Operating Status of the TRISTAN Superconducting RF System

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Abstract

The TRISTAN superconducting RF system consisting of thirty-two 5-cell niobium cavities has been operated for more than 3 and a half years. In this paper, we report change of the cavity performance, trouble and the operating experience.

1. INTRODUCTION

The TRISTAN superconducting RF system has been operated for more than 8300 hours for physics experiments since its commissioning in 1988. Until the end of 1989, it was used to raise the energy of TRISTAN and 32 GeV was achieved using twenty-nine 5-cell cavities, in which the average accelerating gradient was 4.7 MV/m with 6.0 MV/m as the maximum. From 1990, after energy survey, the energy has been fixed at 29 GeV and higher beam current has become more desirable.

During a long shutdown in 1990, which was necessary to install superconducting Q magnets for mini-ß optics, we improved the HOM power extraction system, because the old system limited the beam current below 13 mA due to connector heating. The new system is expected to be safe for the current of more than 25 mA.

In the meantime, two spare cryostats (four cavities) were prepared. We replaced two cryostats in the last summer, one contained degraded cavities and the other leaked at a beam pipe indium joint. Unfortunately, one of spare cavities leaked later at a coupling port indium joint for HOM couplers, and that one old cavity leaked at an outer water jacket for cooling of an input coupler ceramic disk. Eventually, the total number of operational cavities was reduced to 26 in the last running period.

These two kind of failure happened again during the last shutdown, two leaks at beam pipes and two water leaks at outer water jackets. So at present, the number of operating cavities is 23. In Table 1, operating conditions of the TRISTAN superconducting RF system are summarized.

2. CAVITY PERFORMANCE IN THE RING

Since our system is the first large scale application of superconducting cavity, we have routinely measured cavity performance after cool-down and before warm-up of every running periods. During a running period of 3 ~ 5 months, the vacuum pressure measured at warm beam pipes of cavities increases from ~ 5×10^{-10} Torr in the beginning to ~ 3×10^{-9} Torr. The adsorbed gas is mainly hydrogen and amounts to 1 ~ 5 monolayers(1). Masks set on beam pipes of bending magnet side of every cryostats prevent synchrotron radiation from hitting cavities, but it can hit directly three upstream beam pipes between cryostats, where the radiation level is 1 ~ 20 kR/mA·h.

Figure 1 shows the distribution of the maximum accelerating gradient, $E_{acc,max}$, measured after the last report(2). As is described before, two degraded cavities were replaced by spare cavities in the last

Table 1: Summary of the operation of SC Cavities in TRISTAN-MR

Period		Number of cav. (at 4K)	(operated)	Total Vc (MV)	Eacc(ave.) (MV/m)	Energy (GeV)	Current (mA)	Physics Run (days)
1988	Nov-Dec	16	16	105-109	4.4-4.6	30.0	10	18
1989	Jan-Mar	16	14	82-88	4.0-4.2	30.4	9	49
	May-Jun	14	14	87	4.2	30.4	10	17
	Jun-Jul	16	16	105	4.4	30.7	10	37
	Oct-Dec	30	28-29	190-200	4.6-4.7	32.0	12	25
1990	Feb-Mar	32	31	160	3.5	29.0	12	37
	Apr-May	32	30-31	160	3.5-3.6	29.0	12	25
	May-Jun	32	28-30	150-160	3.6	29.0	13	39
	Jul	30	25	130	3.5	29.0	13	31
1991	Jan-Jul	32	29-30	140-145	3.3	29.0	9	36
	Oct-Dec	30	26	140	3.6	29.0	13	35

Total accumulated time of cavities at 4.4 K : 16000 hours summer. Figure 2 shows unloaded Q values, Q_0, obtained by measuring liquid He consumption. Though there are rather large error, about 20 %, in the measurement, we can say that they keep their initial values.

As for the electron field emission, which is measured by field monitor probes at beam pipes, it is not clear whether it represents the global performance like $E_{acc,max}$ and Q_0. However we can see at least the correlation that cavities having higher E_{acc} have better Q_0 and less electrons. The field enhancement factor, ß, are distributed between 200 to 800.

In conclusion, the superconducting Nb cavity can keep the initial performance, $E_{acc,max}$ of 7 MV/m and Q_0 of 2×10^9 at 5 MV/m, for more than 3 years in a storage ring.

3. OPERATION

In spite of good performance without beam, our system trips more frequently than the normal conducting RF system when the beam current is high. Since we have enough RF voltage and can recover tripped cavities, it is rare to lose beam. But frequent trips are undesirable since the recovering procedure shakes beam, so background noise at detectors increases and sometimes it causes other trips. In the worst case, quench happens and a beam dump interlock due to He pressure rise works because our fast quench detector is inhibited during the first stage of recovering.

Figure 3 shows the distribution of average number of trips in one fill (~ 2 hours) in the last December (128 fills). The number of recovering failure was 17. This distribution of trips was reported already in reference (1) and there the relation with synchrotron radiation was discussed. After that we moved the mask of 10D#4 by another 1 mm to the direction of the ring center. Consequently, the trip rate of 10D#3 during acceleration was reduced by one order, and that of 10D#4 at flat top became a half. The increase of the trip rate in 11C and 11D is probably due to missing of the outermost cryostat.

The trips in 10A#4, 10B#1 and #2 became prominent since the last July, and was dominant during the operation with the first 16 cavities[3]. These are divided into two groups. The first group occur at the machine energy of 19 ± 2 GeV and the working interlocks are mainly vacuum pressure of the cavity 10A#4 or 10B#1, in about a half of which both work simultaneously. The other group occur at the energy of 28 ± 1 GeV and are mostly fast quench accompanied by gas burst. Contrary to the first group, these are bunched in time, occur frequently in some week but do not in the next week. When the second group do not occur, the rate of the first group seems to increase. In both cases, trips

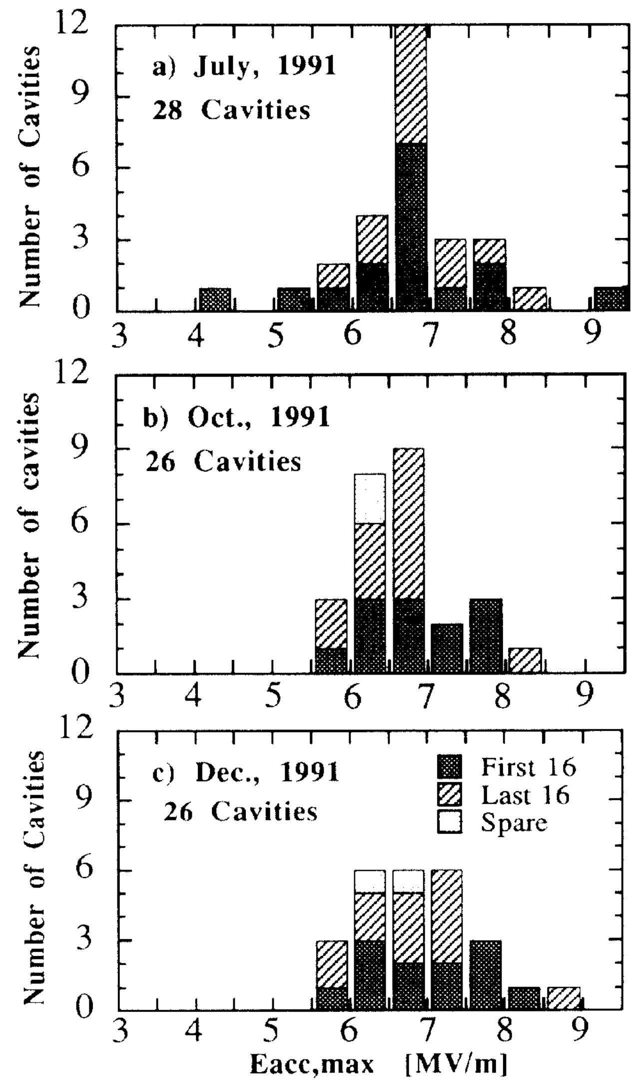

Figure 1. Distribution of the maximum accelerating gradients.

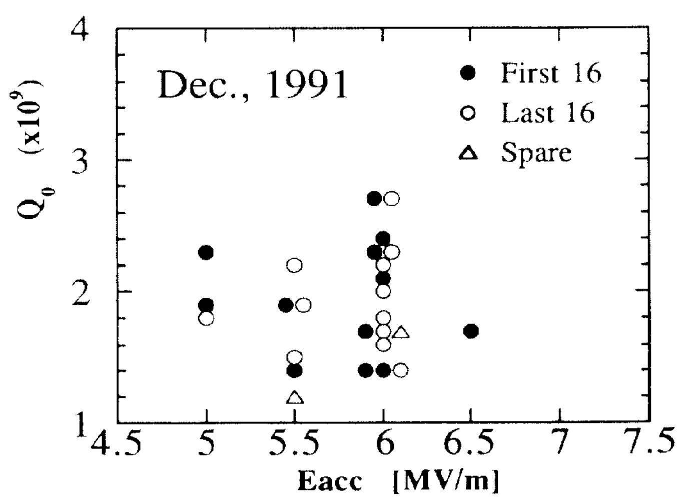

Figure 2. Distribution of the unloaded Q values.

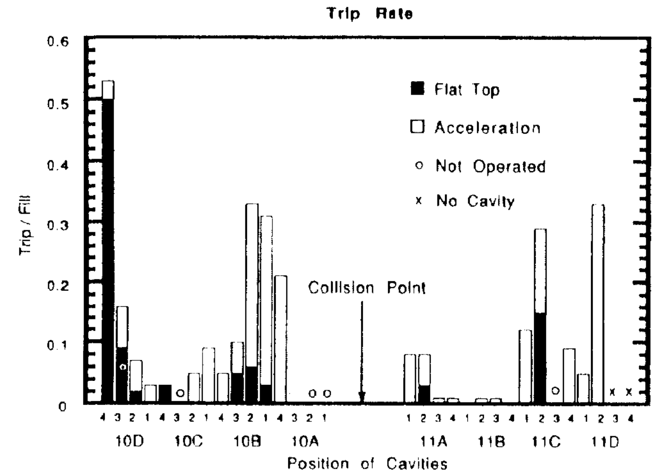

Figure 3. Distribution of the trips.

are not related with multipactings in HOM couplers. The number of HOM coupler processing times during the last running period was 7, only for one coupler of the cavity 10D#3.

In most case, there are strong relation between the trips and the radiation. In the present operation which started on 20 February, we moved the masks further by 0.5 mm for 10D#4, 1 mm for 10C#4 and 11C#4, and installed two cavities at 11D#3 and #4. The trip rate looks decreased but we should watch for a while. For the trips in 10A and 10B, we plan to check alignment of cavities and Q magnets in the next summer.

4. HARDWARE TROUBLES

The major hardware troubles we have met until now are the following five.

1) Heating of N type ceramic connectors for HOM power extraction.
2) Break of piezoelectric transducers for cavity fine tuning.
3) Water leak at outer water jackets of input coupler ceramic windows.
4) Vacuum leak at input coupler ceramic windows.
5) Vacuum leak at beam pipe indium joints.

The trouble 1) happened in the early stage of the operation and 4 N type connectors were burnt. This was solved by using larger ceramic connectors and adding interlocks for excessive fundamental power due to HOM coupler quench.

Piezoelectric transducers are made of 60 layers ceramic disks stacked by plastic bolts. These plastic bolts were broken by radiation damage in 5 transducers, and resulting unbalance of stacking force seems to break ceramic disks. All transducers were replaced by new types, where plastic bolts were changed to SUS bolts. However about a half of the new types were broken, probably because SUS bolts are too strong to absorb rapid change of expanding force. So all transducers were replaced again by old ones with radiation shields.

The trouble 3) occurred in the last summer shutdown firstly and then other two happened in the last shutdown. It was lucky that these happened when cavities were warm, but cavities were contaminated with a large amount of water. We cut several ceramic windows and found many local erosion on thin copper cylinders which were brazed to ceramic disks. The erosion is remarkable only in outer cylinders, specially at the water inlet, but the situation is not related with the age of couplers. This trouble will be solved by using filters and decreasing the water flow rate, but for the moment we have simply stopped water cooling of outer cylinders.

Vacuum leak of ceramic windows has happened 6 times. Two of them were caused by burning of polyethylene backup disks, and one was probably caused by sparking at the coupling port where we had found protrusion of indium. This is liable to happen during aging and recovering from trips where RF power is totally reflected.

The last trouble has also happened 6 times, 2 during warm-up, 3 during cool-down and 1 during operation. It is serious, because 4 of them have happened after 2 or 3 years operation and there are still 11 old cryostats. We consider that the manner to use indium is wrong. Because of difficulty to hold indium when two beam pipes are connected in horizontal position, we use SUS centering rings and surround indium ribbons on them. So the pressing force at outer diameter position is not transmitted sufficiently to indium ribbons since Nb flanges are not rigid enough. Now we have found a good way to set indium ribbons at an outer position of Nb flanges.

5. REFERENCES

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