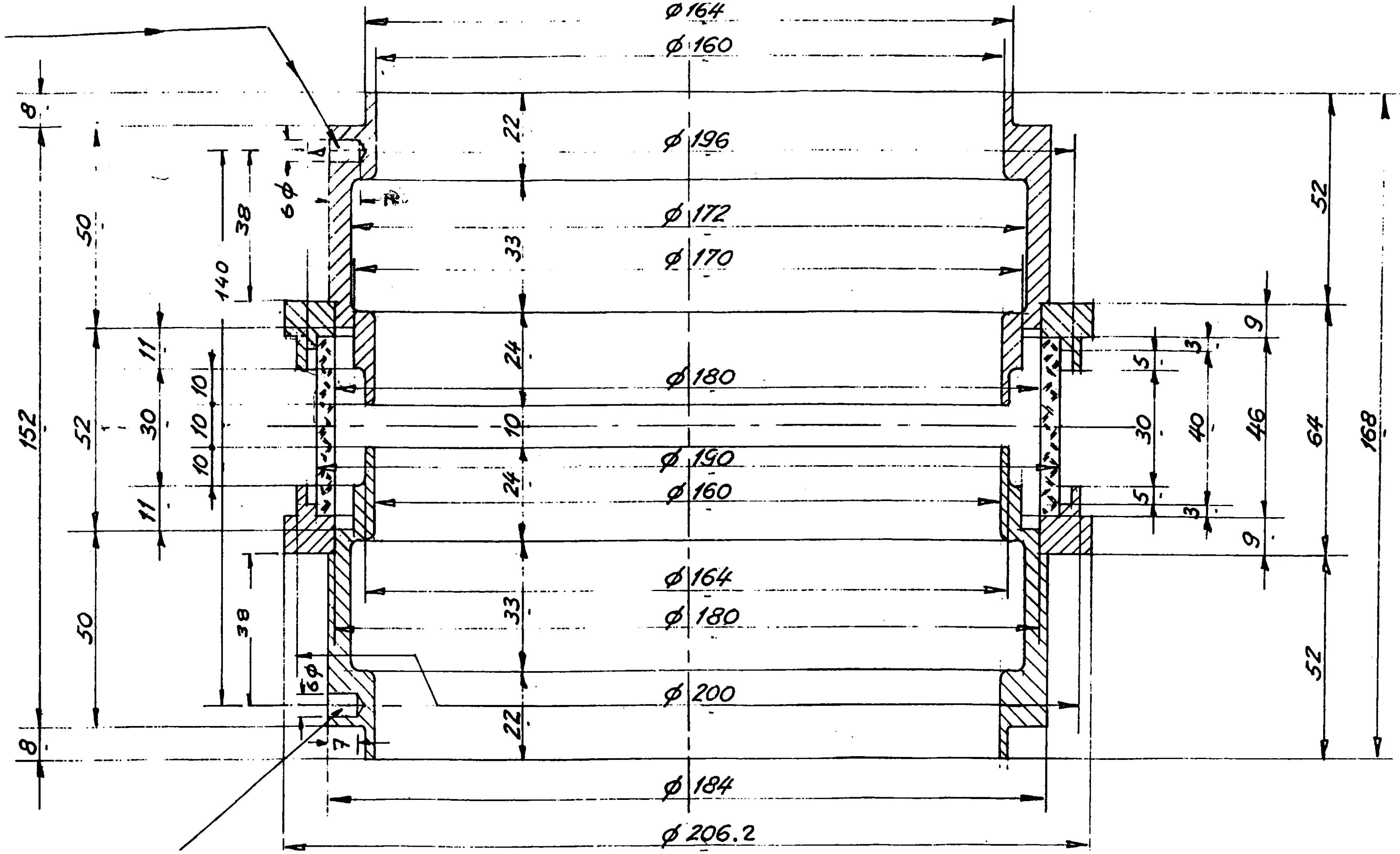

Figure 2. The ceramic gap

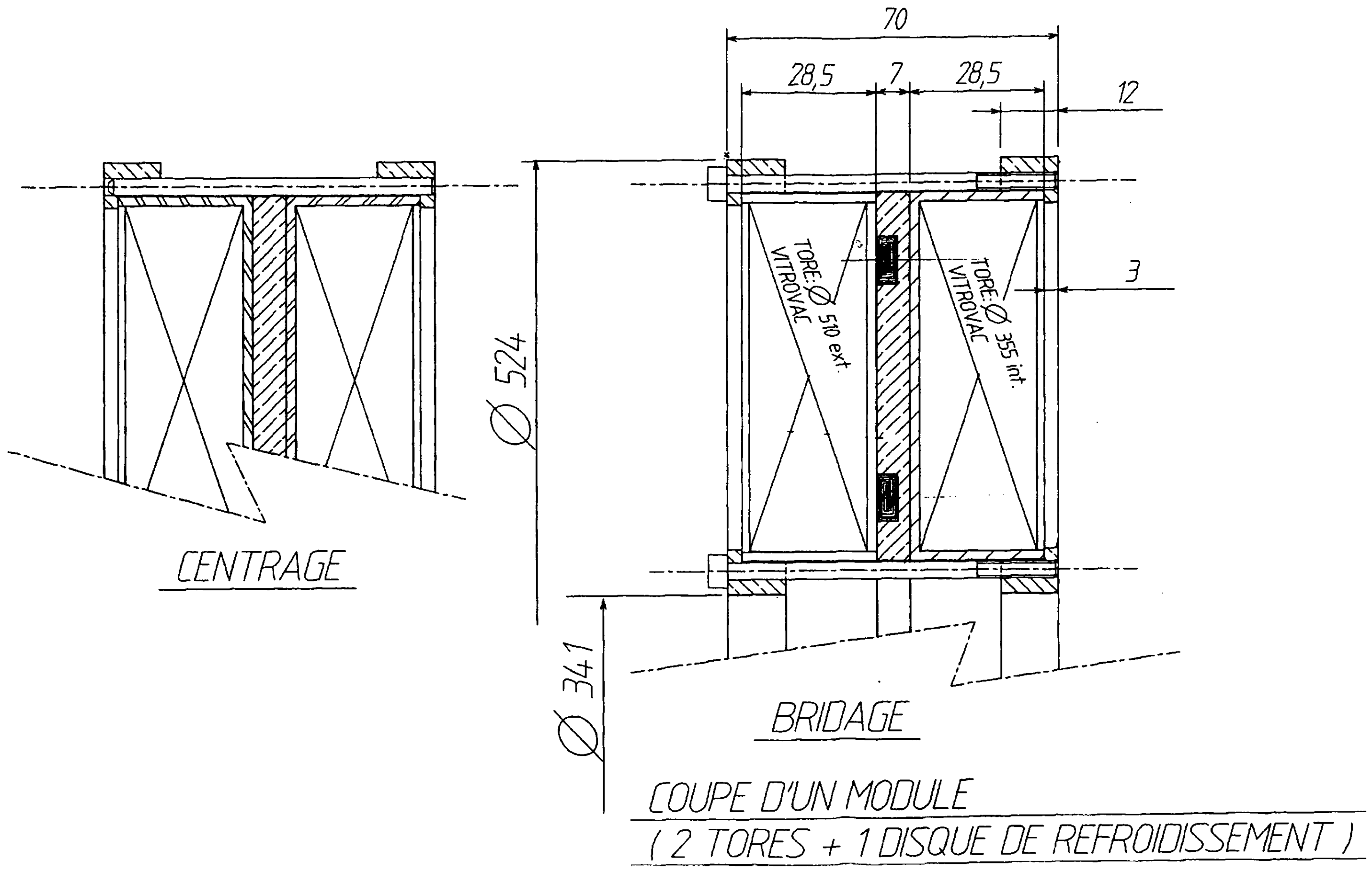

Figure 3. Section of a magnetic module. The cavity is equipped with 24 of these modules (Drawing by courtesy of LNS-CEA).

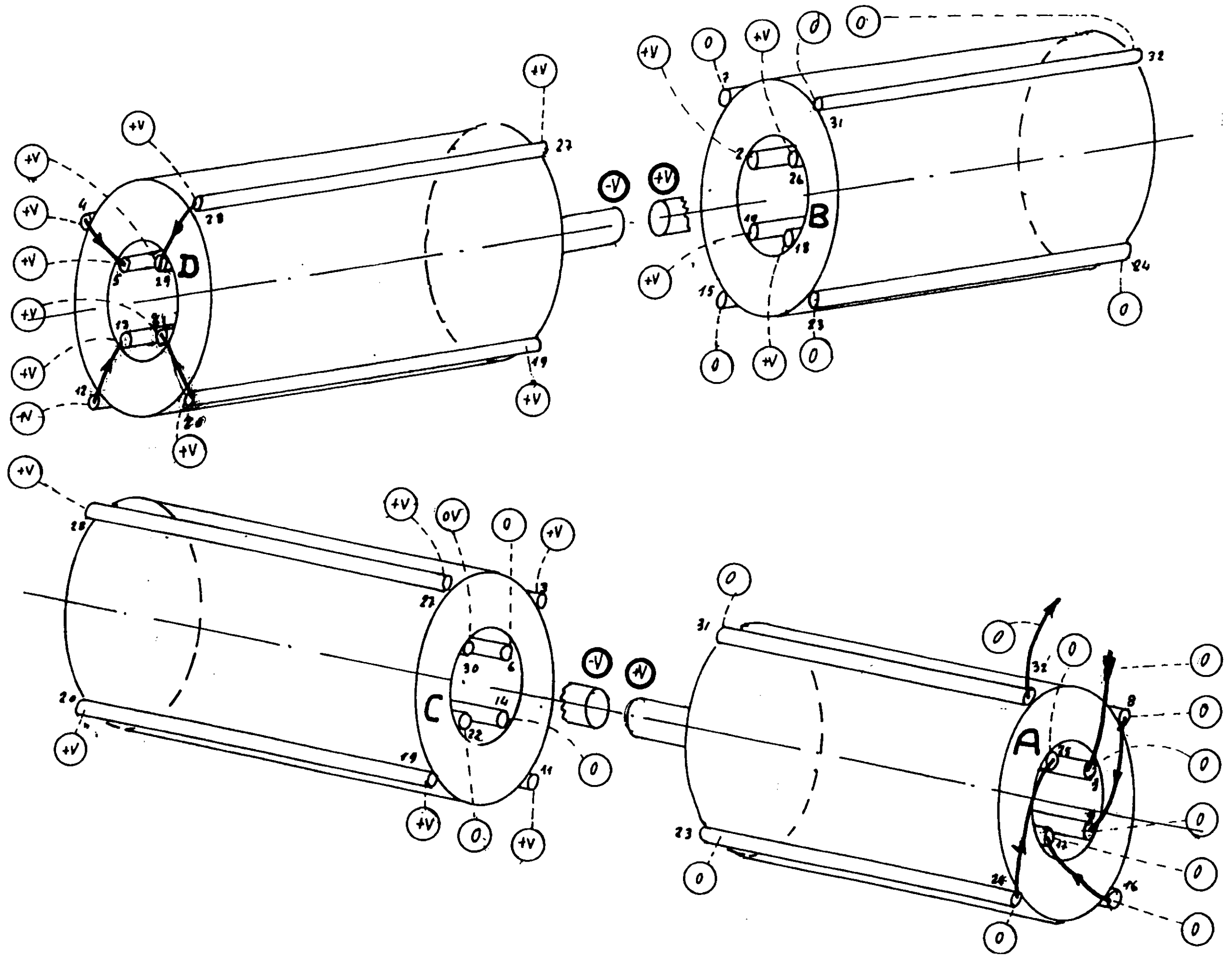

Figure 4. The DC bias system for instantaneous frequency tuning. The 4 bars are put in the figure-of-eight configuration (as can be verified by following arrows and numbers) to put to zero the voltage induced by the RF magnetic field.

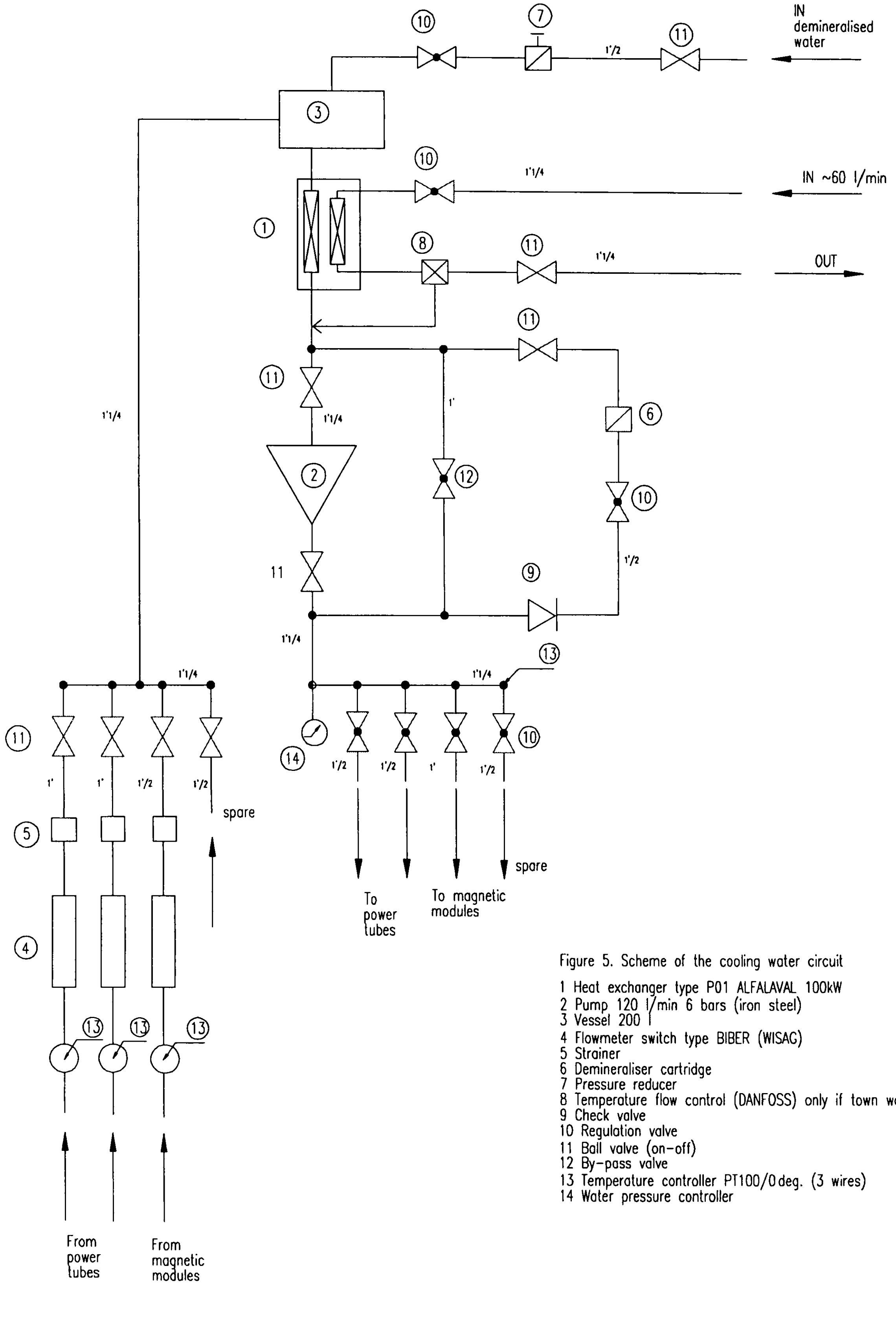

Figure 5. Scheme of the cooling water circuit

1 Heat exchanger type P01 ALFALAVAL 100kW
2 Pump 120 l/min 6 bars (iron steel)
3 Vessel 200 l
4 Flowmeter switch type BIBER (WISAG)
5 Strainer
6 Demineraliser cartridge
7 Pressure reducer
8 Temperature flow control (DANFOSS) only if town water is used
9 Check valve
10 Regulation valve
11 Ball valve (on-off)
12 By-pass valve
13 Temperature controller PT100/0deg. (3 wires)
14 Water pressure controller