STATUS OF THE TRISTAN SUPERCONDUCTING RF SYSTEM

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Abstract: 32 5-cell superconducting cavities have been operated at TRISTAN, a high energy electron positron colliding accelerator. 16 cavities were installed in the summer of 1988 and the other 16 in the summer of 1989. Efforts have been made mainly for the stable operation with the higher beam current.

In this paper, operation experiences and properties of the cavities through the long term operation will be described.

Introduction

Superconducting RF system at the TRISTAN main ring is the first major application of RF superconductivity in the world. The highest beam energy of TRISTAN, 32 GeV, was achieved by the 32 5-cell superconducting cavities added to normalconducting cavities. Recently, the beam energy has been fixed at 29 GeV rather lower than the highest, for high luminosity operation.

16 cavities out of them have been operated for about one and a half years and the other 16 for about a half year. The performances of the cavities have been measured every shutdown of the machine. To obtain high luminosity, stable operation with high beam current is required severely.

Explanations of our system have been described in ref.[1]-[7]. General status and operation history will be reported in ref.[8].

Performances of the cavities through long operation

Maximum accelerating fields (Eacc,max) have been measured at every shutdown of the machine. In most cases, the reason that limits Eacc,max is 'break down', which is detected when the field levels become abnormally low. Another reason is 'coupler arc' which means that visible light is detected through a glass window at a input coupler. When 'coupler arc' occurs, we do not persist to push up the field level for avoiding risk to break the ceramic window of the coupler. Because each set of four cavities is fed by one klystron, our effort to push up field levels tends to be concentrated to the cavities which have the lower Eacc,max among the four cavities in order to achieve higher field in the actual operation. Then, it must be noticed that Eacc,max of some cavities are under estimated.

Q_0 values have been determined by loss of liquid He in the cryostats at slightly lower field than Eacc,max. Amount of electrons from field emission have been measured and field enhancement factors (β: local quality of surface) have been calculated.

Fig.1 shows the change of Eacc,max of all cavities from the installations to the recent measurement as function of days after installations. For some cavities, Eacc,max have been significantly decreased. In the case of the number 3 cavity of the station-11B (11B#3), the input coupler was broken . Since then, the cavity has not been used, because the Eacc,max became too low, though the cavity was retreated and had recovered at the bench test (without an input coupler). 10C#3, 10D#2 and 10D#3 seem to have been suffered by out gasses during the beam operation, because these cavities have frequently tripped by interlock associated with vacuum worsening with high beam current. Eacc,max of 10B#3 was decreased after polluted to the air (in order to replace the connector attached with a higher order mode coupler, about 300 days later from the installation), but recently, it has recovered to the previous level. 11B#2 was deteriorating gradually (there is no clear reason), but it has recovered too. The reasons of the recoveries are not clear, there is not evident relation with warming up of the cavities.

As will be described later, some cavities tripped frequently with high beam current. But the performances of these cavities were not necessarily poor at measurements without beam.

Fig.2 and fig.3 show Q_0 and β of cavities of station 10A for example. There seems to be no clear relations with Eacc,max.

Fig.4 shows the distribution of the Eacc,max measured just after first 16 cavities' installation, just after second 16's installation and recent measurement. Some cavities' Eacc,max have been decreased, but the distribution higher than 5.0 MV/m has not been changed essentially.

Generally, the performance of the cavities have not changed during the 0.5 or 1.5 years' operation, even if some cavities have been deteriorated accidentally.

Some troubles and cures

Higher order mode couplers

In the early stage of the operation, some connectors and cables attached to higher order mode (HOM) couplers heated abnormally and some of them were seriously suffered. Probably, discharges occurred at the connectors because these contacts were not enough tight. Another reason is that accelerating mode power came out through some HOM couplers, because the resonance frequencies of the coupler filters (adjusted to the accelerating mode frequency) were changed triggered by multipactoring in the couplers.

Cures have been made as follows.

1. The structure of the connector was changed for tighter contacts.
2. The cables have been water cooled.
3. If accelerating mode power is detected through a HOM coupler, RF power is shut off by interlock system.
4. Beam current has been limited.

Recently, there are no such troubles with limited beam current, less than 13.5 mA.

For much higher luminosity operation or higher beam current, displacement of all connectors and cables to larger ones is scheduled in this autumn.

Ceramic windows of input couplers

Each 5-cell cavity has an input coupler with a coaxial disk shaped ceramic window, then there are 32 windows operated. Our experience about the couplers, up to the last summer, is described in ref.[5] in detail.

Before installation in the main ring, four ceramic windows were broken. After installed in the main ring, air leakage occurred at three windows. In one case of them (cavity 11B#3), the leakage was so much. Though the surface of the cavity was retreated, its performance was obviously deteriorated and the cavity has not been operated with beam since then. In the other two cases, the leakages are not so much and no deteriorations have been observed after displacement of the couplers.

Since Oct. 1989, for about four month's operation, there have been no leakage at the coupler windows.

For the couplers with arc detectors at optical windows, through which light of discharges can be detected (and the interlock system shut RF off), leakages have never occurred. Discharges at couplers without such glass windows can be detected only by vacuum sensors and there are time delay. Our experience suggest that to detect discharges and shut off the power as fast as possible is very important and effective to prevent leakage at the ceramic windows.

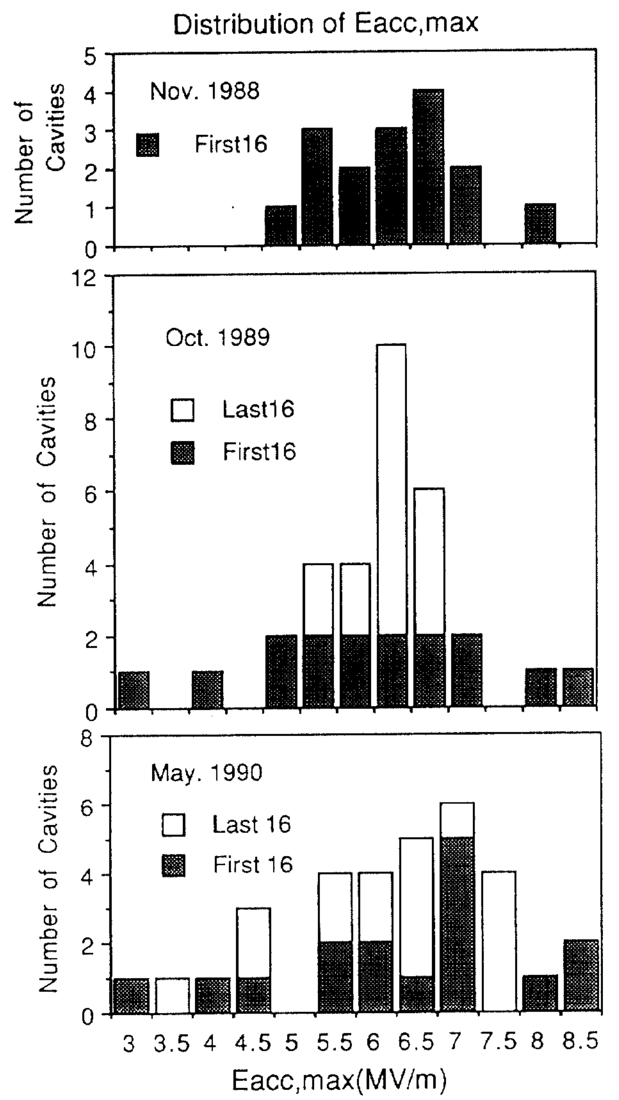

Fig. 4. Distributions of Eacc,max measured in Nov. '88 (just after installation of the first 16 cavities), in Oct. '89 (just after installation of the last 16 cavities) and May '90.

Frequent interlock actions in some cavities

Fig.5 shows average number of interlock actions (shut off RF power) in a beam filling for each cavity as a function of the location in the ring. The interlock actions have occurred for some specific cavities frequently. There seems to be two types of the frequent interlock actions.

First, some cavities, whose Eacc,max are enough high without beam, sometimes trip with beam (>10mA). The voltages of these cavities have been set enough low for stable operation. For example, a cavity, whose Eacc,max is about 7 MV/m, has tripped several times in a beam filling at 3 MV/m with beam.

At the time of these interlock actions, the field level of the cavities fall down very fast (about 10 μsec, much shorter than the filling time of the cavities; or the stored energy in the cavities are spent quickly in the cavities). The vacuum levels become worse at these times. These observations suggest that discharges in the cavities occur.

The second type of frequent interlock actions occurs during beam acceleration (or increasing the accelerating field) as the vacuum level's jump up, one or two times in a beam filling.

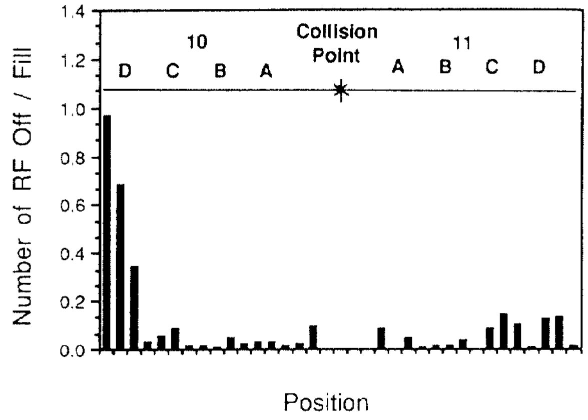

Fig. 5. Average number of interlock actions of each cavity in a beam filling as function of the location.

These actions occur at specific cavities near the bending sections and the trip rate seems to depend on the beam orbit. Probably, the synchrotron light from the arc (bending) section is the trigger of these trips.

Conclusions

After one and a half or a half year's operation, most of the superconducting cavities in the TRISTAN main ring have been kept their performances. On the other hand, some cavities have been deteriorated. One of them was suffered by input coupler's breaking seriously, and probably, some cavities have been suffered by air (or dust) pollutions. But some of them have recovered without any clear reasons.

Stability of the operation depends on not only beam current but also beam orbit and location of the cavities.

Beam current has been limited by connectors and cables of higher order mode couplers, and their replacement is scheduled in this autumn to achieve higher luminosity.

Acknowledgement

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References

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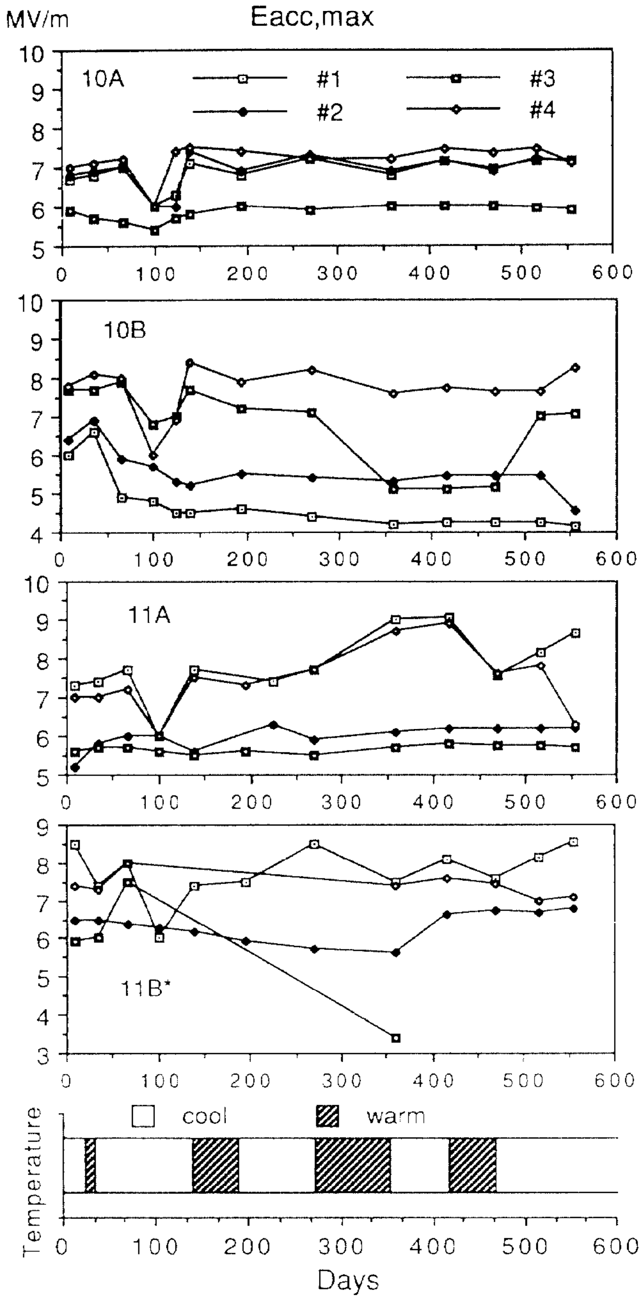

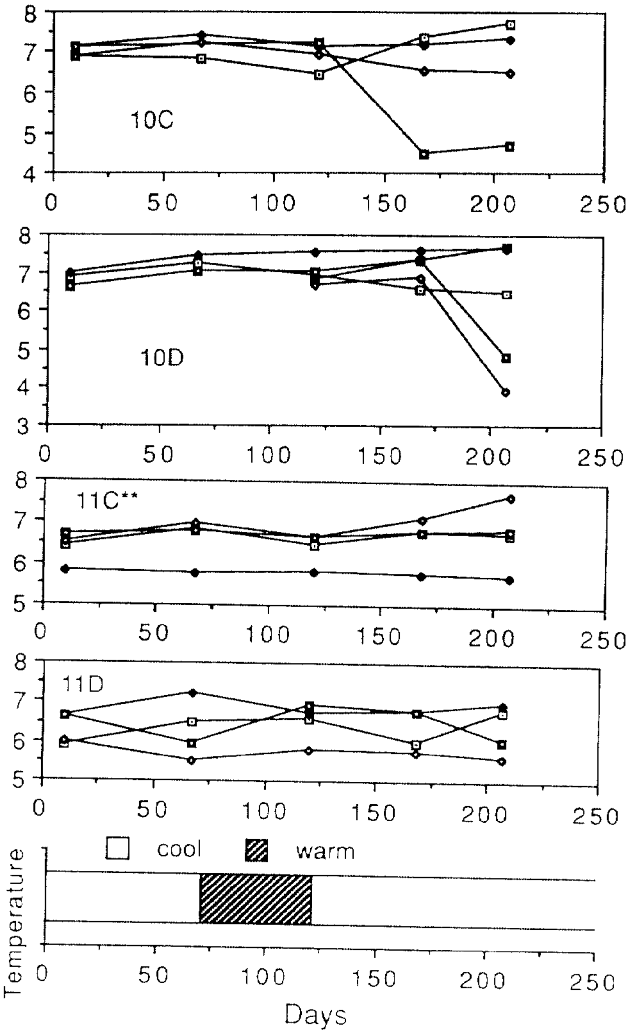

Fig. 1. Change of Eacc,max of every cavities as function of days after installations. Temperature (cooled down or warmed up) is also shown. *,**: The cavities named 11B#3,#4 have been placed at 11C#3,#4 since Oct. '89 and the cavities named 11C#3,#4 have been at 11B#3,#4.

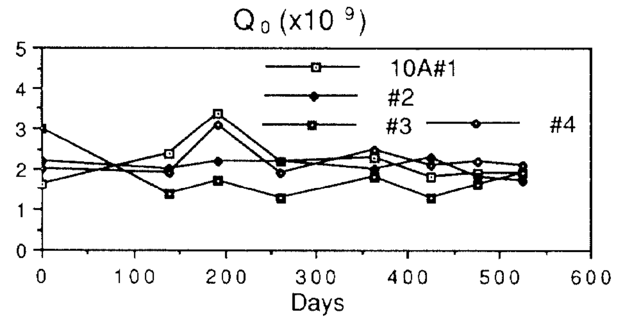

Fig. 2. Change of the Q_0 values of the cavities in 10A station as function of days after installations.

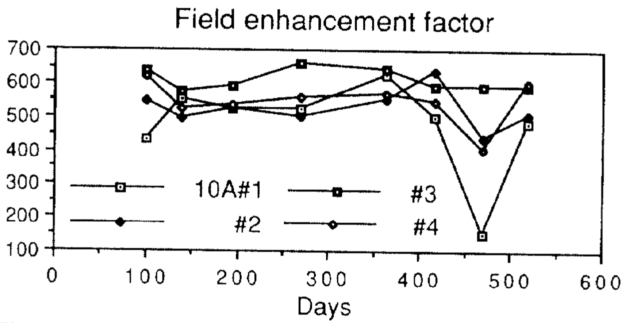

Fig. 3. Change of the field enhancement factor of the cavities in 10A station as function of days after installations. These values express local qualities of the inner surface.