§1. Excitation Properties of Helical Coils of the Large Helical Device in the 4th Campaign

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The propagation and recovery of a normal zone was observed repeatedly in the helical coils at higher than 11 kA. In the second campaign, a normal zone propagated widely at the first excitation up to 11.45 kA. In the following excitations, the ramp rate was reduced to 1/10 at higher than 10 kA in order to keep good cooling condition. The second excitation up to the same current was attained without any abnormal signals. A kind of training effect was observed. The number and amplitude of the spike voltages induced by conductor motions were obviously lessened in the second later excitations. After the third cool-down, a normal zone propagated and recovered when reaching 11.33 kA in spite of slow charging. The effect of slow charging seems to be small, and the training effect is almost lost by warm-up. Since the maximum magnetic fields in the *M* and *O* blocks are lower than the innermost *I* block, these should be excited up to the higher currents within cryostable conditions. Besides, conductor motions in these blocks seem to be much less than the *I* block from comparisons of the spike voltages. We tried currents-grading excitations up to average 11.67 kA. A normal zone propagated and recovered in the *H1-I* block at average 11.65 kA. In the next excitation, a normal zone was induced again at the almost same current. 1)

The major excitation tests in the fourth campaign are listed in Table 1. *#1-o* and *d* mean operation modes of standard and inward shift, respectively. In the current-grading excitations up to average 11.67 kA, the current of *I* block was decreased by 100 A and other blocks were increased by 50 A to improve cryostability of the *I* block. Nevertheless, a normal zone was induced in the *H1-I* block at 11.64 kA in the first excitation, and it was induced in the *H2-I* block at 11.62 kA in the second excitation, as shown in Fig. 1. The first and second normal zones were speculated to be induced at the end of the third and fourth layers, respectively, from the evaluation of the factor to make a consistent wave form of the resistive component from the voltages of *I* and *M* blocks. A large disturbance able to induce a certain length of a normal zone might occur when the conductor slides widely on the end spacer for the first time in each cooling period. The conductors in the lower layers begin to move at lower currents, and the third and fourth layers might begin to move at 11 kA around. In order to detect the position of the propagation of a normal zone, many pick up coils were installed near the helical coil before the fifth campaign.

There is a threshold current depending on the field, as shown in Fig. 2. When a current is slightly higher than it, a normal zone can propagate and recover because of a ripple of the magnetic field, deviation of cooling conditions or decrease of heat generation in the initial normal zone by a current diffusion into a pure aluminum stabilizer. The threshold of the *M* or *O* block should be lower because of the larger spacer rate or the effect of the direction of the magnetic field. Further evaluation and basic experiments are necessary for the higher excitation by current-grading.

Table 1 Major excitation tests in the 4th campaign

Date	Current (mode_field @ major radius)
Sep. 27 '00	11.33 kA (*#1-o*_2.72 T @ 3.75 m)
Sep. 28	av. 11.53 kA (*#1-o*_2.767 T @ 3.75 m)
	av. 11.64 kA (*#1-d*_2.91 T @ 3.6 m) (*1)
Oct. 4	av. 11.62 kA (*#1-d*_2.906 T @ 3.6 m) (*1)
Dec. 1	av. 11.64 kA (*#1-d*_2.91 T @ 3.6 m) 3 times
	[H-I/M/O = 10.975/11.873/12.072 kA]
	R_{ax}= 3.6-4.1 m, B_Q= 72.2-200% at 11.1 kA
Dec. 7	11.30 kA (*#1-d*_2.825 T @ 3.6 m) 2 times
Feb. 2 '01	H-I/M/O = 11.25/6.55/0.2 kA
	(*#1-d*_1.5 T @ 3.6 m, γ=1.18)

(*1) A normal zone propagated and recovered.

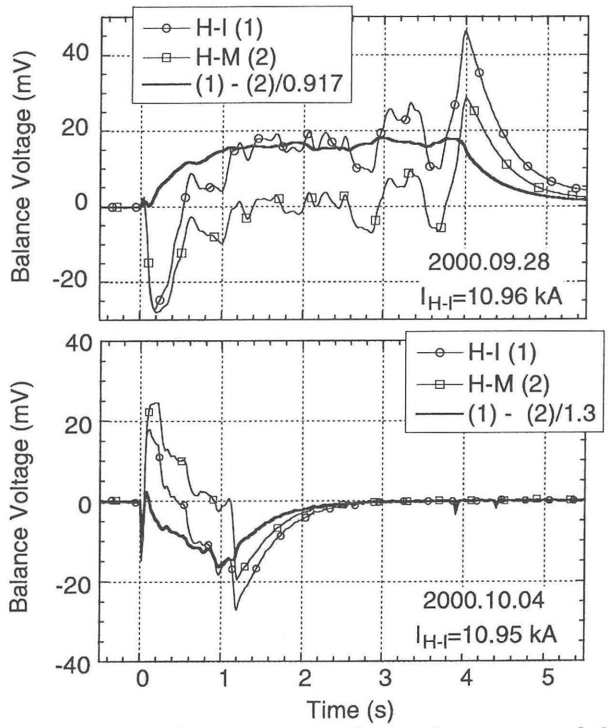

Fig. 1. A normal zone propagation and recovery of the helical coils at #1-d 2.91 and 2.906 T (4th cycle).

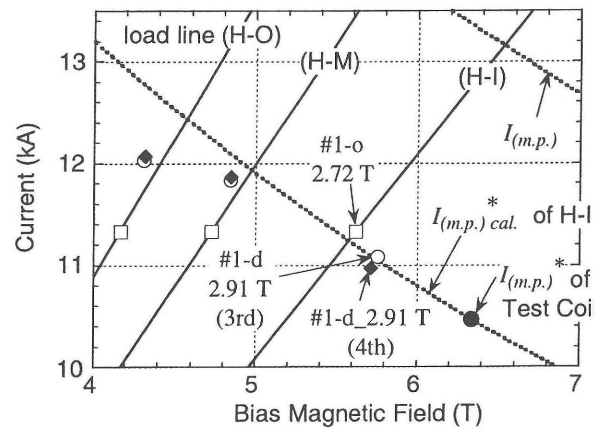

Fig. 2. A dynamic propagating current of a normal zone *I(m.p.)** and the cold end recovery current *I(m.p.)*.

Reference

1) S. Imagawa, et al., IEEE Trans. Appl. Supercond., Vol. 11 (2001) 1889-1892.