TECHNOLOGIES OF THE PERIPHERAL EQUIPMENTS OF THE J-PARC DTL1 FOR THE BEAM TEST

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Abstract

First beam test of the DTL1 was performed in November of 2003 at KEK site. A 30-mA H^- beam was successfully accelerated from 3 to 19.7 MeV. In order to accomplish the successful beam test, various peripheral equipments were developed: the electrode plates for connecting the hollow-conductor coil and the power cable were developed since quadrupole electromagnets are built in all DTs (77 sets) of the DTL1 [1], the water-cooled multiconductor copper tubes (Control Copper Tube) were used as the power cable from the electrode plates to power supplies, and the interlock system assembled by PLCs (Programmable Logic Controller) was also prepared for the surveillance of many cooling channel.

INTRODUCTION

High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Research Institute (JAERI) are together constructing the high intensity proton accelerator at Tokai site, which is called Japan Proton Accelerator Research Complex (J-PARC) Project. We are conducting the beam test of the first tank of DTL (DTL1) at the Proton linac test facility at KEK site. A negative hydrogen beam was accelerated to its design value of 19.7 MeV. A peak current of 30 mA was achieved with almost 100 % transmission at a 12.5 Hz repetition rate in a 20-microsecond pulse width [2].

It is required for the beam test that the wiring from the power supply to the quadrupole magnet (Q-magnet) copes with the following technical subjects:

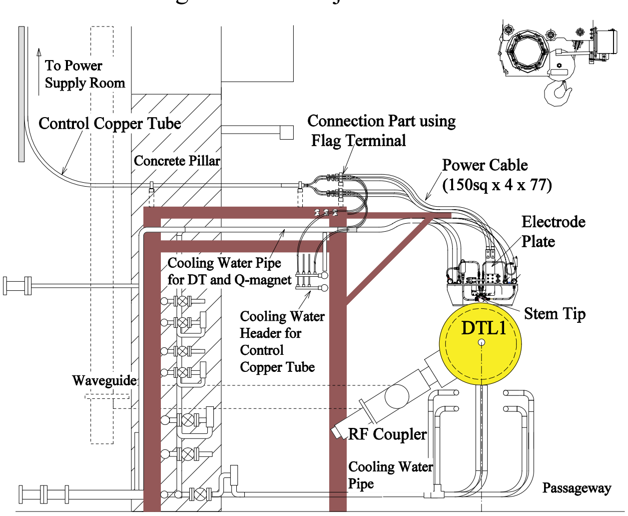

Figure 1: Schematic drawing of the wiring in the tunnel.

1) Suppressing cable vibration with the pulse excitation of the Q-magnet.
2) Design of the electrode which connects the power cable and the Q-magnet in small installation space.
3) Assembling procedure of the electrode in order to minimize the effects on the position of the stem. (Because the electrode can push the stem, it may shift the position of the drift tube.)
4) The performance test of the busduct which is intended to use mainly as the power cable in Tokai site.
5) Construction of a local interlock system for errors in the magnet power supplies, the cooling water system and the vacuum pump controllers.

Investigated results for these subjects are described in the following sections.

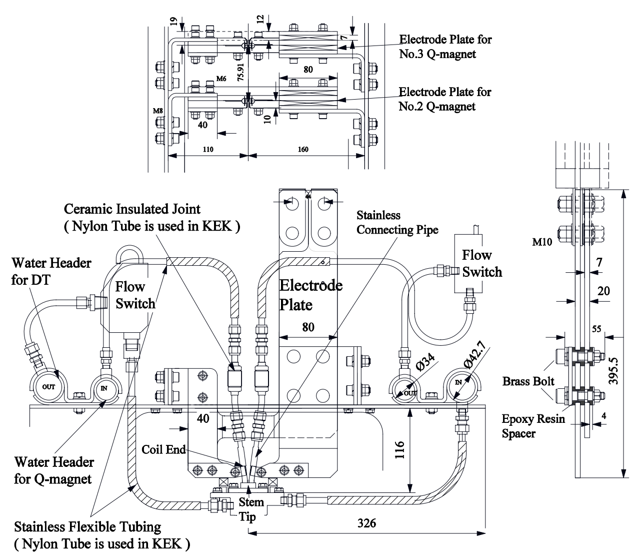

Figure 2: Schematic drawing of the connection part between the power cable and the electrode at the top of the stem.

WIRING COMPONENTS

Schematic drawing of the wiring in the tunnel at kek is shown in Fig. 1. All magnets were wired by the cables which satisfy the pulse excitation specification (Max. 1000 A, 50 Hz). Therefore wiring was done after the confirmation test that the effects of the pulse vibration of those cables were negligible for the DT alignment.

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Connection Between the Power Cable and the Electromagnet

The end of the hollow conductor coil was extended by only about 3 cm from the stem tip, since the extension length was limited by the assembling procedure of the DT in the tank [3]. It was observed in the preliminary assembling test that the position of DT deviated from the initial position when the connection of the power cable to the end of the coil was done without careful attention to the load of the stem. Then, we decided to connect the coil-end and the power cable by using electrode plate (see Fig.2) which is finally fixed on the DTL so that the direct effects on the stem due to the load of the power cable can be prevented. The gap of both positive and negative electrodes were made as small as possible in order to reduce the amplitude of the vibration by pulse excitation of the Q-magnet. Moreover, the position of the electrode plate was fine-tuned by using the larger screw hole when the electrode is connected to the coil. In addition, the thermostat was attached in all electrode plates in order to observe temperature rise of the power line.

Control Copper Tube

The copper pipes (Control Copper Tube) were used for the main wiring from the power supplies to the Q-magnets for the beam test at KEK; CCPP-EE 7x8x6 (No. of Pipe x Outside Diameter x Inside Diameter) made by Hitachi Cable, LTD (see Photo 1) [4]. They were applied for 73 lines among 77 lines. The reasons for using Control Copper Tube are as follows:

1) It can be expected that pulse vibration reduces compared with the power cable, since the Control Copper Tube has twist structure of the multi-core.
2) The thermal influence on waveguide near a wiring can be reduced, since the heat from the power line is suppressed by cooling water.
3) The material cost of Control Copper Tube is lower than the power cable.
4) It is comparatively easy to do wiring work, since it is lightweight and flexible. Moreover, a required installation area is small since the cross-section per line is much smaller than that of the busduct and/or other air-cooled cables.

After relocation to Tokai site the busduct and the thick power cable will be used instead of Control Copper Tube, since the water-cooled power line for the Q-magnets are not permitted to be used as the power cable in JAERI.

Connection between Control Copper Tube and the Power Cable

Since the tube fittings for cooling-water is attached to the terminal of Control Copper Tube, it is impossible to connect the magnet power supply or the magnet coil to the Control Copper tube directly. Then, the short power cable was used to connect them.

After testing various types of clamps, it was found that the flag terminal (J.S.T. Mfg. Co., Ltd : SF38-12) was the best way and it costs lower [5].

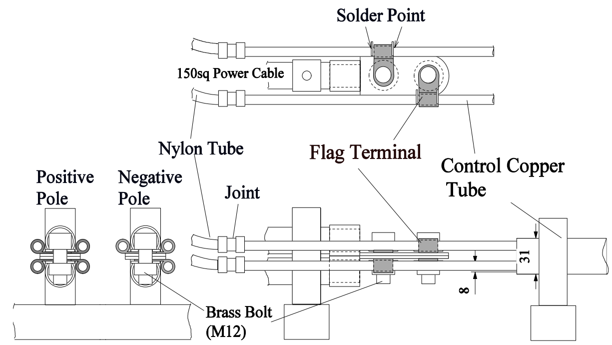

Figure 3: Schematic drawing of the connection part between Control Copper Tube and the power cable.

The outline of the connection part using the flag terminal is shown in Fig.3. Fixing of the terminal has been done by soldering both ends after cramping to the Control Copper Tube moderately.

Busduct

We used the busduct for the main wiring of 4 lines among 77 lines instead of the Control Copper Tube. The E-BD type made by KYODO KY-TEC CORP was chosen as the busduct [6]. Since the structure of the bus duct is a 4-wire x 2-stage, it is connectable with four magnets by one set (see Fig.4). The conductor is made of aluminum with the insulator of a polyester sheet.

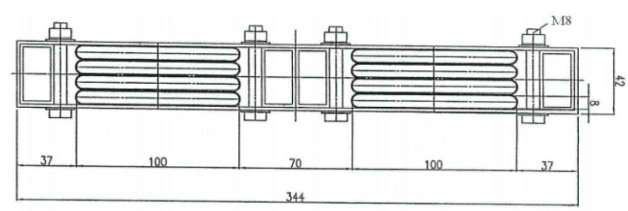

Figure 4: Cross-sectional drawing of the busduct.

PLC

We are using PLC (Yokogawa Electric Corp. : FA-M3) as a cooling-water interlock system for DTL. For the beam examination, signals from flow switches of DT's and Q-magnets (electrodes) has been connected to the magnet power supplies via PLC. However, signals from flow switches of DT's and Q-magnets will be connected to the magnet power supplies directly at Tokai site. The number of input and output signals to PLC of DTL1 is shown in table 1. This system links “Beam operating and safety system” [7] and stops a beam at the alarm.

PRELIMINARY TEST RESULTS

The preliminary test of each equipment was done before the actual run.

Preliminary Test of the Electrode Plate

The prototype model of the electrode plate was made and installed on the DTL test cavity for the preliminary examination (see Photo 2). The bolting procedure has been investigated in order to decrease the deviation of the drift tube within an allowable limit.

Next, the electrode and the magnet power supply were connected by using the Control Copper Tube and the flag terminal, and then, a pulse excitation examination was done. In the beginning, the maximum difference of temperature the electrode-surface and the tank-wall was approximately 20 degrees centigrade. So, the following countermeasures were taken. (1) The material of the bolt was changed from SUS to brass. (2) Each cable terminal was fixed to the plate of the electrode one by one since the large thermal gradient was observed when the terminal was fixed to a pair of plates simultaneously. As a result, a temperature difference decreased below 15 degrees centigrade.

There were few vibrations of the Control Copper Tube and the electrode plate in comparison with the power cable. It will be necessary to consider how to reduce the vibration more about wiring of the power cable in Tokai site. The connection part of the flag terminal was satisfactory.

Table 1: The number of input and output signals to PLC of DTL1

	INPUT	OUTPUT
Flow Switch	214	
Resistance Temperature Detector	58	
Thermostat	77	
Power Supply Status	77	
To Power Supply		77
Beam, RF, etc		3
TOTAL	426	80

Preliminary Test of the Busduct

Because each line in the busduct is close in the structure, it is expected that the influence of the electromagnetic induction by pulse excitation is sufficiently small. So, on the condition that one line was connected to the test Q-magnet, and other 3 lines were short-circuited, an influence on each line in the busduct was measured. In this case the neighboring line had the reverse polarity. As a result, the measured voltage induced by the mutual coupling was 0.3 % in maximum shown in Figure 5. Therefore, it can be concluded that the stability within 1 A can be achieved if voltage polarity is reverse and pulse shape is the same.

PLC Response Examination

The delay, from when the alarm happens to the time when the power supply is cut off, is about 18 msec. Therefore, there was no problem because the measured delay time was less than the repetition rate of the pulse operated magnet power supply.

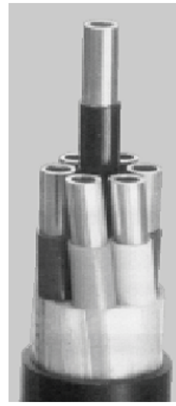

Photo 1 (Left): Control Copper Tube.

Photo 2 (Right): Preliminary test of the electrode plate.

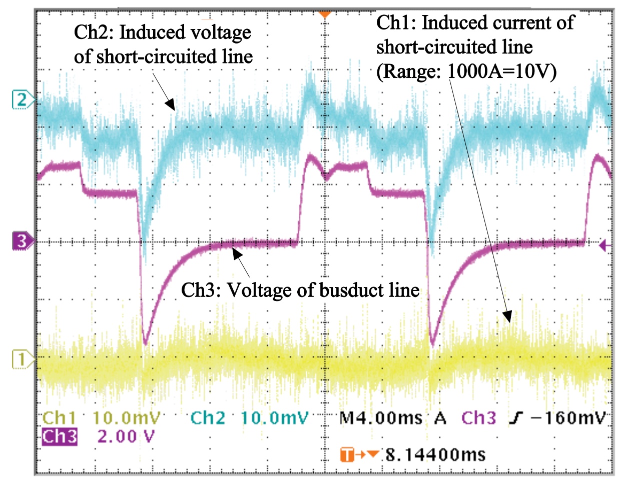

Figure 5: Induced voltage of the short-circuited line.

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