RF POWER LOAD FOR PROSCAN

M. Schneider, W. Tron, Ch. Geiselhart, A. Scherer, D. Bieri

*High power tests of a RF (**R**adio **F**requency) amplifier require a matched load for the conversion of RF power into heat. The load for the PROSCAN RF amplifier was built at PSI. It is a 50 Ω wideband load and can dissipate up to 300 kW RF power. A solution of sodium carbonate in water is used as the absorbing material*

INTRODUCTION

The COMET cyclotron will be supplied with RF from an amplifier made by Bertronix. This amplifier operates at 72 MHz and delivers about 150 kW RF-power. PSI will provide a 50 Ω wideband power load (Voltage Standing Wave Ratio (VSWR) ≤ 1.15) for commissioning and for the acceptance tests. Since the load will be permanently installed, we will be able to test the amplifier on a load during maintenance at the cyclotron.

There are two possible ways to realise such absorbers. The first one is to use a water cooled solid silicon resistor but that would be very difficult at the power levels required in this case.

The second method is to use a solution of sodium carbonate in water. Building a water column and changing the mixing ratio of water and sodium carbonate provides a simply variable resistor. The solution efficiently transports the heat away. The solution of sodium carbonate in water acts both as the absorbing material and the cooling medium.

DESIGN

The RF theory of an ideal absorber is described in [1, 2]. We take a coaxial line and replace the inner conductor by a resistor. To avoid reflections, the transmission line must be terminated by a resistor with the same value as the characteristic impedance of the line. Starting from the RF connection end, the characteristic impedance of the coaxial line has to be the same as the impedance of the remaining resistor at each point along the absorber.

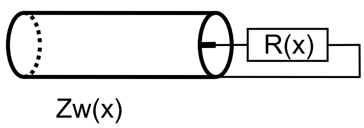

Fig. 1: Simplified electrical scheme of the absorber.

The characteristic impedance Zw for a coaxial line is given by:

$$Zw(x) \approx 60\,\Omega \cdot \ln\left(\frac{D(x)}{d}\right) \qquad (1)$$

where D is the diameter of the outer conductor, d the diameter of the inner conductor and x is the axial position in the load.

The resistor R_0, in our case the solution of sodium carbonate, has the nominal impedance of the absorber, which is 50 Ω. Depending on the axial position (x), the resistance changes from 0 to 50 Ω. (l is the full length of the resistor)

$$R(x) = R_0 \cdot \frac{x}{l} = 50\,\Omega \cdot \frac{x}{l} \qquad (2)$$

The condition for zero reflection is given when Eqs. 1 and 2 are equal. The outer diameter of the coaxial line as a function of x can then be solved:

$$D(x) = d \cdot e^{\left(\frac{50\,\Omega}{60\,\Omega} \cdot \frac{x}{l}\right)} \qquad (3)$$

The result is shown in Eq. 3. Because it is difficult to fabricate a tube with this shape, the exponential function is approximated by 4 steps using 5 tubes of different diameters. As a result, the bandwidth of the load is reduced.

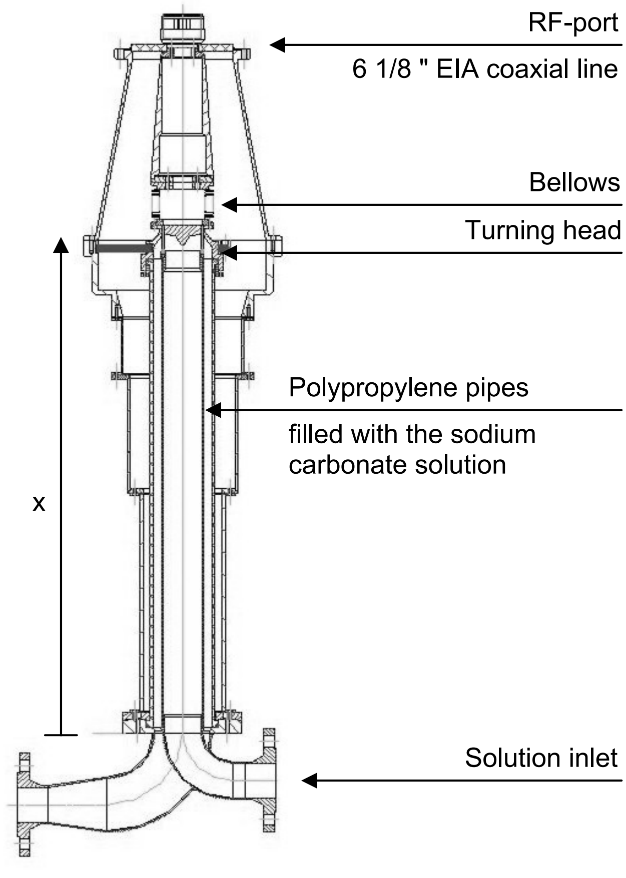

Fig. 2: Cross-section of the absorbing unit.

The sodium carbonate solution column is made from two concentric polypropylene pipes. The solution flows up the inner pipe to the turning head and returns downwards in the space between the two tubes as shown in Fig. 2. While the solution is being heated up, the polypropylene pipes change their lengths. To avoid mechanical forces, the turning head is connected to the inner conductor of the coaxial line using a bellow.

In addition to the absorbing unit itself, a system is required to cool the sodium carbonate solution. In Fig. 3 the tank containing 300 litres of the sodium carbonate solution can be seen in the lower right corner underneath the absorbing unit. Driven by a circulation pump (black object in the centre) with a capacity of about 250 l/min, the solution passes through a heat exchanger before it flows through the absorbing unit. The primary side of the heat exchanger is cooled by a water circuit fitted with a valve to allow the temperature of the sodium carbonate solution to be controlled. All circuits are designed for an absorbed power up to 300 kW. Finally, a device is needed to control the temperature of the solution. The temperature is measured before and after the absorbing unit and the average is regulated. From these two temperatures, the dissipated power in the absorber can be calculated in a calorimetric way.

Fig. 3: The complete absorber system.

MEASUREMENTS

The load was tested by heating up the sodium carbonate solution with an immersion heater. The VSWR was measured via a cone at the RF port with a Rhode & Schwarz Network analyser.

Fig. 4 shows an optimal operation point for 72 MHz near 55°C. To reach this region from a cold start, the RF-power is used. One handicap of this method is that, during this warm-up time, the absorber is not well matched and the amplifier power level has therefore to be limited. Once up to temperature, the control system stabilises it within a range of 3°C.

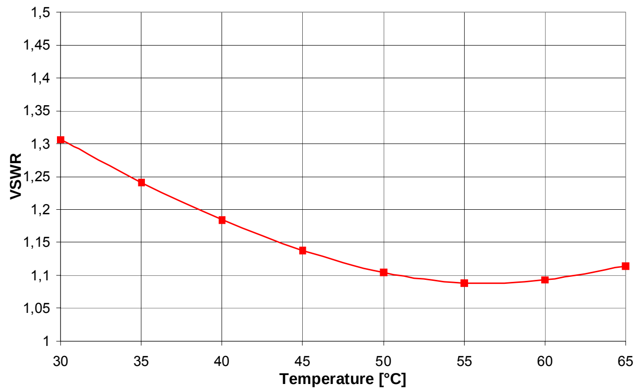

Fig. 4: Measurement of the VSWR versus the temperature at 72 MHz.

The VSWR versus the frequency at a solution temperature of 55°C is shown in Fig. 5. Up to 280 MHz, the VSWR is below 1.15. At the operating frequency of 72 MHz, the value is 1.09. We can conclude that we have achieved our goal and are looking forward to run the load with the new amplifier.

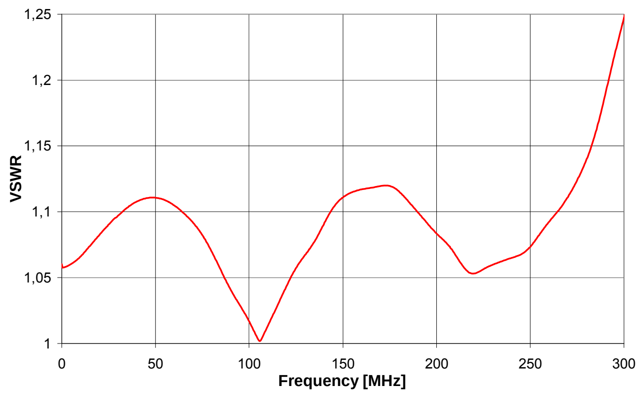

Fig. 5: Measurement of the VSWR in function of the frequency.

REFERENCES

[1] Meinke / Gundlach, *Taschenbuch der Hochfrequenztechnik*, 3. Auflage, Springer-Verlag, p. 376 - 378, 1968.

[2] M. Märki, *Hochleistungsabsorber für einen grossen Frequenzbereich,* SIN TM-04-18, 1970.