DTL AND SDTL INSTALLATION FOR THE J-PARC

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Abstract

Three DTL tanks and 32 SDTL tanks have been installed precisely in the underground tunnel of the J-PARC. The tank position for the X- and Y-axis was aligned by using an alignment telescope. The tank support has an earthquake proof system, which is also used for the position tuning. This report describes the structure of the tank support and the outline of the intended procedure of the tank installation and the alignment.

INTRODUCTION

The high-intensity proton accelerator facility named J-PARC is being constructed in the Tokai campus of Japan Atomic Energy Agency (JAEA) under the close collaboration between the JAEA and High Energy Accelerator Research Organization (KEK) [1] . The accelerator consists of a 181-MeV linac, a 3-GeV rapid cycle synchrotron and a 50-GeV synchrotron. The 181-MeV injection linac comprised of the an H^- ion source, a radio frequency quadrupole (RFQ) linac, a drift-tube linac (DTL), and a separated function type DTL (SDTL). All of them have been installed in the tunnel of the J-PARC. The high-power conditioning of the cavities will be started at October 2006 and the first beam extraction from the linac is planned at December 2006.

The Alvarez-type DTL accelerates the H^- ion beam from 3 to 50 MeV. It consists of the three independent tanks which is about 9 m in length. Each tank is composed of three short unit tanks which are approximately 3m in length. The inside diameter of the tank is 560 mm. The resonant frequency of the DTL is 324 MHz. Each drift tube (140 mm in diameter) in the DTL accommodates the electro-quadrupole magnet. The DTL-1 has 77 magnets. The DTL-2 and -3 have 44 and 28 magnets, respectively. Figure 1 shows the side view of the DTL-1. The figure shows that each unit tank is supported independently.

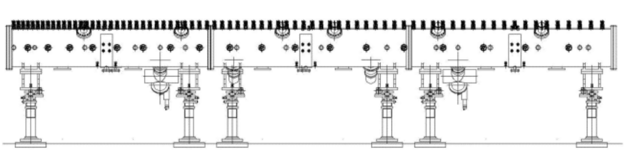

Figure 1: Side view of the DTL-1.

While the SDTL tank which follows the DTL is short shown in figure 2. Each tank has 5 accelerating gaps (5 cells). The SDTL accelerates the beam from 50 to 181 MeV with 30 tanks. Although 32 SDTL tanks were made, the last two tanks are used as the debuncher in the beam line from the linac to the RCS ring at the first stage of the J-PARC. All drift tubes (90 mm in diameter) in the SDTL have no magnet. The doublet of the electro-quadrupole magnet is set between the tanks. of the SDTL. The inside diameter of the SDTL tank is 520 mm. The resonant frequency of the SDTL is 324 MHz also.

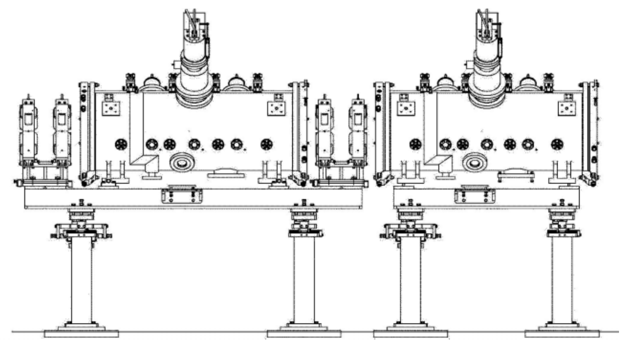

Figure 2: Side view of a pair of the SDTL.

The set up of the tank support for the DTL and the SDTL started at April 2005 and the installation of the whole tanks was completed at February 2007. In the following section, the requirement and designed procedure for the installation and alignment of the tanks are described. Of course the actual procedure carried out in the tunnel was different from the designed one. Thus the modified procedures are also described.

REQUIREMENTS FOR THE TANK INSTALLATION

The requirements for the tank alignment are as follows:

1. Overall accuracy of the alignment for the DTL tanks are ±0.1 mm for X/Y/Z- direction;
2. Overall alignment accuracy for the SDTL tank are ±0.3 mm for X/Y- direction (over the every 30 m distance along the beam line) and ±0.1 mm for Z-direction, respectively.
3. Overall alignment accuracy for the magnet of the SDTL are ±0.1 mm for X/Y- direction (over the every 30 m distance along the beam line) and ±0.1 mm for Z-direction, respectively.

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4. The center of the tanks are aligned by the measurement of the center of the tank which has been used for the assembling of the DTs. The measurement is done by an alignment telescope. This is the main procedure for the tank alignment.

5. Each tank has two reference arms at both tank ends for the measurement with a laser tracker, which supports the telescope measurement.

The following items are requirements for the tank support:

1. The support must have an earthquake proof system which works for the earthquake measuring more than or equal to the level four on the Japanese seismic scale. (The earth-quake level is almost equivalent to the ground acceleration of approximately 100 gal.)

2. Two sets of the quadrupole doublet are put on the same upper stage of the SDTL tank of an even number. The alignment of the center of both quadrupole magnets is achieved by the following conditions:
   - A pair of the magnets which form the doublet are stood precisely on the sub-support in the factory.
   - The sub-support has the side and the bottom standard planes, which fix the X- and Y-position of the magnet, respectively. (The mechanical accuracy and the magnetic properties of the doublet have been confirmed by the measurement in the KEK.)
   - Both doublets are put on the upper stage of the tank by touching the standard planes of the magnet with ones of the upper stage. Then the beam axes of the magnets are aligned without any tuning.

3. The center of the SDTL tank is aligned with the line defined by the quadrupole magnets.

STRUCTURE OF THE TANK SUPPORT

The front view of the tank support for the DTL and SDTL are seen in figure 3 and 4, respectively. The support consists of the following parts [2]:

1. The base plate fixed in the floor concrete of the tunnel.

2. The anchor plate fasten on the base plate by the bolts which adjust the height and the level.
   - The achieved level of the plate is ± 0.1 mm/m.
   - The height of the plate was adjusted with the accuracy of ± 1 mm.

3. The legs which stand on the anchor plate.

4. The earthquake-proof system for the Z-direction on the leg. (The support at the downstream only has this system.)

5. A linear guide for the Z-direction.
   - The movable range of the guide is approximately 150 mm.
   - The guide must be parallel to the beam line within the distortion of $\pm 50\mu$m for the full range because the smallness of the distortion guarantees the alignment accuracy for the DTL unit tanks when these are docked together.

6. A metal plate, which is a kind of the interface board between the linear guides for Z- and X-direction.

7. A linear guide for the X-direction.

8. The earthquake-proof system for the X-direction.

9. The upper stage for the SDTL tank and the two quadrupole doublets.

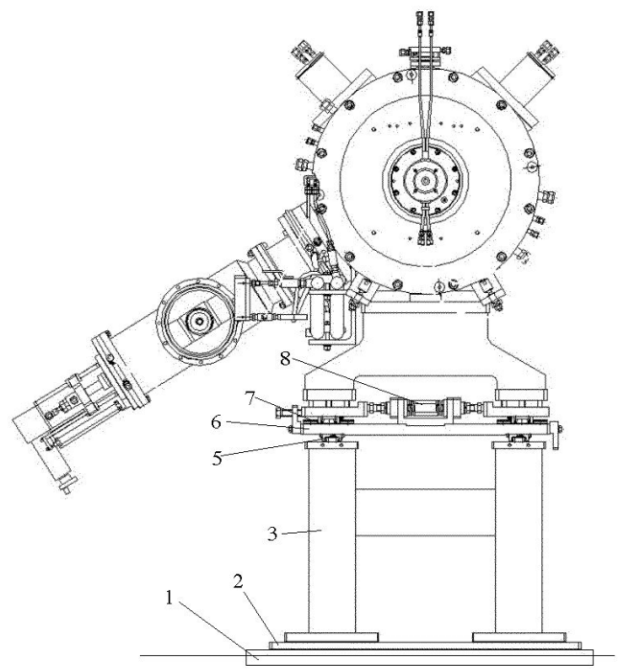

Figure 3: DTL front view. The numbers show the item number in the article.

Since the precise alignment of the tank support makes the alignment of the tank on the support easy, we spent almost two months for the alignment of the 82 supports.

Structure of the Earthquake Proof System

The schematic view of the structure of the earthquake proof system for X-direction is shown in figure 5. (The scheme for Z-direction is the same as for X-direction.)

The position for the X-direction is adjusted by the tuning of the length of two bolts colored purple in the figure 5. If a big earthquake happens, it makes the legs of the tank shift horizontally. However the earthquake proof system leave the tank stable. Furthermore a mechanical damper is attached in order to reduce the oscillation of the tank.

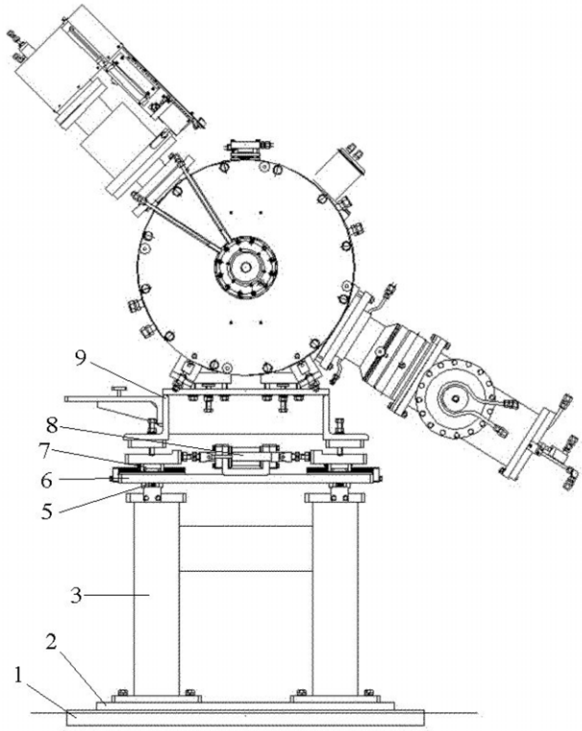

Figure 4: SDTL front view. The numbers show the item number in the article.

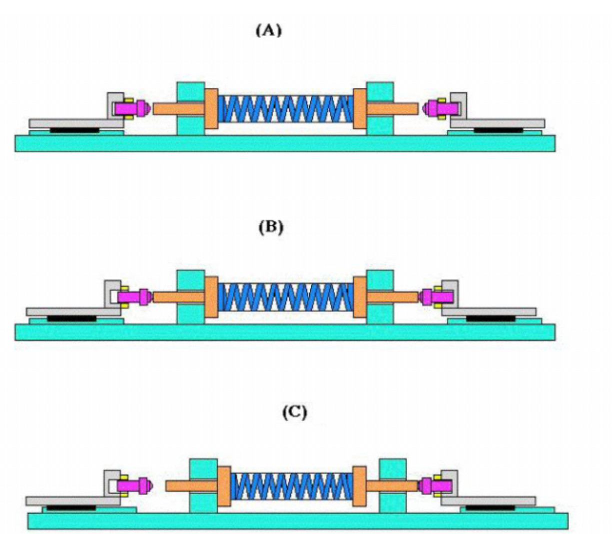

Figure 5: Scheme of the earthquake proof system. (A) Before the adjustment of the X-position. (B) After the position adjustment. The screws (purple) are tuning knobs. (C) The appearance when the earthquake has moved the leg to the right.

ACTUAL TANK INSTALLATION

For the tank installation, the optical axis of an alignment telescope was aligned on the beam axis at first, which is defined by using the floor makers made by the metrologocal survey [3, 4]. The master telescope we used is ”Farrand Optical 95360 Alignment Telescope 60X” for the longer range measurement ($>$10 m, for instance the alignment of the whole DTL tanks which total length is approximately 30 m). For the shorter range measurement (for instance, the alignment of the one DTL unit tank or SDTL tank), ”Taylor-Hobson Micro Alignment Telescope” was used.

During the alignment, the following unexpected phenomena were found and fixed:

1. The dislocation of the DTL unit tanks happened when the docking of them.
    - The center of the docked unit tank was slipped transversely approximately 0.1 mm by the twist of the unfitted O-ring between the tanks. It disappeared after the several trials.
    - The bend of the docked unit tank (about 0.02 mm/m) was observed. It has been fixed by the control of the gap between the unit tanks.
2. The upper stage of the SDTL tank is deformed due to the weight of the magnet. As the result, the magnet is tilted on the stage. It was compensated by putting the shims under the sub-support of the doublet. Typical thickness of the shim is less than 0.1 mm.

The peripheral equipments, for instance a movable tuner and a input coupler, were also fixed on the tank after the installation of the tanks. The position along the beam line was adjusted by measuring the gap between the neighboring tanks length with a block gauge or a inner micro-gauge. Finally the Z-position of the tank was cross-checked with a total station.

CONCLUSION

Three DTL tanks and 32 SDTL tanks have been installed precisely in the underground tunnel of the J-PARK. The tanks were aligned on the beam line by an alignment telescope for the X/Y-axes and by a block gauge. The tanks are set on the support which has a earthquake proof system. Achieved alignment accuracy is sufficient for our requirements.

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