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Development of 52 kA HTS Current Lead for the ITER CS Magnet Test Application

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ASIPP

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Abstract: Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) was contracted by General Atomics Company (GA) to develop a superconducting feeder system, including a pair of 52 kA high temperature superconducting (HTS) current leads for ITER Central Solenoid (CS) magnet test. These HTS current leads are majorly based on the previous ITER lead design experiences. However, the vertical assembly design is different from ITER horizontal assembly. The HTS current leads were integrated in the feeder system to perform 4.5 K full current test. The factory acceptance test was implemented to verify the high voltage and thermodynamic performances. It was cold tested in ASIPP at the end of 2016. The test results demonstrated their excellent performance on low joint resistance, long Loss Of Flow Accident (LOFA) time and high current-sharing temperature, the overheating time, mass flow, and heat loads to 5 K ends.

The 52 kA HTS current lead consists of four major components :

1) Room temperature terminal — with water cooling and heater

2) Resistive heat exchanger — zigzag-flow fin-type

3) HTS module — 90 Bi-2223/AgAu stacks on a S.S. shunt

4) LTS joint — a twin-box joint

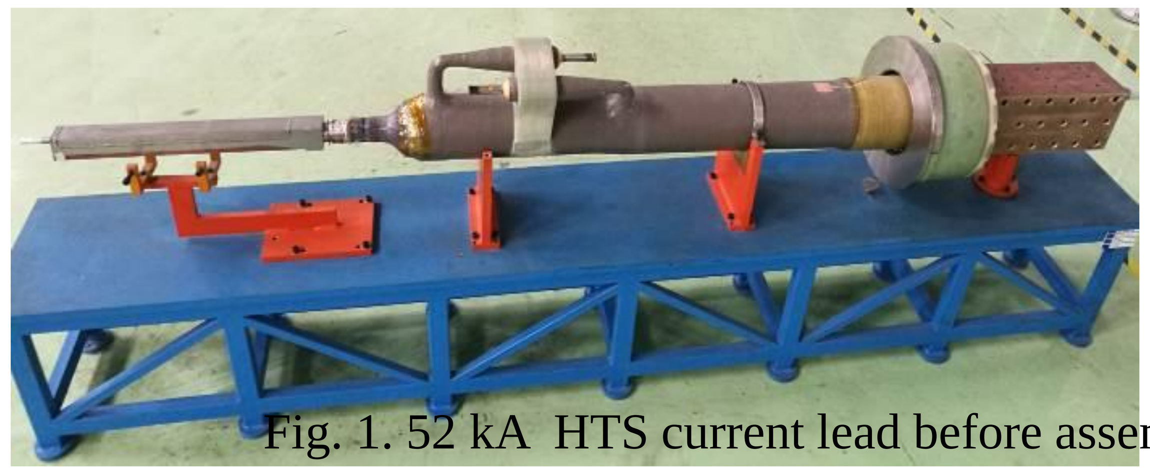

Fig. 1. 52 kA HTS current lead before assembly

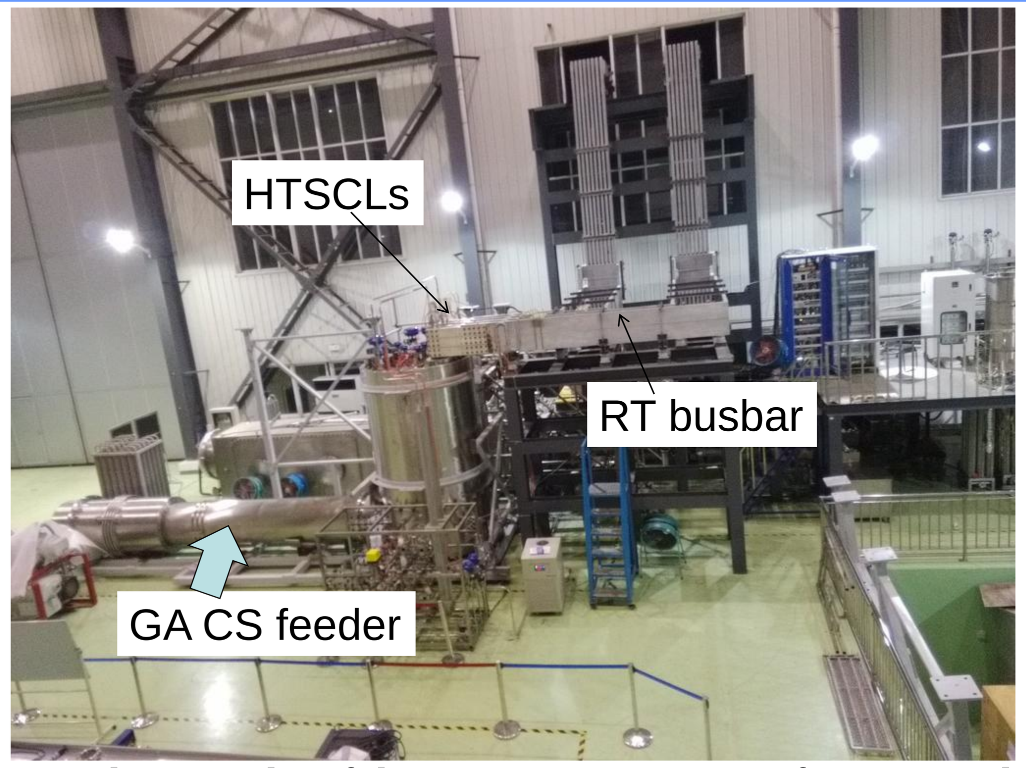

Fig. 2. Photographs of the cryogenic test setup for GA Feeder system containing two 52 kA CLs

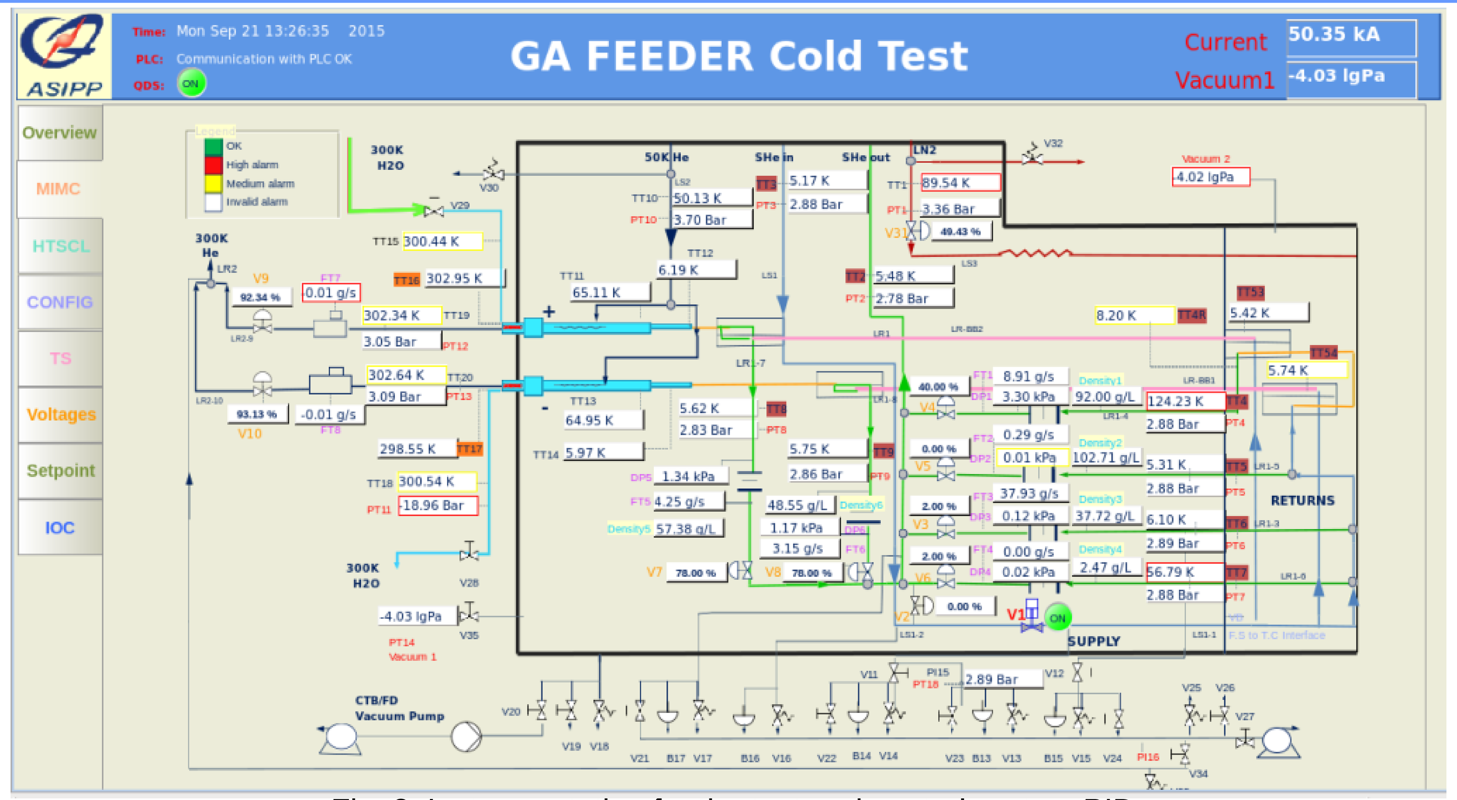

Fig. 3. Instrumentation for the test and control system PID

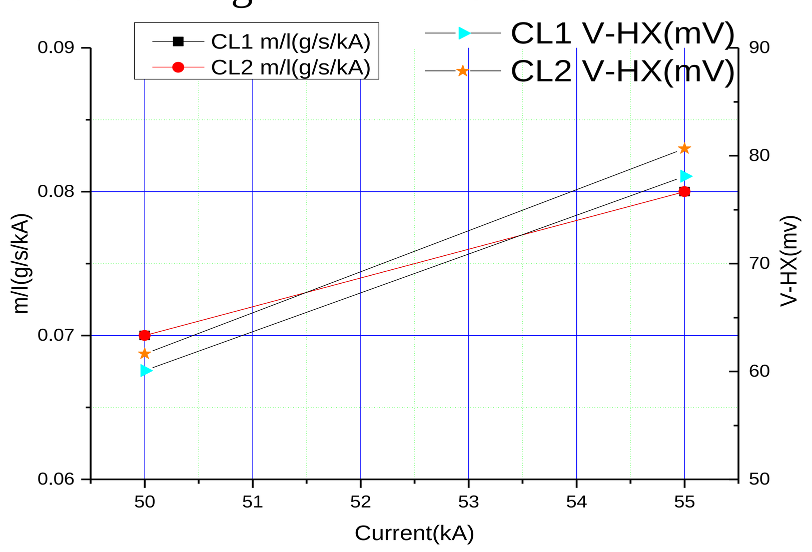

Fig. 4. HX flow and HX voltage for different current steady states

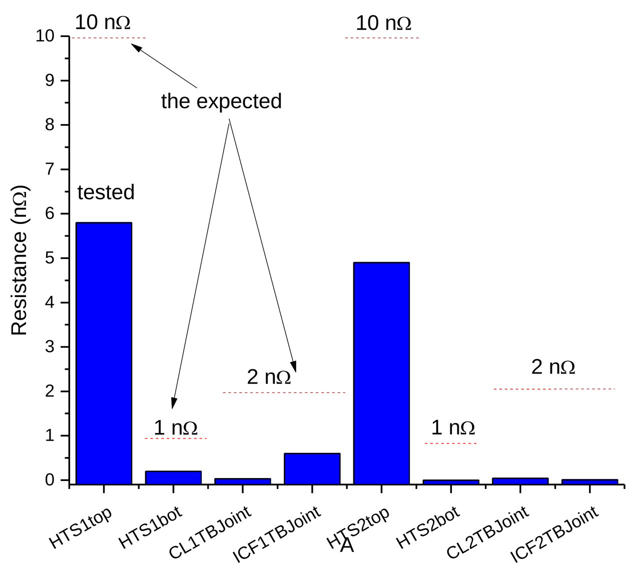

Fig. 5. Resistance test results

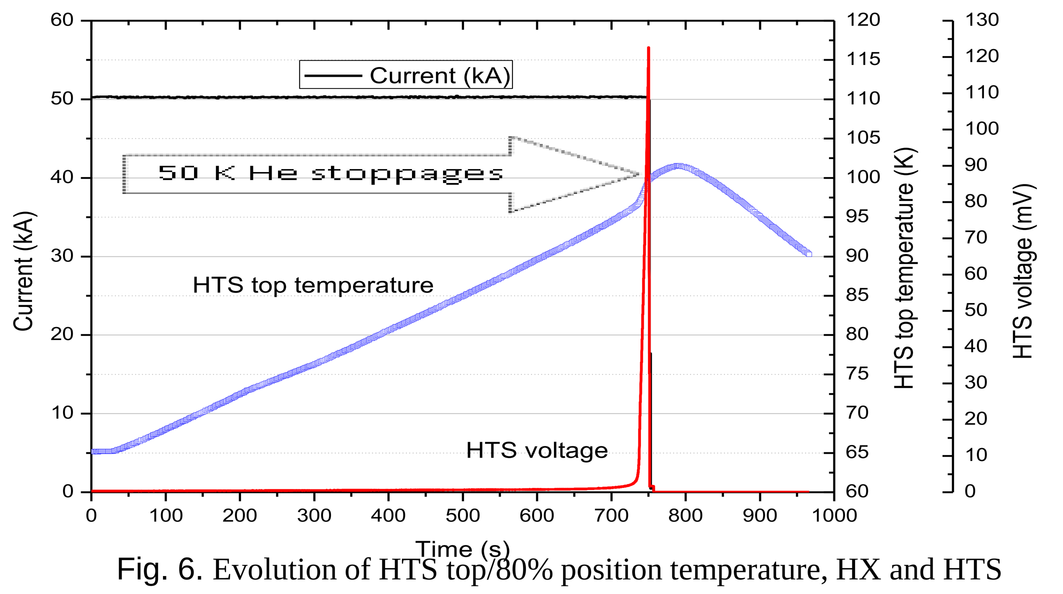

Fig. 6. Evolution of HTS top/80% position temperature, HX and HTS voltage during 52 kA steady-state operation and LOFA test.

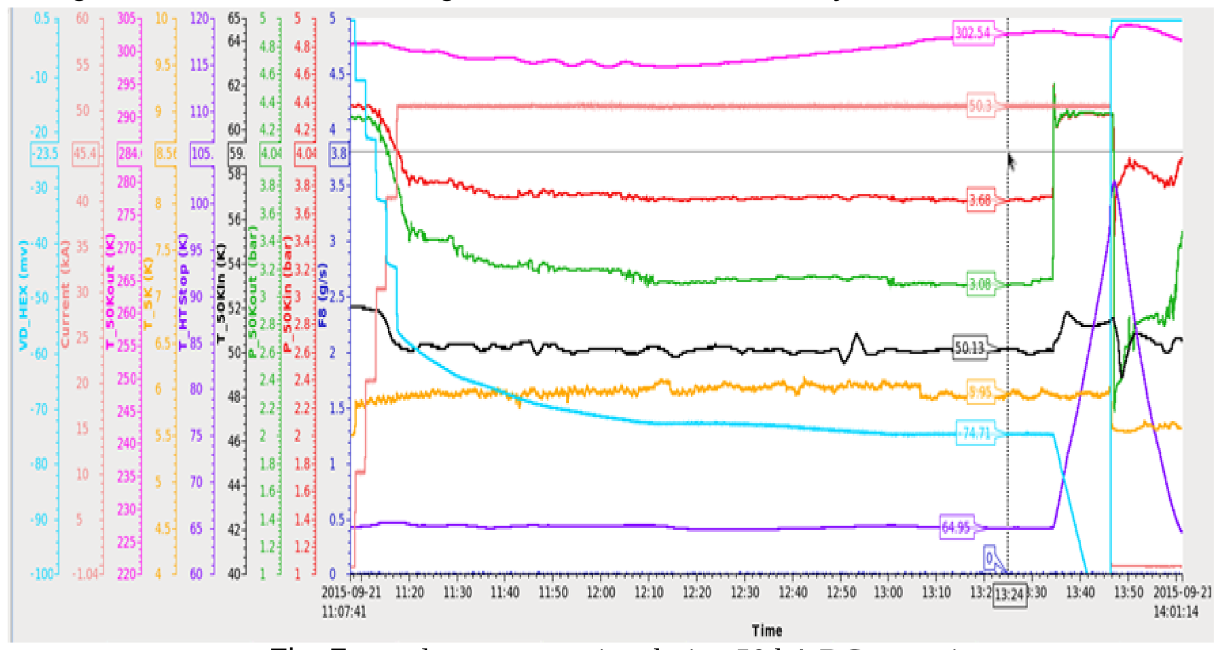

Fig. 7. steady state operation during 50 kA DC operating current

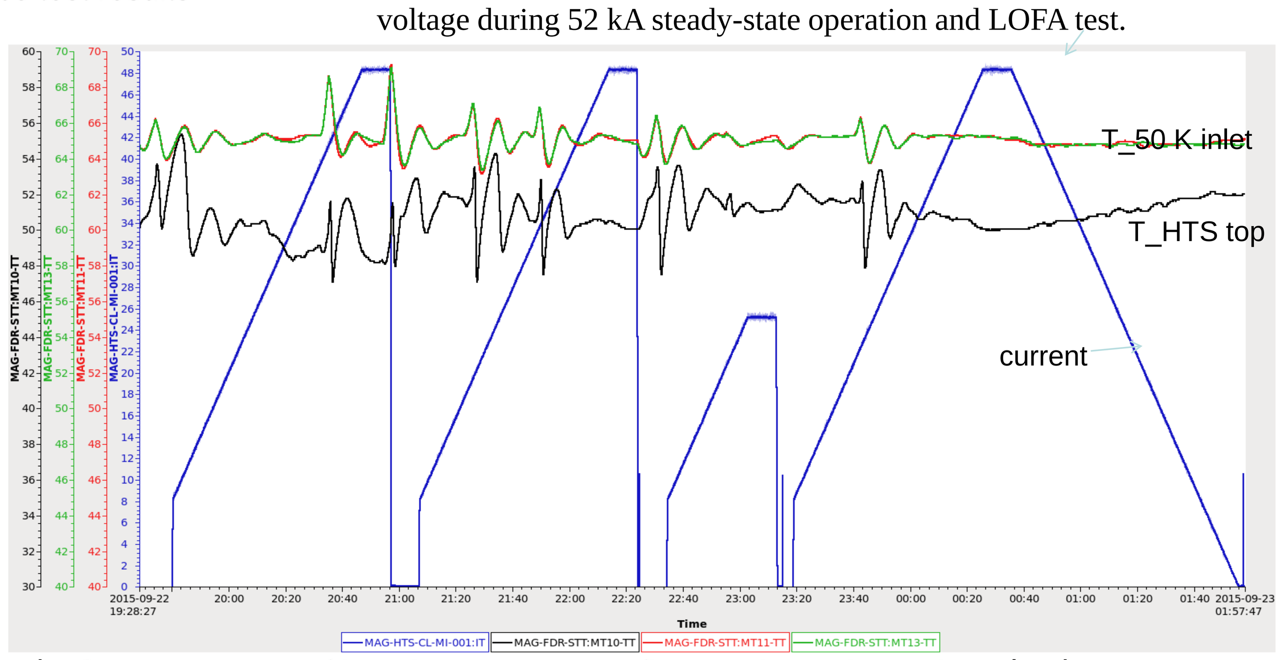

Fig. 8. Temperature profile under 50 K two-step flow regulation during the pulsed current test

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Table I The major test results for 52 kA HTS CL prototypes

Items	Test results	The expected
Mass flow rate	3.2~3.3 g/s	3.8 g/s for 50 kA
HEX pressure loss	0.6 bara	1 bara
Joint resistance of four twin-box joints	Max. 0. 6 nOhm	2 nOhm
Joint resistance of HTS tops	5~6 nOhm	10 nOhm
LOFA time	600 s	300 s
Vacuum	< 1E-4 Pa	1E-3 Pa
Thermal shield	< 90 K @ 7 days cool	100 K
Pulsed current	Yes. NO voltage in HTSCL is larger than 1 mV which guide the threshold setting for GA operation in future.	HTS top control stability Induction voltage is small
HTS conduction heat load	10.3 w per lead	12 w per lead

The 50 K helium consumption for the HX is an important parameter for standby. The 50 K mass flow is about 1.5/1.0/0.6 g/s for 65/80/100 K standby.

The HTS conduction heat load is measured calorimetrically ($Q=m*\Delta H$). The heat load is 20.6 W for the two leads at HTS top 65 K. This is below the requirement of 12 W/lead.

To measure the joint resistances, keeping the 5 K loop and HTS top temperature table, then testing current was supplied in step (10 kA step) to reduce the noise and remove the offset. The test result is shown in Fig. 5.

The 50 K loss of flow accident is performed by stopping the 50 K helium supply after establishment of steady state operation at 50 kA (Fig. 6).

Fig.7 shows the steady state operation of HTS current lead during 50 kA operating current which is the max. CS magnet current in GA site.

The pulsed current test item is to simulate the GA feeder current operation under the CSM current scenario, the HTS warm end can be successfully controlled to 66 K $\pm$2 K by PID regulation (Fig. 8).

According to the test, the main results are summarized in the table I

Summary: A pair of 52 kA current leads were successfully built and tested with the short circuit busbar in the GA CS feeder system at ASIPP. The measured flow-rate requirements, joint resistances, LOFA and overheating times can meet the ITER requirements. The 15 kV Paschen voltage tests were also passed. At present, this two current had been delivered to GA site. The site acceptance test has been achieved.

In recent years, the manufacture and test of ITER 10 kA, 52 kA and 68 kA HTS current lead prototypes were achieved. And ITER series HTS leads are under-construction. 16 pair of 12 kA & 6 kA HTS current leads for Russia NICA project were developed at ASIPP.

The GA CS feeder system development can be referred to the poster: Superconducting Feeder System For ITER Central Solenoid Module Final Test Facility, Tue-Af-Po2.03-10 [38] in this conference.