OPERATIONAL STATUS OF SUPERCONDUCTING RESONATORS OF THE JAERI TANDEM-BOOSTER

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Abstract

Since the JAERI tandem booster started operating in 1994,the forty superconducting quarter-wave resonators of the frequency of 129.8 MHz and the optimum beta of 0.1 have been working for heavy ion energy boost. This paper reports the resonator performances measured recently, making a comparison with old data. Present operating field levels at the rf input of 4 watts give the same mean value of 4.6 MV/m as obtained in 1995. Degradations of Q factors due to electron field emission at high fields were, however, seen increased in many resonators. The Q-degradations due to hydrogen Q-disease were partly recovered by a fast cool-down process.

1 INTRODUCTION

The superconducting booster has been operating since 1994 as a heavy-ion post-accelerator of the 18MV tandem accelerator at JAERI, Tokai [1].As is shown in Fig.1,the booster is located on one of twelve beam lines from the tandem accelerator. Energy of the heavy ion beams to the booster target room can be increased two to four folds by the booster. The booster linac is composed of ten acceleration modules, each of which contains four superconducting quarter wave resonators illustrated in Fig.2.The cavity surfaces are fully made of niobium and outer cans are oval cylinders backed with copper [2]. The frequency is 129.8MHz,and the optimum beta 0.10. The booster is equipped with two identical refrigerators with 250 watts.

We report in this paper the resonator performances measured in July 2001 and compare the data with those in June 1995.

2 RESONATOR OPERATION CONDITIONS

The beam acceleration time of the booster has been 25 to 30 %of the tandem 's total beam time of 190 to 230 days a year. The resonators were cold for 3,500 to 4,500 hours and warm in several periods a year from 1994 to 1998 and over 6,000 hours a year in recent years. There have been no troubles with resonator tuners and couplers. We have not opened any cryostat except cryostat no.7 and a buncher unit, since 1994.The cryostat no. 7 in which resonators no. L-25 to L-28 are placed was opened for fixing a helium leak though indium gasket in 2000. There have been several times of nitrogen gas fill-back into a cryostat since 1994.

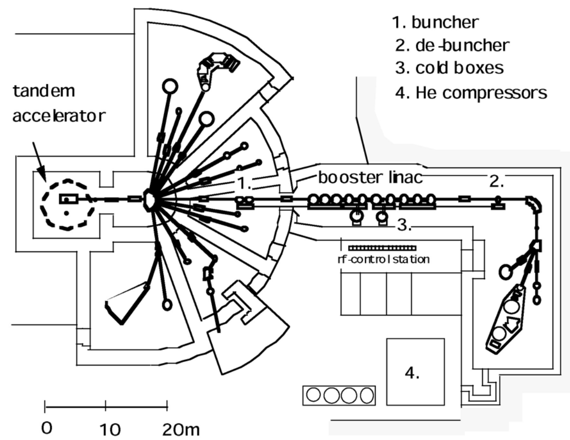

Fig.1 Layout of the JAERI Tandem and its booster

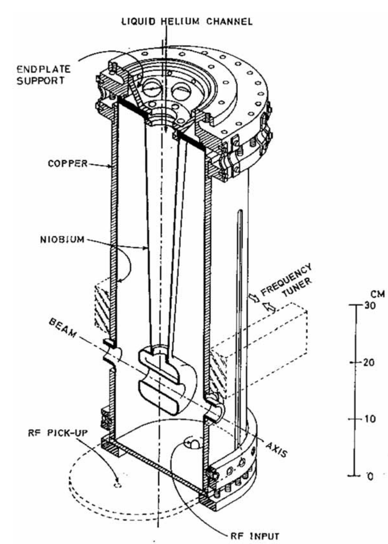

Fig.2 Cutaway view of superconducting quarter wave resonator in the JAERI Tandem-Booster

The hydrogen Q-disease, which is a Q-degradation due to hydrogen absorption during surface treatment and precipitation during a slow cool-down, was found in many of the first 16 resonators. The precipitation temperatures of niobium-hydrides were found in 130K to 90 K from the off-line tests [3]. The normal cool-down

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rate by the refrigerator is 10 -12 K/h. The symptom could be eased a lot by a fast cool-down sequentially manipulating the valves to concentrate the whole cold gas to a small number of resonators [4]. In May 2001,at the beginning of the operation period through July 2001 when the resonator performances were measured, the first 20 resonators were cooled down at a rate of about 17K/h by applying the sequential cool-down method.

With respect to rf conditioning, CW conditioning is done every time after cool-down to overcome electron multipactoring. It took normally about ten minutes per resonator or about 30 minutes for severe ones. High power pulse conditioning with an 1.2 kW amplifier was used to recover degraded Q factors at high fields when it was necessary. Helium processing has not been applied yet. Mean operating field gradients were mostly between 3 and 4.5 MV/m. High power pulse conditioning was not done prior to the measurements in July 2001.

3 RESONATOR PERFORMANCES

Resonator performances measured in July 2001 are presented in Fig. 3 to 6,together with the data of June 1995 for a comparison [4]. Q factors at 1 MV/m are shown in Fig. 3. The present Q factors are scattered around 6×10^8 similarly as in 1995 but lower than those of off-line test because of hydrogen Q-degradation. The mean values (and standard deviations) of the data of July 2001, June 1995 and off-line, except resonators no. 2 and 4 which exceptionally absorbed much hydrogen in the electro-polishing, are 5.7×10^8 (2.3×10^8), 5.6×10^8 (2.2×10^8) and 1.0×10^9 (2.6×10^8), respectively. Among the first 20 resonators, there are many Q factors higher than those obtained in June, 1995. These must be a result of sequential first cool-down executed 4 months before. The cool-down rates were about -17 K/h, according to the temperature monitor records for resonators L-1 and L-5.

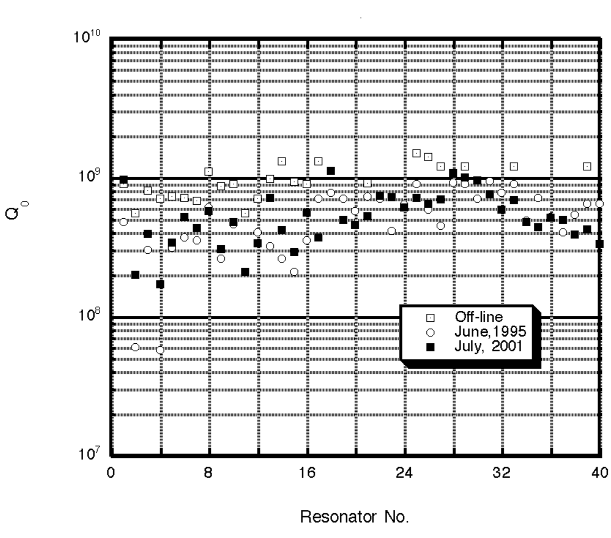

Fig. 3 Q factors at 1 MV/m measured in off-line test, in June 1995 and in July 2001

Field gradients at an rf input of 4 watts are shown in Fig. 4, and the field gradients are summarized as a histogram in Fig. 5. The mean was 4.63 MV/m, and very close to that of 4.69 MV/m obtained in June 1995.

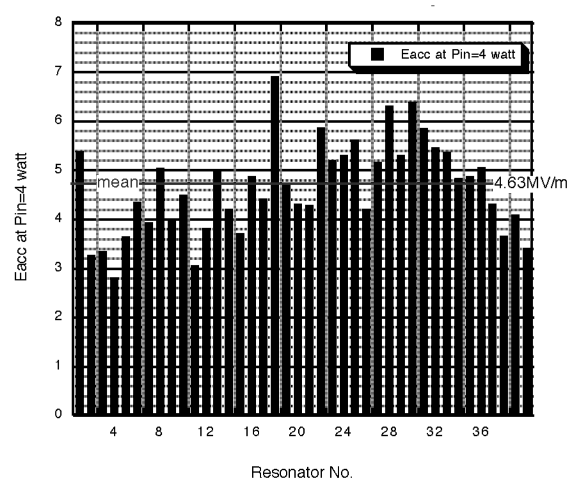

Fig. 4 Field gradients E_{acc} at the rf input of 4 watts measured in July 2001

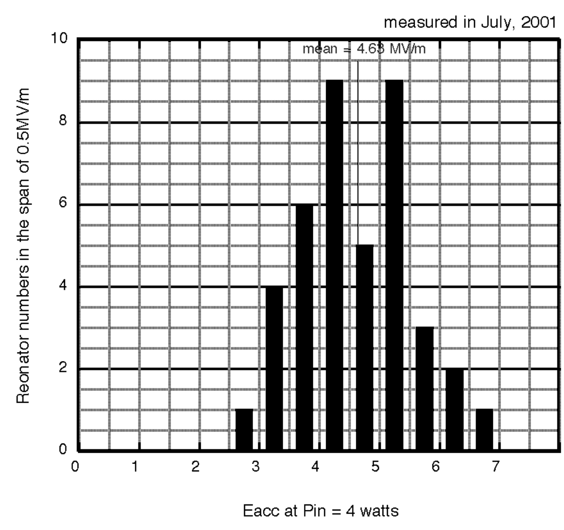

Fig. 5 Histogram of the field gradients at the rf input of 4 watts

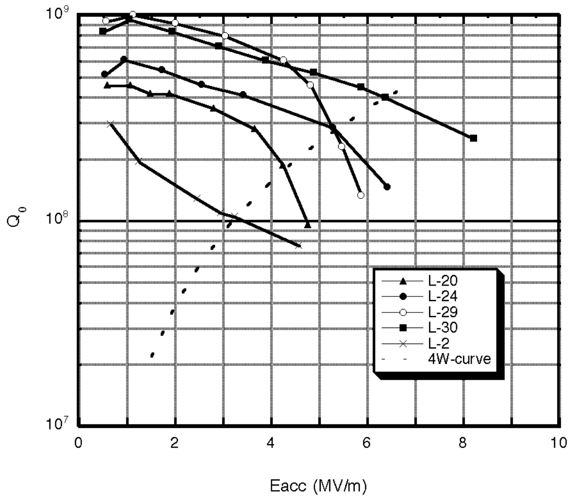

Fig. 6 Typical Q-E_{acc} curves

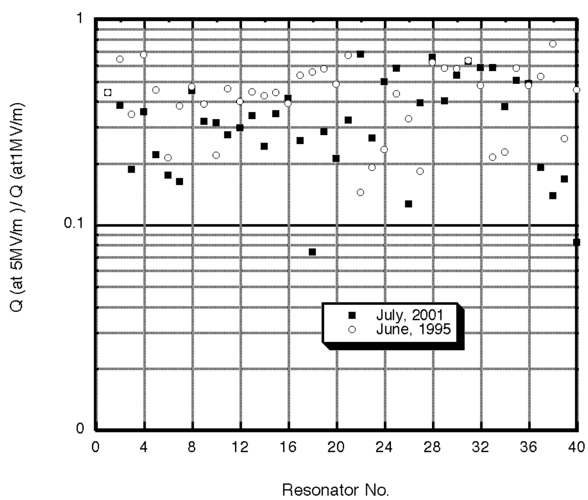

Fig. 7 Ratio of Q at 5 MV/m or near 5 MV/m to Q at 1 MV/m

Some typical Q-E_{acc} curves are displayed in Fig. 6. Resonator L-20 is one of the best resonators with high Qs up to the high field end. Resonator L-24 is a good resonator but the curve is bent down at high fields due to electron field emission(EFE). Resonators L-29 and L-30 show the both symptoms of low-field Q-degradation and high-field EFE. Resonator L-2 is one of the two which absorbed a lot of hydrogen during many times of electro-polishing. The symptom of the Q decrease due to EFE can be seen above an rf input of about 4 watts or a field gradient of about 5 MV/m. Ratios of Q factors at two different fields of 5 MV/m and 1 MV/m are plotted in Fig. 7, in order to see how the EFE has increased since 1995. For the data in which the highest field was lower than 5 MV/m, the Q at the field nearest to 5 MV/m was chosen.

It is clearly seen that many Q factors have decreased at 5 MV/m; the mean of the ratios for July 2001is 0.35,and that for June 1995 is 0.44. There was a possibility, however, that the Q values of July 2001 could have been recovered to some extent, if high power pulse conditioning was carried out prior to the measurements.

4 SUMMARY

It was found that the latest resonator on-line performances were as good as the early time ones; the mean Q of 5.6×10^8 at 1 MV/m and the mean field of 4.63 MV/m at the rf input of 4 watts. However, many Q factors of the first 16(20) resonators at low field gradients were improved by a fast cool-down in a sequential mode, while many Q factors at high field gradients were appreciably degraded by EFE.

5 REFERENCES

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