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PRELIMINARY DESIGN OF THE RF AMPLIFIER FOR TERA/PIMMS MEDICAL SYNCHROTRON

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Abstract

A single gap push–pull RF cavity is designed to accelerate the therapeutic beams in the TERA/PIMMS synchrotron. In this note the RF amplifier, which is foreseen to power the cavity, is described. The main part consists of two tetrodes tubes operating in push-pull. The power to be installed is about 2x50 kW, and the power gain is more than 13 db. The input signal comes from a commercial RF pre-amplifier.
The actual status of the mechanical design, of the electrical set-up and of the interlock control system is presented. The first two items are in an advanced design stage. The latter exists and is fully operational.

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INTRODUCTION

The final design of the RF cavity is documented in reference [1]. The design of the amplifier follows the specifications and constraints already established by the RF cavity. In particular, the maximum available space is limited by the dimensions of the cavity and by the height above the floor of the nominal beam line, that has been fixed as 1.2 m.

Two coaxial push-pull operated transmission lines with a single gap in the middle constitute the resonator. The power to be installed is about 2x50 kW.

The tetrode tubes SIEMENS RS1084 have been chosen due to their availability at CERN. Indeed, some tubes can be borrowed for low power tests for a limited time. The data sheets can be found in reference [2].

The electrical circuitry is in agreement with the operating characteristics recommended by the manufacturer. The configuration is grounded cathode. The operation mode is class A. Despite low efficiency, this mode has the advantage to produce low distortion. Low distortion is needed because the resonator has low Q (see reference [3]), and any harmonic distortion introduced by the amplifier is found almost unattenuated at the gap voltage. A two-channel 2x500 W commercial pre-amplifier available at CERN gives the RF input to the control grid. For a 5 kW (2x2.5) peak gap voltage on 300 Ω impedance, the gain of the amplifier is about 13 db.

The controls and interlock system is based on a Programmable Logic Controller (PLC). The start-up procedure is automatic, but can be manual for specialist checks. The system has been developed in collaboration with a commercial firm[3], and is fully operational.

Since the allowable volume is quite small (less than 0.9 m^3), the mechanical design has to deal with a precise distribution of the space, to allow location of all the elements. The volume has been separated in three functional zones, the accesses have been carefully studied in order to minimise the efforts for assembly and maintenance, and particular care has been given to the choice of the components. The result is a compact, robust and functional assembly. The conceptual design is completed, whereas some details have not yet been fixed.

1. ELECTRICAL SET-UP

The electrical configuration of the power amplifier is given in Figure 1. To increase the lifetime of the tube, thermal stresses to the filament when switching on and off have to be reduced. Since the filament resistance increases with temperature, the voltage increase has to be slow at start-up, and then progressively increased to reach the voltage working point. Vice-versa at shut down. This is obtained by controlling the voltage at the primary of the filament transformer by a two speed motorised VARIAC.

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An anti-hum system is installed connecting directly the positive of the grid to the cathode via a variable resistor. RF input is fed to the grid via a matched low-pass filter, with a bandwidth of 0.2-10 MHz. The 50 Ω resistive matching load is water cooled, allowing a 1 kW maximum dissipation.

2. CONTROLS, INTERLOCKS AND START-UP PROCEDURE

In Figure 2 a global view of the controls and interlocks is presented, with each power tube belonging to a control and interlock chain. The system is completely automatic. The start-up procedure is divided in three levels. Level one starts all the services: cooling water, fan, and control grid power supply. There is then a one-minute wait to allow the working conditions to be properly established. Then level two starts and the anode and screen power supplies are switched on. For tube protection the screen power on is delayed by a few seconds. Finally level three gives the RF input to the power tubes.

A PLC controls the whole system. The procedure can be automatically started by a simple push button by the operator, or can be manual. In this case, the operator can follow and check level by level on the PLC screen the set-up of the system.

The interlock system is also automatically set. If there is a fault, it appears directly on the screen for an immediate check and recovery. If the fault refers to an element belonging to level two or three, the services of level one still remain in function. If the fault appears on level one and is not recovered within one minute, all the procedure has to be restarted.

In Figures 3, 4, and 5 the procedure is explained with some detail.

3. MECHANICS

The base support for the cavity is shown in Figure 6. The 80x80 mm iron bars form the skeleton. Two lateral bars and another bar at the rear are added, to give sufficient stiffness to sustain the weight, estimated to about 600 kg. The spatial positioning with respect to the beam axis is not too critical for the RF cavity. A precision in position of ±1 mm in the three axes is sufficient.

Externally, the amplifier appears as a closed structure on wheels, to be inserted below the cavity. Internally it is divided in three parts: the RF well, the bottom well and the rear emplacement.

Once in position the structure is lifted and then fixed by special hooks to keep it in contact with the bottom part of the base plate of the cavity. The ground return is insured by means of special pressure RF contacts via a thin copper layer.

The RF well (see Figure 7).

This contains the power tubes, the tuning capacitors and the water tube connections. To guarantee the confinement of the electromagnetic field inside the cabinet and a controlled path of the anode current to ground, it is important to have a closed cabinet for the RF well.

A silvered brass cover enclosing the anode and fixed to it ensures the HV contact. The upper contact with the blocking capacitor plate is made with special elastic RF contacts. The total blocking capacitance is obtained with twelve capacitors in parallel for a total of about 25 nF for each tube.

Two tuning capacitors (Jennings) are fixed between the two anodes. The capacitance is varied by two helipot-like turn-buttons on the front panel.

The cooling water comes from the distribution system. The needs per tube are about 35 l/min for an inlet temperature of 35°C at 5 bar, see Figure 8. Additional space has to be allocated for the water tubes and connections. The input and output tube length is about 1 m to insure high impedance (the water conductivity should be better than 100 kΩ/cm).

- **The bottom well.**

This locates the air-cooled socket. The required flow per tube is 0.6 m^3/min at 1.5 mbar. This flow is generated by a fan and directed to the socket from the bottom.
Beneath the socket there is a variable rheostat for hum suppression, an RF filter for the control grid RF input and a 50 Ω water cooled matching load.

- **The rear emplacement.**

All the services are placed here. There is room for the filament transformer, the motorised VARIAC, the fan, a box containing the sockets for interlocks and controls, and a box for the main power distribution. The HV cables come directly on the rear side of the cavity, via a low-pass filter. In Table 1 the list of the fundamental elements is presented.

Table 1. List of the fundamental elements composing the RF amplifier

Element	Num.	Type	Dimensions x,y,z	Use
Rheostat	2	LCC 10Ω	L=100, Ø=80	Hum suppression
Filament transformer	2	Step down 220-12.5V, 2.5kW	220x240x200	Power filament
RF power tube	2	SIEMENS RS1084 CJ, Tetrode	H=400, Ø=200	RF power generator
Socket	2	SIEMENS Q81-X-1852	H=100, Ø=265	Power tube support
Fan	1(2)	MARELLI	350x350x350	Air cooling filament
VARIAC	2		H=200, Ø=150	Filament voltage controller
Motor	2	24Vdc 1 turn/min	L=140, Ø=140	VARIAC control
Resistive load	2	BIRD 50Ω 1kW water cooled	L=120, Ø=15	Control grid matching load

CONCLUSION

The mechanical design and the electrical set-up design of the RF amplifier are almost completed. The controls and interlock system has been designed, developed, and is now operational. The final design and the practical mechanical and electrical construction are strictly connected and need now to proceed in parallel.

ACKNOWLEDGEMENTS

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REFERENCES

[1] M. Crescenti, G. Primadei, and A. Susini. *Mechanical Design of the RF Cavity for TERA/PIMMS Synchrotron,* to be published.

[2] SIEMENS. *Data Book Transmitting Tubes*, Edition 1996 pp.101-110.

[3] M. Crescenti, G. Primadei, and A. Susini. *A New Compact Large Frequency-Swing RF System for Hadron Acceleration: Test Results*, CERN/PS 97-60 (DI).

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PIMMS Study Team

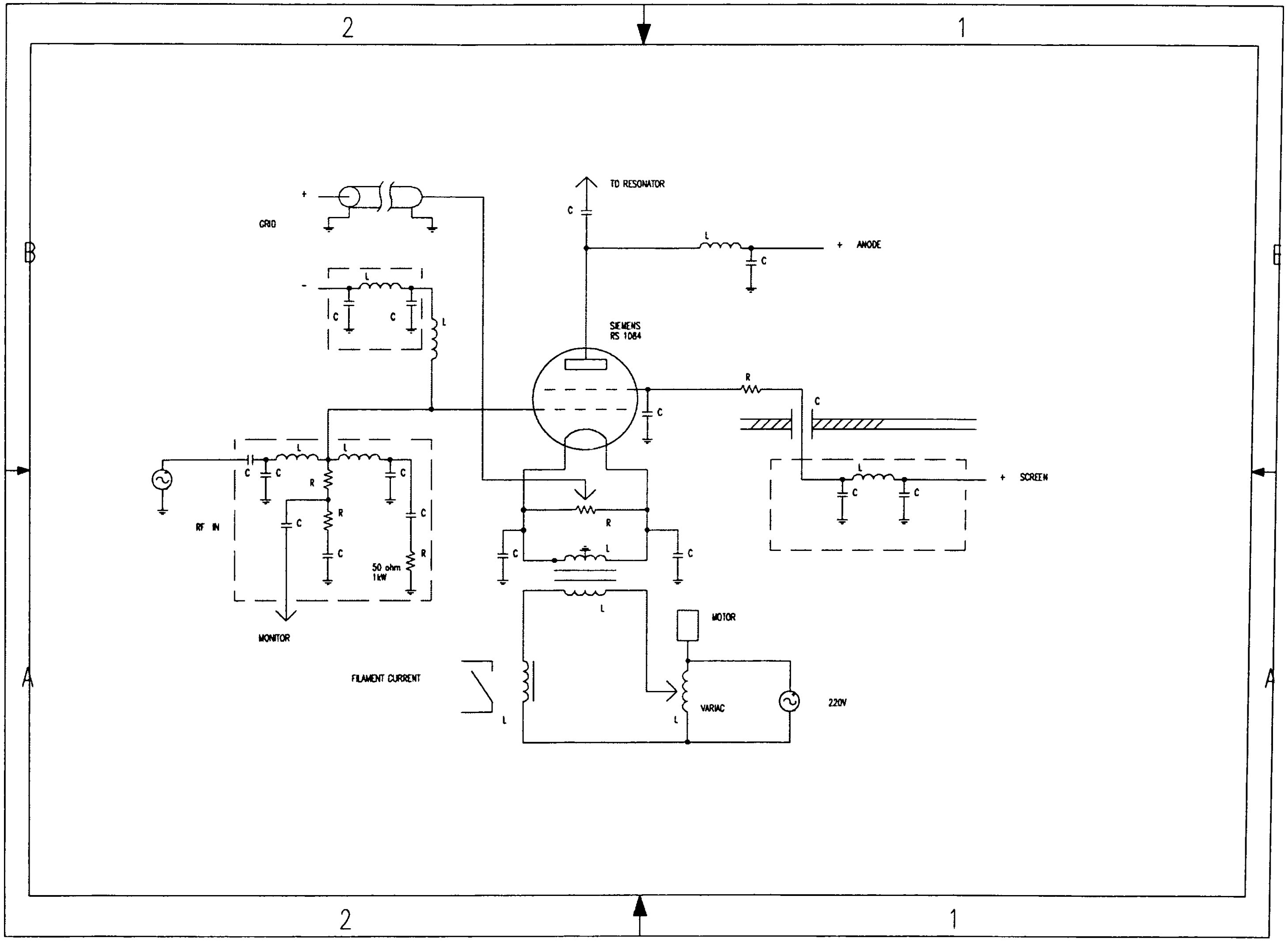

Figure 1. Electrical configuration of the amplifier module

RF controls & interlocks, global view

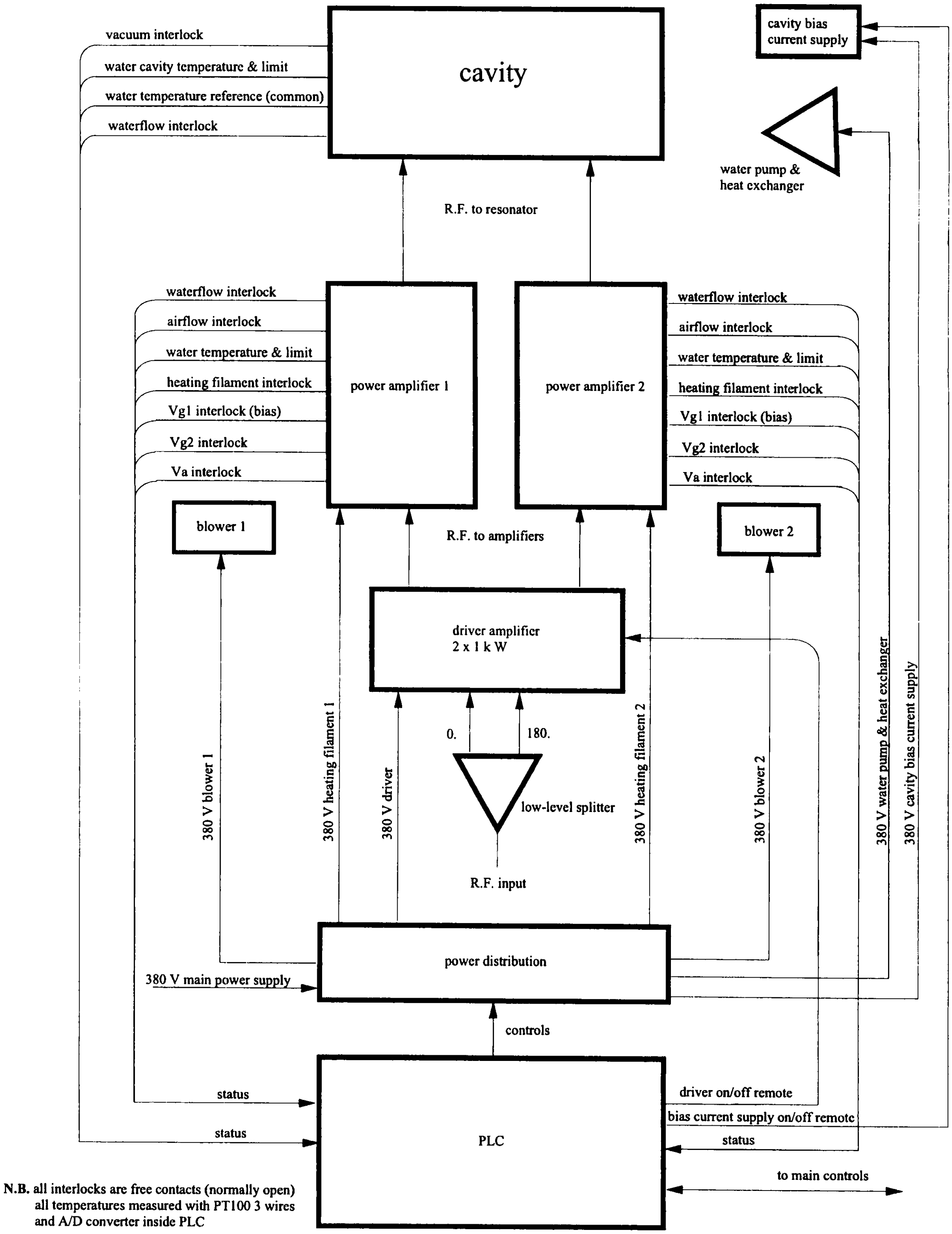

Figure 2. Global view of controls and interlocks

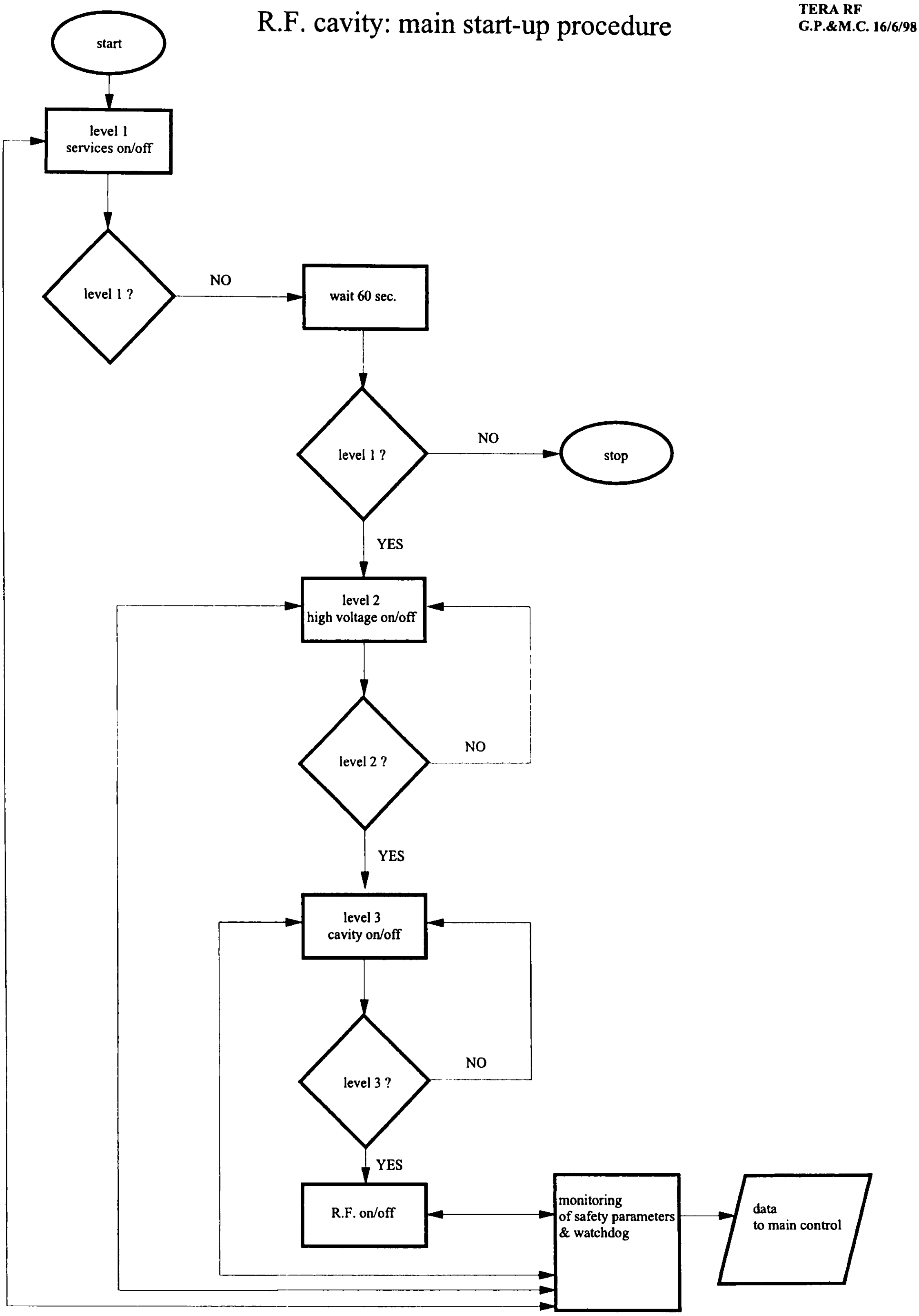

Figure 3. RF cavity main start-up procedure

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logic chain interlocks

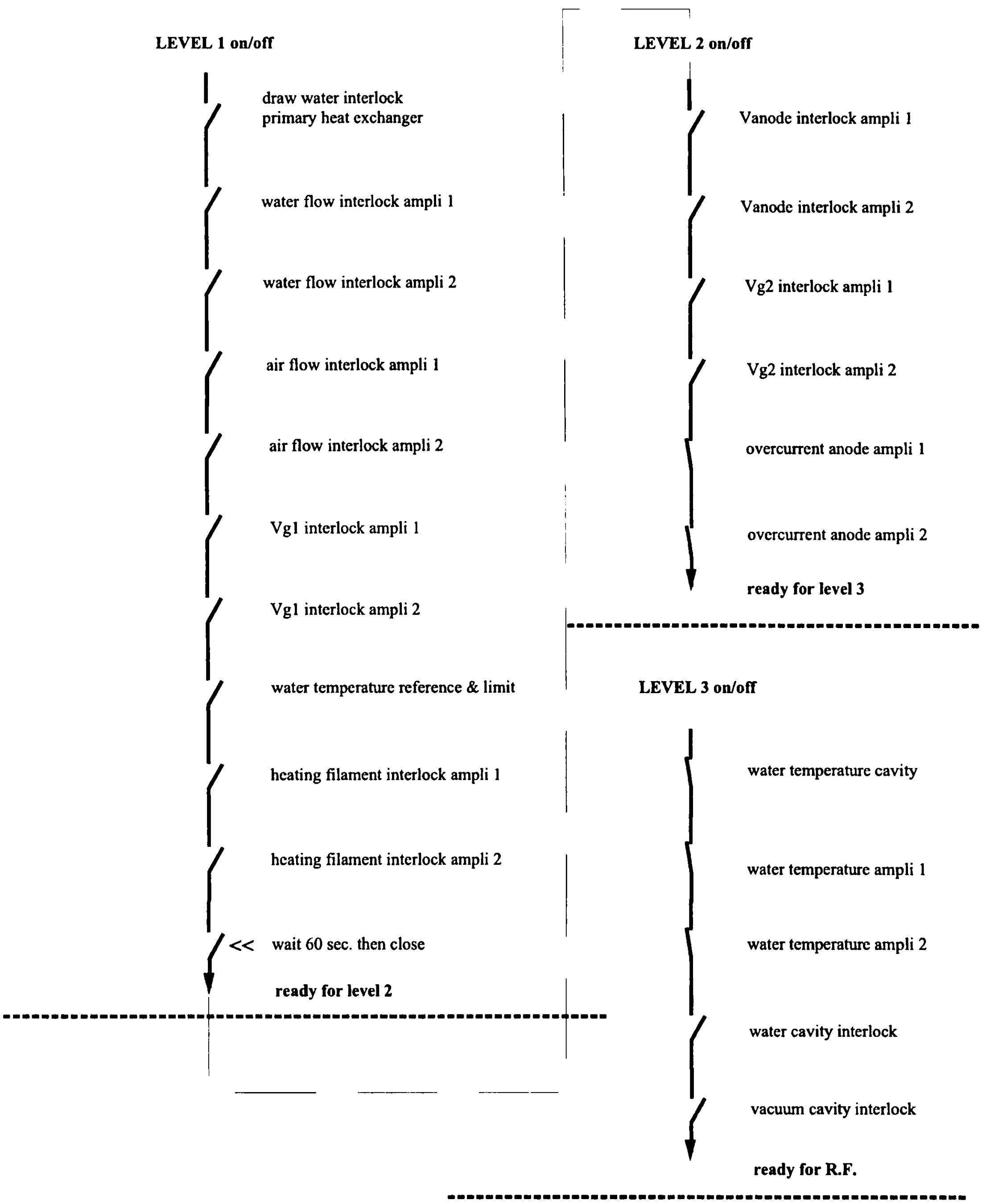

Figure 4. Logic chain interlocks sequence

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Controls : schematic diagram

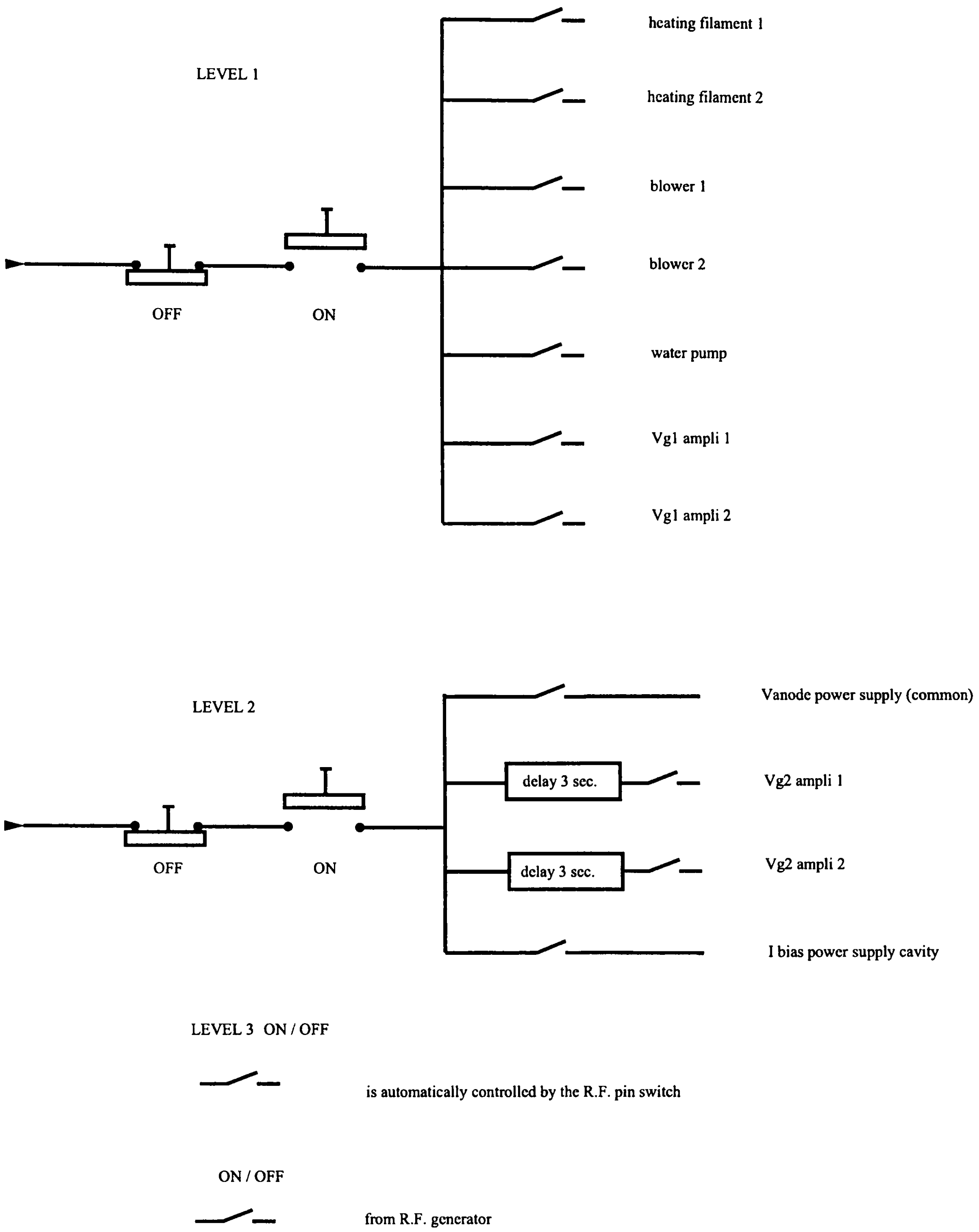

Figure 5. Controls: schematic diagram

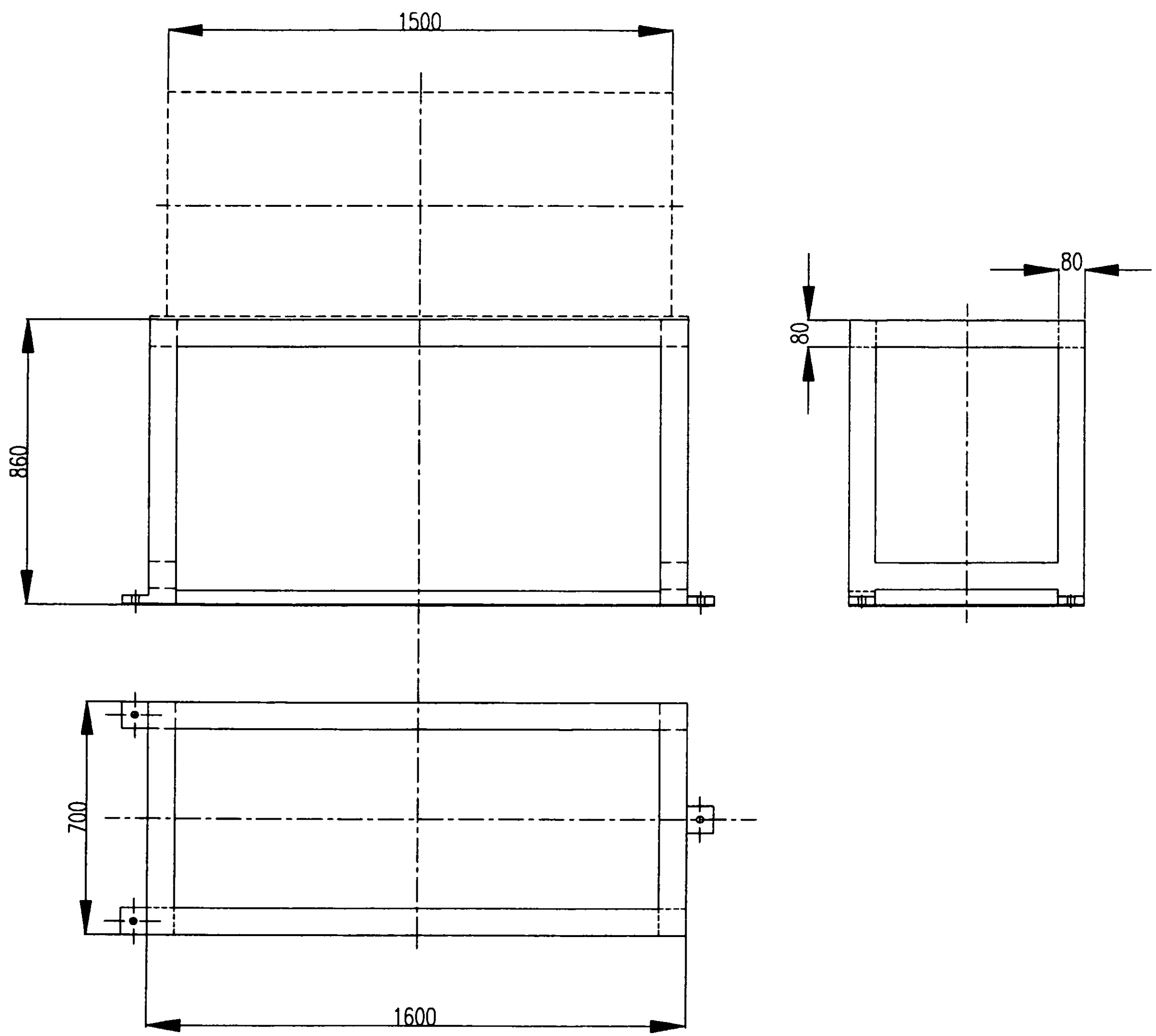

Figure 6. Cavity base support

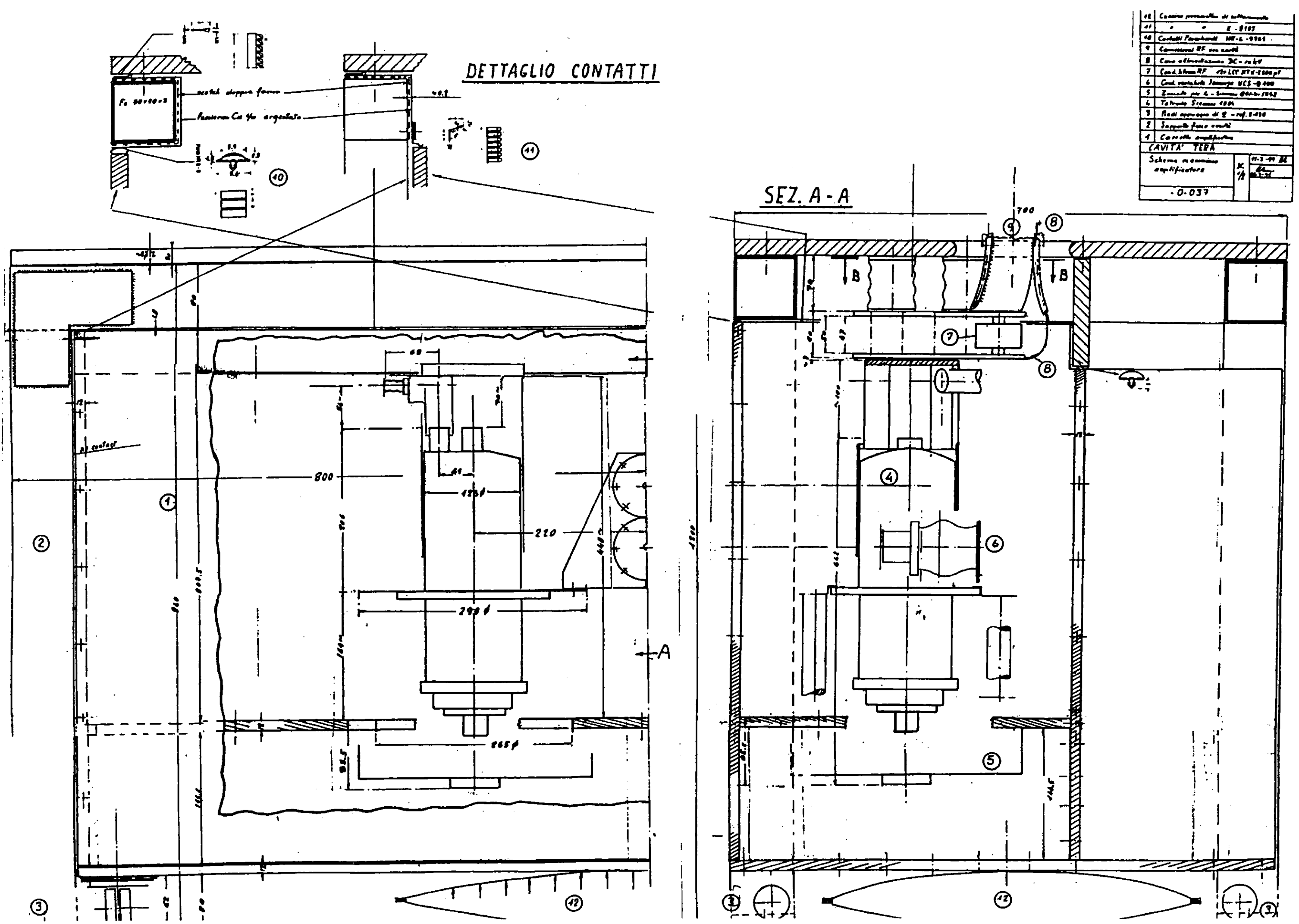

Figure 7. Technical drawing of the amplifier, detail of the RF well.

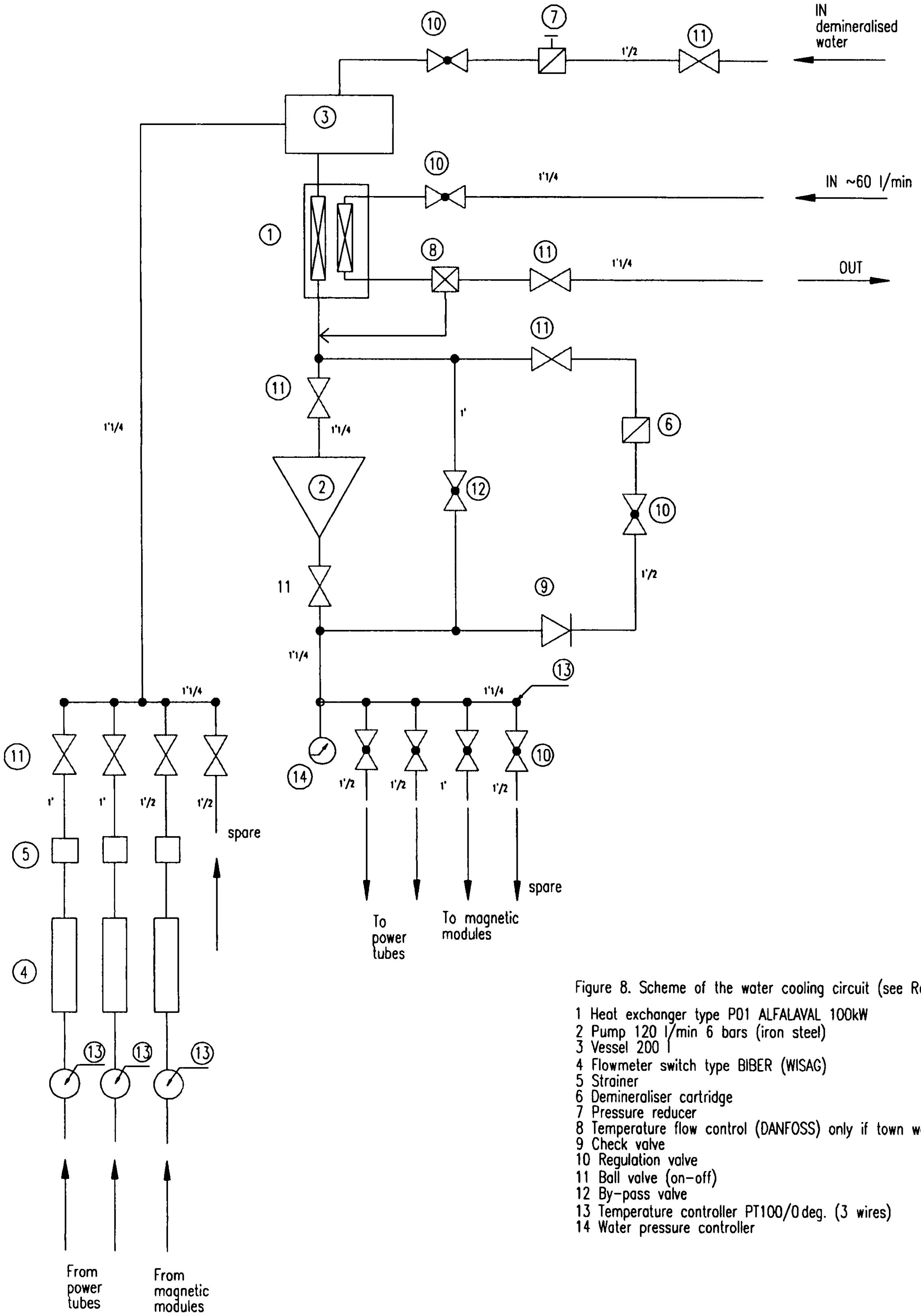

Figure 8. Scheme of the water cooling circuit (see Ref. [1])

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 PT100/0 deg. (3 wires)
14 Water pressure controller