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Overview of JT-60SA HTS current lead manufacture and testing

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Introduction

- HTS current leads (CL) reduce power consumption for refrigeration by a factor 3 to 5
- HTS CL Demonstrator by KIT up to 80 kA
- For ITER: Approx. saving of >1 M€ operating cost/year

JT-60SA HTS current leads

- KIT responsible for design, manufacturing and testing of
  - 20 HTS CL for PF/CS (20 kA) and
  - 6 HTS CL for TF (26 kA)
- Design agreed with JAEA in early 2012
- Design checked by testing W7-X current leads under JT-60SA relevant current scenarios

Design

Copper heat exchanger
- Meander flow type
- Temperature range: 300 K → 60 K
- Cooled with 50 K He

HTS module
- Temperature range: 60 K → 4.5 K
- Conduction cooled from 4.5 K end
- HTS material is Bi-2223/AgAu

Cold contact to superconducting coil
- Copper bar with Nb_3Sn insert
- Clamp contact with Au plated surface

HV insulation
- Glass + epoxy insulation
- Paschen tightness

Manufacturing, assembly and cold test

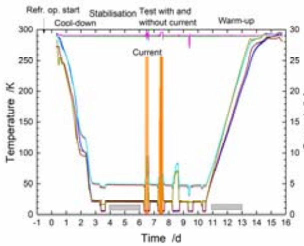
- Half pieces manufactured in main workshop of KIT
- Assembly carried out in ITEP
- Acceptance test at cold conditions performed in test facility CuLTKa

Completed HTS current lead for JT-60SA TF coil system

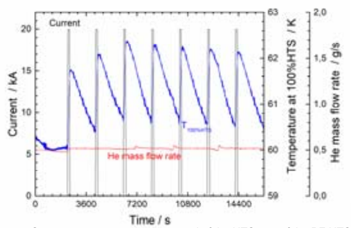
Acceptance test results

- The cold acceptance test provides information about the operation parameters
  - the He mass flow rate for the heat exchanger
  - the heat load at 4.5 K
  - the safety margin in case of a loss of flow accident
- Furthermore, the TF CLs were subject to a six hours' test at 25.7 kA to prove their long-time stability
- One PF CL pair was also tested in pulsed operation

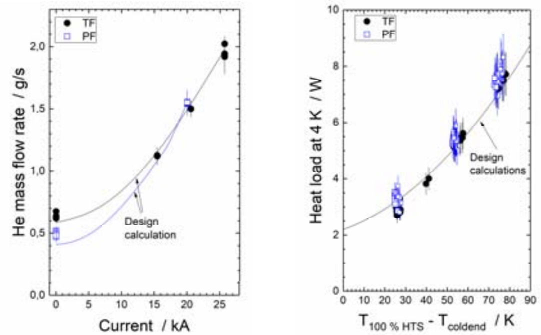
Left: picture of the test facility CuLTKa showing two test cryostats (left and right) and the valve box (center). Right: test setup located within a test cryostat with two current leads (1,2) connected by a short circuit bus bar (3).



Example for the test history, here that for TF03 and TF04 is shown. The grey rectangles identify the weekends



Current, temperature at warm end of the HTS part of the PF HTS CL ($T_{100\%HTS}$) and He mass flow rate through the HX as a function of time during pulse operation.



50 K helium mass flow rate vs current (left) and heat load at the 4 K end vs temperature gradient along the HTS part of the TF (black) and PF (blue) HTS CL (right).

Main results of the JT-60SA TF and PF current lead series tests: average numbers are given for the TF and PF CL

Parameter	Specification	Test results
TF current lead		
Operation current	25.7 kA	25.7 kA
He mass flow rate at 25.7 kA	<2.37 g/s	(1.94±0.04) g/s
He mass flow rate at 0 kA	<0.78 g/s	(0.65±0.03) g/s
Heat load at 4.5 K end	3 W	(3.15±0.57) W
Joint resistance at clamp contact	<5 nΩ	~1 nΩ
Transition resistance at cold and warm end of HTS part	-	(19.77±0.55) nΩ
LOFA time at 25.7 kA	3 min	(14.7±0.3) min
Current sharing temperature	-	(74.3±0.9) K
PF current lead		
Maximum current	20 kA	20 kA
He mass flow rate at 20 kA	<1.8 g/s	(1.52±0.06) g/s
He mass flow rate at 0 kA	<0.78 g/s	(0.49±0.03) g/s
Heat load at 4.5 K end	3 W	(3.21±0.54) W
Joint resistance at clamp contact	<5 nΩ	(2.2±0.4) nΩ
Transition resistance at cold and warm end of HTS part	-	(17.9±0.7) nΩ
LOFA time at 20 kA	3 min	(14.7±0.4) min
Current sharing temperature	-	(73.6±0.9) K

Conclusion

- KIT designed, manufactured and tested 26 HTS CLs for the satellite tokamak JT-60SA
- The design is based on that for the HTS CLs procured for the Wendelstein7-X stellarator which is under operation at IPP in Greifswald, Germany
- All acceptance tests of the TF- and PF-CL were conducted without any problem and the results were within the expectations; all current leads behave very similar
- The experience of the personnel at KIT ensured a smooth execution of the project within the envisaged time and budget