CONDITIONING OF RF CAVITIES AND RF INPUT COUPLERS FOR SPring-8

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Abstract

We have been conditioning rf cavities and rf input couplers for the booster synchrotron and for the storage ring of the SPring-8. In this conditioning, the rf input power to the cavity is controlled by a computer using CAMAC modules. The power is increased paying attention not to exceed a limit of vacuum pressure in the cavity. We have successfully finished the conditioning of eight cavities and eleven input couplers for the synchrotron ring. The conditioning of cavities and couplers for the storage ring is underway.

1 INTRODUCTION

The SPring-8 is facilities of a synchrotron radiation source in Japan with high brilliance in X-ray region [1]. The SPring-8 is composed of a 1 GeV pre-injector linac, an 8 GeV booster synchrotron and an 8 GeV storage ring. The resonant frequency of rf cavities for the synchrotron is 508.58 MHz and the maximum voltage is 18.7 MV. Two 1 MW klystrons are used to drive eight five-cell cavities. The maximum wall loss is estimated to be 250 kW. The conditioning was carried out with the maximum input power of 250 kW. As for the storage ring the frequency is 508.58 MHz and the nominal voltage is 12.9 MV [2,3]. There are four rf stations in the storage ring. Each station has eight single-cell cavities driven by one 1 MW klystron. The nominal wall loss of the single-cell cavity is 50 kW. The conditioning is carried out at the maximum input power of 120 kW which is allowed with the thermal analysis. In the synchrotron and the storage rings, same type of rf input coupler is used to feed rf power to cavity. The conditioning of the input couplers (its nominal input power is 300 kW) is carried out at the maximum power of 270 kW, which is limited by the cooling system for the five-cell cavity.

2 SYSTEM FOR CONDITIONING

The rf power flow is as follows (see Figure 1). The rf signal is generated by a synthesized signal-generator. An rf switch cuts the rf power by interlock signals caused by such as an extremely high pressure (more than 5×10^{-4} Pa), a large rf reflection from the cavity (larger than 20 kW) and an arc in the circulator. The interlock signals are latched until a reset signal is received. A linear rf modulator modifies the rf level according to a control signal from the computer. The klystron can amplify the rf signal up to 1 MW. The output of the klystron is transmitted through the waveguide system of WR1500. A Y-junction type circulator with a 50 kW dummy load is used to protect the klystron against the reflected rf power from the cavity. A directional coupler is used to monitor the input and reflected power in the waveguide. The cavity is tuned at 508.58 MHz by the tuner.

There are two radiation shield rooms made of concrete blocks and iron plates. One is used for the conditioning of the five-cell cavities and the rf input couplers, and the other is used for the conditioning of the single-cell cavities. A waveguide switch is used to select the rf path to the A shield room or the B room.

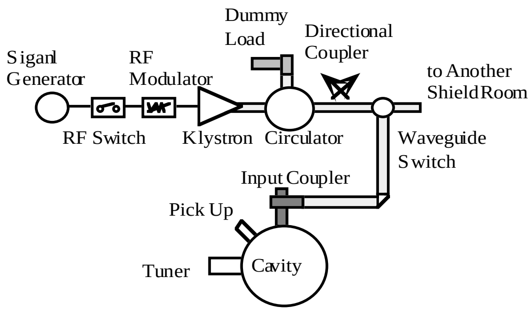

Figure: 1 Set up of the conditioning.

The vacuum system is composed of a 400 l/s ion pump and a 300 l/s turbo molecular pump (TMP) with a roughing pump. The vacuum pressure is monitored by a cold-cathode gauge because of its fast response time (less than 50 msec). When we replace the cavity or the coupler, we purge the cavity with dry nitrogen gas through a leak valve with a 2 µm filter.

The baking of the cavity is done in another room because of saving time of the conditioning process. A 250 l/s TMP is used for evacuation. A programmable heater controller is used to control the current of heaters. The rate of temperature rise and down is 10 ˚C/hr. The temperature is increased to 150 ˚C and is kept constant for 120 hours and 70 hours for a five-cell cavity and a single-cell cavity, respectively.

A demineralized water line cools down the cavity, the circulator, the dummy load and the klystron body. The total water flow is about 400 l/min and the temperature is kept at 33 ± 1 ˚C. The water flow in the five-cell cavity is more than 200 l/min and that in the single-cell cavity is about 120 l/min. A tap water line cools down the klystron power supply and the demineralized water line. The water flow is totally about 3500 l/min and the temperature is kept at 30 ± 2 ˚C.

3 COMPUTER CONTROL

A computer program has been developed for the conditioning. The rf input power is controlled by a personal computer through CAMAC modules. The cold-cathode pressure gauge, the linear rf detectors, the linear rf modulator, the klystron power supply and so on are connected to the CAMAC modules.

We have five operating modes; UP, DOWN, CYCLE, STEP and AUTO. In UP mode, the rf power is increased to a preset value (RFmax) gradually. The power is increased when the vacuum pressure is lower than the threshold value (PL). The pressure is monitored for 1 second after the power increase. If the pressure exceeds the higher threshold value (PH), the power is decreased immediately. When the pressure is between PL and PH, the input power is kept at the value until the pressure becomes lower than PL. If the power reaches the value of RFmax, the power is kept at the value. In DOWN mode, the power is decreased to a preset value (RFmin) if the vacuum pressure is lower than PL. The pressure is monitored for 1 second after the power decrease. If the pressure is higher than PL, the power is kept at the value until the pressure becomes lower than PL. Figure 2 shows the action in UP and DOWN modes.

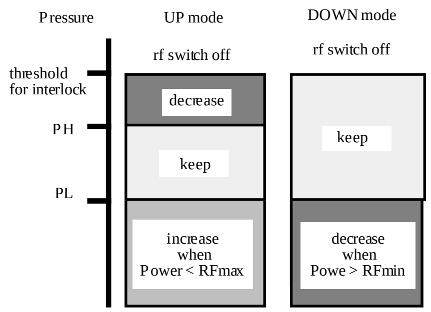

Figure: 2 Action in UP and DOWN modes.

The modes CYCLE, STEP and AUTO are the combination of UP and DOWN modes. In CYCLE mode, the power is changed repeatedly between RFmax and RFmin in order to reduce the multipactoring in the full range of power. In STEP mode, the power is increased with a preset power step and time interval. This mode is provided to measure the relation between the temperature of the cavity and the input power. The AUTO mode is a combination of the UP and CYCLE modes and the conditioning is done automatically.

The interlock can be reset by the computer to continue the conditioning. If the interlock signal comes from the failure in the klystron power supply, the computer makes a phone call to the rf staff. If the interlock is caused by another reason, the reset signal is sent from the computer to the switch when the vacuum pressure becomes lower than PL, and the conditioning is automatically restarted.

4 RESULTS

4.1 Five-cell Cavities

A typical example of a vacuum pressure change during the baking period is shown in Figure 3. The pressure increased as the temperature of the cavity rose. The pressure reached maximum of 8×10^{-4} Pa at 150 °C, decreased gradually, and reached the minimum pressure of 3.5×10^{-6} Pa after cool down of the cavity.

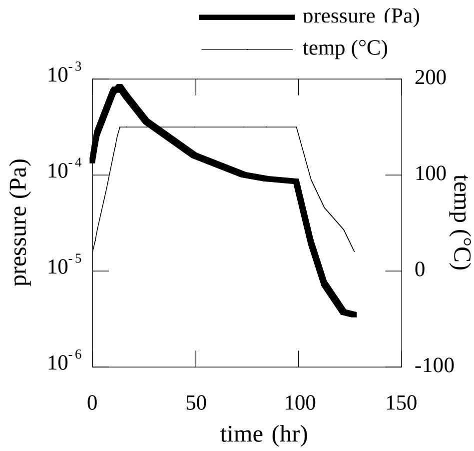

Figure: 3 Chart of the pressure and temperature of a five-cell cavity at baking.

The conditionings of the eight five-cell cavities were carried out in the early stage. The increase of the rf power was done in day time and the power was kept to be constant in night. The value of PL was chosen between 5×10^{-5} and 2.5×10^{-4} Pa. The value of PH was usually set above that of PL by 2×10^{-5} Pa. Typically it took for 1.5 days to reach RFmax, then the power was kept at the value for 1 day or more. The final vacuum pressure was reached around 5×10^{-5} Pa at RFmax. An example of a change of the power and the vacuum pressure for the five-cell cavities is shown in Figure 4.

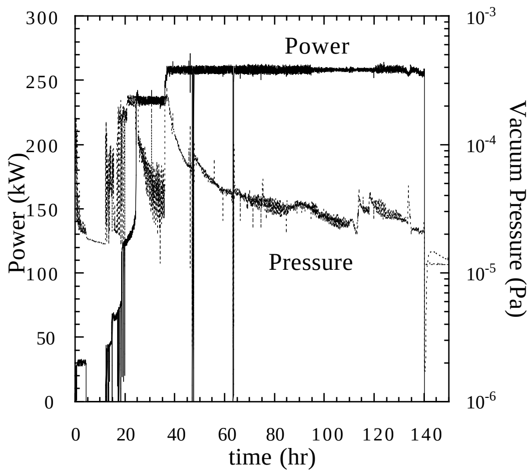

Figure: 4 Chart of the rf input power and the vacuum pressure.

In the conditioning of the first cavity, the power was fluctuated after the power reached to RFmax. It was caused by the fluctuation of the voltage of the 6.6 kV AC line. After that time, the power control function was added in the program and the power was kept steady. In the conditioning of another cavity the vacuum pressure gradually grew up and exceeded the threshold value after about 30 minutes. We found that one of the movable tuners was not cooled properly. After the replacement of that tuner we could continue the conditioning.

4.2 Single-cell Cavities

At baking of the single-cell cavity the pressure usually reached maximum of about 1×10^{-4} Pa at 150 °C, decreased gradually, and reached the minimum pressure less than 1×10^{-6} Pa after cool down of the cavity.

In the conditioning of the single-cell cavities, the value of PL was chosen between 5×10^{-6} and 5×10^{-5} Pa. The value of PH was set above that of PL by 1×10^{-5} Pa. It typically took for 4 hours to reach RFmax and the power is kept at the value for one day. The final vacuum pressure was reached around 2×10^{-6} Pa at RFmax.

We finished the conditioning of eight single-cell cavities. An example of a change of the power and the vacuum pressure for the single-cell cavities is shown in Figure 5. The value of PL was set to 3×10^{-5} Pa. The pressure reached to 1.3×10^{-4} Pa with increasing power. The power reaches to 120 kW in 3 hours and is kept at the value for 15 hours. The pressure is decreased gradually as the time passes. Then the power is modulated from 30 kW to 120 kW repeatedly (CYCLE mode). The period of the modulation was about 10 minutes. After that, the power is increased in 5 kW step with the interval of 7 minutes (STEP mode). In CYCLE and STEP modes, the vacuum pressure is lower than 8×10^{-6} Pa at full range of power. The final vacuum was 3.4×10^{-6} Pa at 120 kW.

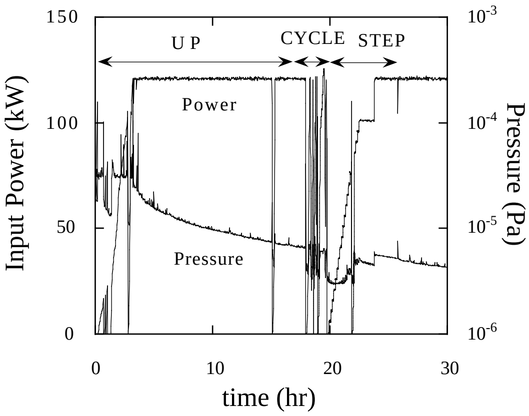

Figure: 5 Chart of the rf power and the vacuum pressure.

4.3 Input Couplers

In the conditioning of the input couplers, the value of PL was chosen between 5×10^{-5} and 1×10^{-4} Pa. The value of PH was set about 2×10^{-5} Pa above the value of PL. It typically took for 10 hours to reach RFmax and the power is kept at the value for one day. The final vacuum pressure reached around 2×10^{-5} Pa at RFmax.

In the conditioning of the first coupler, the proto-type five-cell cavity was used. After conditioning, this coupler was used for the conditioning of the five-cell cavities. Then the conditionings of ten couplers were carried out using one of the conditioned five-cell cavity. After the five-cell cavities and couplers were installed in the synchrotron, the proto-type cavity is used for the conditioning of couplers again. The conditionings of couplers for one rf station of the storage ring were already finished.

The temperature of a ceramic window of the coupler rises as the input power increases almost linearly. Figure 6 shows the temperature as a function of the power.

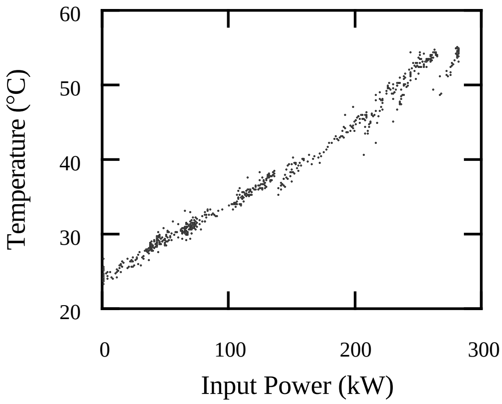

Figure: 6 Temperature of a ceramic window of a coupler as a function of the rf power.

5 CONCLUSION

The conditioning of couplers and cavities for the synchrotron and those for one rf station of the storage ring have been successfully completed. Our computer control system is very helpful to shorten the time needed for conditioning.

The couplers and five-cell cavities for the synchrotron have already installed. The couplers and cavities for one of the rf stations of the storage ring have just installed. The conditioning of those for remaining rf stations of the storage ring is underway.

REFERENCES

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