HIGH POWER CONDITIONING OF THE DTL-1 FOR THE CSNS*

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Abstract

The RF tuning of the first DTL tank for the China spallation neutron source was finished leading to a stabilized-uniform accelerating field. After the installation of the DTL-1 in the linac tunnel, the high power conditioning was carried out deliberately. Consequently a peak RF power of 1.6MW with 25Hz repetition rate and 650 μ sec pulse width was put into the tank stably. A 3MeV H- ion was injected into the DTL-1 and was successfully accelerated to 21.6MeV with almost 100% transmission. During the operation, The DTL-1 tank worked stable in the design power level. The conditioning details will be presented in this paper.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is an accelerator-based neutron source being built at dongguan, Guangdong province in China. The accelerator consists of an 80MeV linac and a 1.6GeV rapid cycle synchrotron. The injection linac is comprised of an H^- ion source, a LEBT, a 3 MeV RFQ, a MEBT and a 324MHz Alvarez-type Drift Tube Linac. The DTL section consists of four independent tanks, of which the average length is about 8.6 m. Each tank is divided into three short unit sections for ease of fabrication and assembly. The inner diameter of the tank is 560mm. Each drift tube accommodates an electro-quadrupole magnet [1]. The first DTL tank which contains 63 full DTs and 2 end-plates was assembly precisely in the testing room. The RF tuning of DTL-1 was successfully performed in the testing room by using bead-pull method, and the cavity was stabilized by the post-couplers [2]. After then, the DTL-1 was transferred to the linac tunnel (figure.1). Limited by the capability of the crane in the linac tunnel, the tank has to be dismantled during the transportation. The realignment result as shown in figure2 confirmed us that the positions of DTs remain unchanged. We also measured the E-field distribution after the reassembling of the tank. Compare to the results we get from the testing room, no obvious change was found.

Figure 1: CSNS DTL-1 in the linac tunnel.

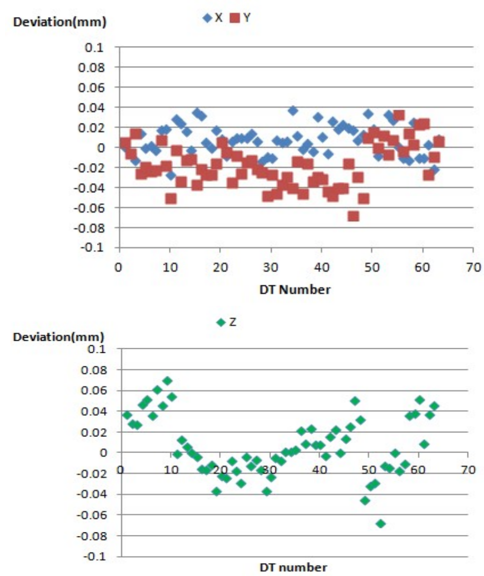

Figure 2: The alignment results of DTL-1.

Each DTL tank will be powered by a 3MW klystron via an iris based ridged waveguide. The coupling coefficient can be changed by adjusting the diameter of the iris end hole. The observed unloaded Q of DTL-1 is 43000, while the calculated Q by the superfish without the effect of tuners and post-couplers is 53800. Accordingly the observed Q_0 is 80% of the theoretic value which is acceptable. The main parameters of DTL-1 are listed in table1. The power needed to establish the required accelerating field inside the cavity was approximately 1.35MW.

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Table1: Parameters of DTL-1

	DTL1
Output energy(MeV)	21.67
Average electric field(MV/m)	2.86
RF driving power(MW)	1.35
15mA Beam power(MW)	0.28
Tank length(mm)	8507
Tank diameter(mm)	566
DT diameter(mm)	140
Bore radius(mm)	8
No. of cell	64
No. of post coupler	31
No. of fixed tuner	12
No. of movable tuner	2
Operating frequency(MHz)	324

Setup

Between the klystron and a power coupler, there are directional couplers to monitor the power signal. For RF measurements, two pickups were placed in the first and the third unit section for monitoring the field levels. Three thermocouples were drilled into the tank wall to monitor the temperature of the cavity and to estimate the uniformity of the thermal distribution on the cavity wall along the beam axis. Several interlocks were used to avoid any damage. A vacuum interlock system used the pressure reading from the ion gauge on the DTL cavity and on the RF window to turn off the RF power whenever one of them indicated poor vacuum. Besides, the VSWR protection system was also incorporated into the interlock system to protect the RF window and cavity from severe arc breakdown. Water flow signals related to the cooling of RF components were also connected directly to the RF interlock system.

HIGH POWER CONDITIONING

The conditioning process started with a pulse length of 650μs and a peak power level of less than 10kW in order to firstly verify the setup. The parameters that were monitored were the vacuum in the cavity and near the window area, the temperature of the cooling water at inlet and outlet, the water flow of the individual DT and associated components. At the beginning, the RF power was totally reflected by the RF window, it took 16 hours to condition the ceramic window. During this period, the forward RF power was 5kW~10kW with full duty cycle (650μs, 25Hz). Then, the RF power entered into the DTL tank, the VSWR measured by the directional coupler located right before the RF window was about 1.35, which guarantees the minimum reflection in case of a heavy beam loading in operation. The out gas from the inner surface was enhanced easily by the RF power according to the fluctuation of vacuum. It is noticed that the vacuum pressure in the DTL-l cavity, 6·10-5Pa, was not so good due to the possible leakage of a few DTs. The interlock most frequently triggered was linked to the vacuum level. It stopped the RF when the pressure level increased above $5\cdot10^{-4}$ Pa.

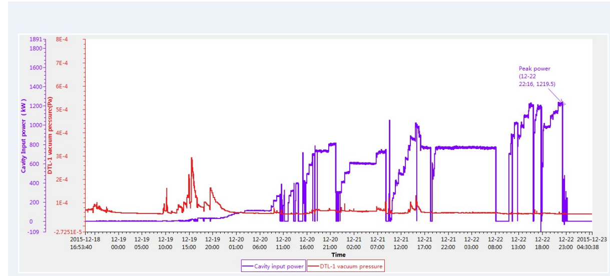

Figure 3: Conditioning history in the first stage.

As Figure3 shows, the first 20 hours is considered as the aging of RF window, during which the power level is 5~10kW. Once this power level was exceeded, the conditioning went fast. After 10 hours, the cavity was conditioned to 900kW. Considered that the cavity was conditioned without a prior bake-out, in order to fully warm-up the cavity, we completely stop the cooling of cavity and increase the temperature of the cavity intentionally. The cooling of DTs and other components was still in operation at that moment. The highest power level was limited to 800kW to keep the temperature measured by the thermocouple equipped on the cavity out wall below 40 degree. After ten hours bake-out, the cooling of cavity was restored, we adjusted the RF pulse width to 200us, 5Hz, and gradually increased the peak power to 1.2MW. While VSWR of the transmission line right before the RF window was larger than 3, the LLRF system record it as arcs automatically, the RF interlock threshold was 3 arcs per second in case of 5Hz rep. During this period, the pickup signal from DTL tank was very stable. It took 11 hours to increase the RF peak power from 100kW to 1.2MW. The power needs to enter into the DTL tank for maintaining operating field gradient is slightly over 1.35MW. But unfortunately, the power was shut down by the RF interlock system after a severe arc when the peak power was 1.22MW. After then, we attempted to feed the power into the DTL tank again, but the RF discharge appeared to be more frequently even below the 100kW power level. So we decided to open the RF coupler to check the RF contact between cavity and waveguide. In the meanwhile, we performed the vacuum leak detection. The 51th DT was found to have a large vacuum leak (figure 4), the reason was mainly due to the improper EB welding between stem and DT shell, and excessive strength on the drift tube during the installation. However, the leak point was blocked by the vacuum epoxy, results in an improved vacuum in the DTL-1 to $1\cdot10^{-5}$ Pa.

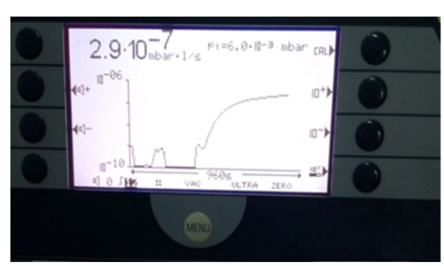

Figure 4: The leakage rate of 51th DT.

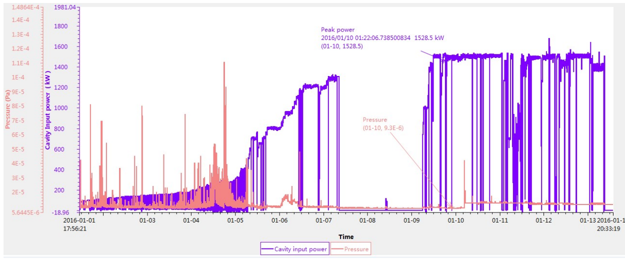

Figure 5: The second stage of conditioning.

The conditioning restarted after a series of actions, as shown in Figure5, The second stage of conditioning was not going very fast since the cavity was exposed to air during the maintenance. The RF trip rate was sharply increased compared to that in the first stage. We have to slow down the conditioning schedule and reduce the pulse length and repetition rate of the RF power. Another view point is that the multipactoring is responsible for the slow progress of the conditioning [3]. The spikes on the vacuum pressure plot in Figure5 indicate that the multipactoring was occurred in case of the power level was below 300kW. It is puzzling that this issue was not found in the first stage of conditioning, and the reason was still uncertain. Eventually this issue was naturally resolved. After passing through the suspected multipactoring region, the cavity peak input power was gradually increased to the design power level.

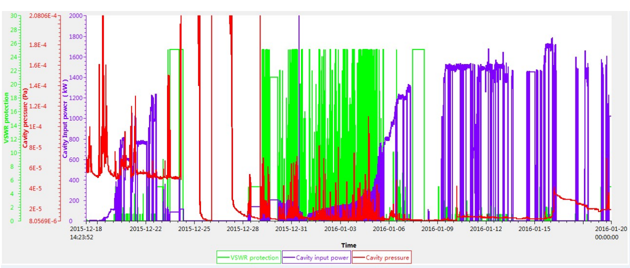

Figure 6: Conditioning history.

Figure 6 shows the entire conditioning history includes stage1 and stage2. The red curve represents the vacuum pressure in the DTL cavity. The purple line indicates the input power level. Once the arc occurred, LLRF will cut off the RF within one single pulse, and resume automatically in the successive pulse, that's the reason of the frequently power drop-down in figure6. After the peak power level has been confirmed, we gradually increased the average power to design value.

Beam Acceleration

The beam commissioning of RFQ and MEBT has been already finished in advance. The H- ion was accelerated to 3MeV and was injected into the DTL-1 after the high power conditioning. The focusing lattice in DTL-1 was set up based on the beam dynamics simulation result. The synchronous phase of two MEBT bunchers and DTL-1 was determined by the phase scan using a pair of FCT (fast current transformer) in the downstream. The beam energy was measured by the time of flight method with two FCTs. The designed energy 21.67 MeV was achieved with up to 18mA peak current. The transmission was nearly 100% within the accuracy of CT (figure7).

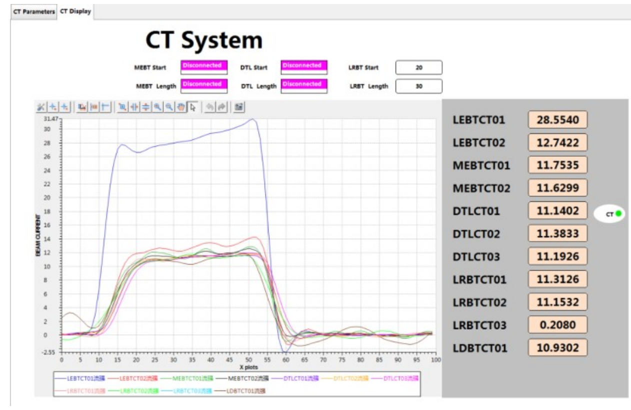

Figure 7: The CT parameters.

CONCLUSION

The high power conditioning of DTL-1 for the CSNS was carried out deliberately. Consequently 1.6 MW peak RF power (25Hz rep. 650 μ s) was put in to the DTL tank successfully. At a certain power-level (100~300kW) during the conditioning process, the RF trip rate was high, and the reason was still uncertain. However, After a long time conditioning, the cavity become almost stable and the H- ion beam which has18 mA peak current was accelerated up to its design value of 21.67 MeV with almost 100% transmission.

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