HIGH POWER CONDITIONING OF THE DTL FOR J-PARC

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Abstract

The high-power conditioning of the three DTL tanks for the J-PARC has been started in October 2006. The design rf peak-power levels for beam acceleration of the tanks are about 1.1MW (DTL1), 1.2MW (DTL2) and 1.0MW (DTL3), respectively. As a result of the conditioning, we have achieved that the rf power levels are about 1.3MW, 1.45MW and 1.23MW of which are 1.2 times the power levels of the desired one (the pulse length is 650μs and the pulse repetition is 25Hz). During the linac beam commissioning, the DTLs can keep the required rf power stable now.

INTRODUCTION

A Drift Tube Linac (DTL) is used to accelerate an H^- ion from 3MeV to 50MeV for Japan Proton Accelerator Research Complex (J-PARC). The DTL consists of three tanks and each tank is made up of three unit tanks. The tank length is about 9m, the diameter is 0.56m and the operating frequency is 324MHz.

The DTL has acceleration electrodes named Drift Tube (DTs), tuners to adjust the resonant frequency, post couplers to stabilize the electric field and rf couplers to feed rf power. Each DT contains a focusing electric quadrupole magnet. The main parameters of the DTL are shown in Table 1.

Table 1: Main parameters of the DTL

		DTL1	DTL2	DTL3
Beam Energy [MeV]	In	3.0	19.7	36.7
	Out	19.7	36.7	50.1
Average electric field [MV]		2.5	2.7	2.9
Tank length [mm]		9920	9440	7323
Tank Diameter [mm]		560	560	560
DT diameter [mm]		14	14	14
Bore diameter [mm]		13, 18	22	26
No. of Cell		75	42	26
No. of Post coupler		36	42	26
No. of RF coupler		2	2	2
No. of Movable Tuner		2	2	2
No. of Fixed Tuner		10	10	8
Operating Frequency [MHz]		324	324	324

The DTL and the peripheral equipments were installed in the accelerator tunnel and the klystron gallery of the J-PARC building by October 2006. After the installation, the high power conditioning of the DTL has been started. The photograph of the DTL installed in the accelerator tunnel is shown in figure 1.

In this paper, the results of the high power conditioning of the DTL tanks are described.

Figure 1: Photograph of the DTL

HIGH POWER CONDITIONING

An rf power source of the DTL is klystron. The rf power is transferred in the rectangular waveguide and the coaxial one, and fed into the DTL by using the two rf couplers. The total coupling constant of the pair of couplers to the tank is adjusted to about 1.0 (VSWR ~ 1: slightly under coupling) by the low power measurement. The target of conditioning is to feed the design rf power into the tank stably with pulse length of 650μs including the build-up time and the repetition rate of 25Hz [1]. It means that the duty factor of the rf pulse is 1.625%.

For the DTL1, the high power conditioning had been carried out and the beam acceleration test up to 19.7MeV had been done at KEK in 2003 [2]. However, the tank was divided into the unit tanks for the transportation from KEK to JAEA [3] and these have been reassembled [4, 5] in the J-PARC tunnel. Thus the inner surface of the tank had been exposed to the air. Therefore the rf power was increased up to the design value carefully.

We started the conditioning with the short pulse length (100μs) at first. When the level of the rf power reaches the design value, the pulse length was extended slightly (+ 50~100μs) and the input rf power was increased from lower level up to the design value again. By repeating those processes, we have been able to achieve that the rf power levels are about 1.3MW, 1.45MW and 1.23MW of 1.2 times the power levels of the desired one. The conditioning histories of the DTLs are shown in figure 2.

The horizontal axis is the conditioning time, the vertical axis are the klystron output power to the DTL and the vacuum pressure in the tank measured by the BA gauge.

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The vertical scale of the averaging power is 1.625% (DTL1 and 3) and 1.5% (DTL2) of the scale of the peak power because the maximum rf pulse length for DTL2 was 600μs. The measured VSWRs of the rf power during the high power conditioning are about 1.5 for the DTL1 and 1.2 for the DTL2 and DTL3. However all VSWR values were set to approximately one by the low level tuning as described before. Now we are investigating the reason for the increment of the rf reflection.

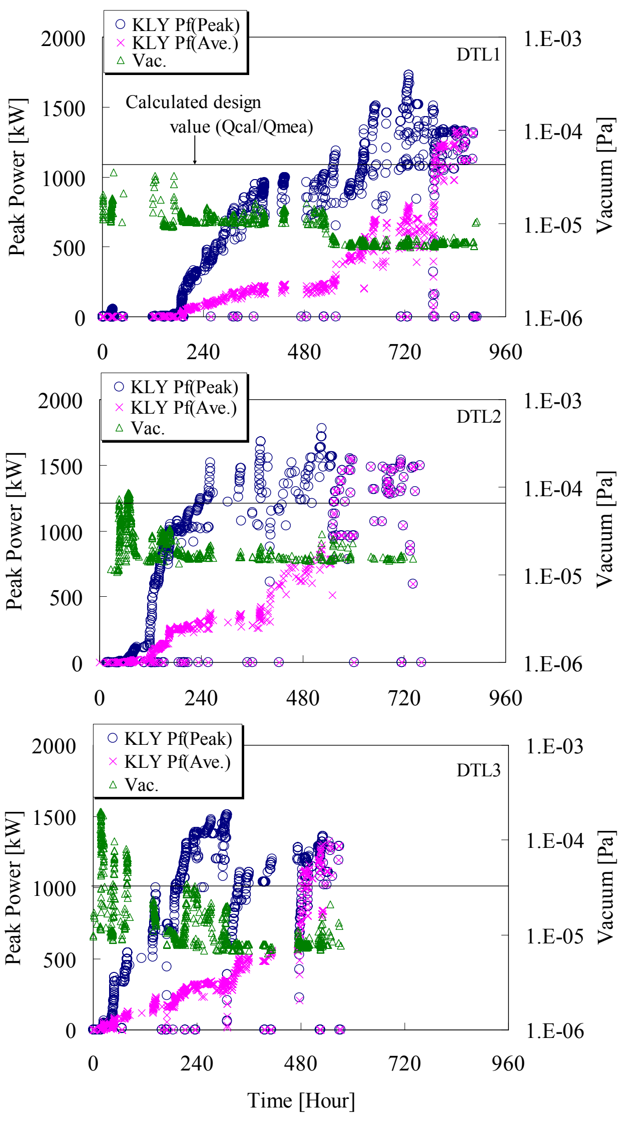

Figure 2: Conditioning histories of the DTLs. The scale of the averaging power is 1.625% (DTL1 & 3), and 1.5% (DTL2) of the peak power level.

The conditioning times spent in achieving the design power level are about 800 hours for DTL1, 700 hours for DTL2 and 500 hours for DTL3, respectively.

At the beginning of the conditioning (< ~ 20kW), the vacuum pressure become worse in spite of the low input rf power, because the out gas from the inner surface of the tank includes the ceramic window of the input coupler is enhanced easily by the rf power. On the other hand, the multipactoring starts also in the cavity. Figure 3 shows the waveforms at the beginning and the end of conditioning for DTL3. At the beginning of conditioning, we have observed the typical waveform of a multipactoring (topside picture: klystron output power is 4kW). After the conditioning, the tank level and the reflection waveform was very smooth (downside picture: klystron output power is 1.1MW).

Passing through the multipactoring regions, the rf power is fed into the tank stably and the vacuum pressure improves. As a result of the conditioning, we achieved that the peak power level for short pulse less than 300μs was more than 1.5 times and was approximately 1.2 times as large as the design value for the full duty pulse. While the vacuum level is balanced around the pressure of 1E-5 Pa for all DTLs. Currently, the DTL has been operated for the beam commissioning [6, 7] stably with low fault rate (about a few times per day).

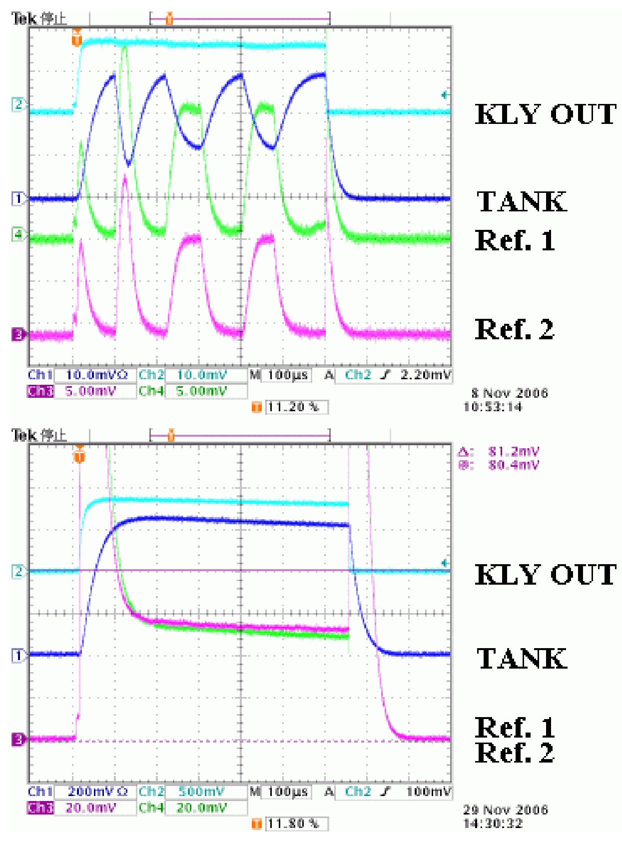

Figure 3: Waveforms of rf power for the DTL3. The topside picture is at the beginning of the conditioning (klystron output is 4kW) and the downside picture is at the end of the conditioning (Klystron output is 1.1MW). Note that the vertical scales are different.

POWER DISSIPATION OF THE DTL

In order to estimate wheter the DTL is cooled enough, we measured the temperature rise of the cooling water and compared the data with the power dissipation calculated by using the Multi cell DTLFISH (MDTFISH) [8].

Figure 4 shows the power dissipation of each parts of the DTL. The scale of the power dissipation is represented as the CW mode (i.e. duty 100%).

The bar chart shows the calculated power dissipation to generate the desired electric field. The calculated values have been corrected by multiplying the factor Qcal/Qmea. (Qcal is the calculated Q value by using the MDTFISH and Qmea is the measured Q value by using a network analyzer.)

The circle marks are the power level calculated form the temperature rise of the cooling water of each part. The temperature of the cooling water is measured by the platinum resistance temperature detector (PRT) installed in the cooling water pipe.

The diamond marks are the power level in the tank. These are measured by the pickup loop attached on the DTL tank.

"Tank" showed below the abcissa of figure 4 means the total power dissipation of the unit tanks, "End Plate" means the sum of power dissipation for two end plates at both side of the tank, "DT & Stem" means the sum of power dissipation for the DTs and stems. "Total" means the sum of all power dissipations for each tank. However the power dissipation of the post coupler is not included in this graph becausethe cooling system of the post couplers have no PRT.

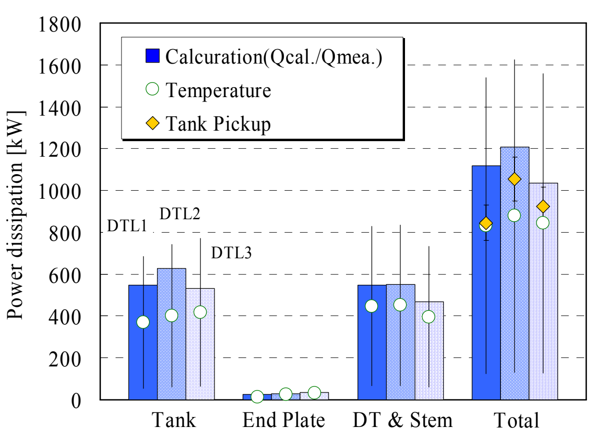

Figure 4: Power dissipation of the DTL

The error of the power dissipation, which is estimated by the temperature rise of the cooling water, is large as shown in figure 4 because the water temperateure rise (~0.2 degree) is approximately the same as the measurement accuracy of the PRT (~0.15 degree). Thus it is hard to compare the measured data to the calculated one accurately. However the tendency of the distribution for the measured power dissipation data is roughly consistent with the calculated one.

SUMMARY

The high power conditioning of the DTL for the J-PARC has been started in October 2006. As a result of the high power conditioning, we have achieved that the peak power level for short pulse length less than 300μs was more than 1.5 times and that for the full duty rf pulse was approximately 1.2 times as large as the design value (DTL1:1.3MW, DTL2:1.45MW and DTL3:1.23MW). After the conditioning, the DTLs are operating at beam commissioning stably at present.

We measured the temperarure rise of the cooling water of the DTL to confirm the rf power dissipation in the tank. As the result of comparison between the MDTFISH calculation and the measured data, both data are approximately consistent each other.

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