Comparative study of cryogenic NbTi/Cu and MgB_2/Brass based current leads

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♦ Introduction

- SC magnet system in SST-1 consists of 16 TF & 9 PF coils to obtain up to 3 T field to confine and shape the plasma
- To excite these coils, 10 pairs of 10 kA rated vapor cooled current leads (VCCLs) envisaged, presently made of NbTi/Cu and optimized 300 K to 4.5 K
- Current leads (CLs), an optimized interfacing devices required due to being a considerable temperature difference between SC coils at its T_C inside cryostat and power-supply located at room temperature
- 9 PF SC coils to be energised by individual power supplies, hence requiring total 18 VCCLs under pulse operations
- Existing VCCLs reviewed and new approach carried out by altering the present materials using MgB2/brass to save cryogen consumptions during operations
- This work highlights design of MgB2 VCCL, test set-up, experimental results along with comparison of LHe consumption between NbTi/Cu CL and MgB2/Brass CL to assess the operational cost of CLs

♦ Motivation & Objective

- Existing, NbTi/Cu made, VCCLs designed ~ 55% of total cryogenic plant capacity (1.3 kW at 4.5 K).
- To save precious cold capacity, it was envisaged to minimize LHe intake by an innovative/alternative solution with materials-alteration in VCCLs particularly for pulse operation based on operation duty cycle.
- Main objective of this work to develop MgB2/Brass CL for future to minimize operating cost, fulfill the operational requirement, reliable and specifically to pulse operations

♦ Methodology

- MgB2 as Medium Temperature SC (Tc ~ 39K) used in lieu of (Nb-Ti) as LTS, ~ 30 K higher than earlier SC.
- Brass HEX replaces Cu HEX, more specific heat and recrystallization temperature so that it can be overloaded.
- Cryo plant offers the best exergy in the range of 25K – 40 K

- In this perspective, a prototype MgB2/brass based and vapour cooled current lead designed, developed and tested for its performance at cryogenic temperatures

♦ Design of MgB2/Brass Current Lead

- Prototype MgB2/Brass VCCL designed [1] and developed in-house at IPR
- Obtained thermo-physical properties at cryo temperatures
- Assumptions: 1-d model heat flow & heat transfer rate between the helium cryogen and CL assumed to be perfect
- Shape factor computed using following relation [1]

$$\int_{T_0}^{T_\ell} \frac{dT}{\rho(T)} \simeq \left(\frac{I_t \ell}{A}\right)_{ot} \sqrt{\frac{h_L}{c_p k_0 \rho_0}}$$

- Evaluated sizing of heat exchanger in case of brass
- Consequently, LHe consumption rate evaluated in stand-by mode as well as in Current operation mode

Fig 1: *MgB2 VCCL*

Table I: *Important design outcome of MgB2 VCCL*

Parameters	MgB2/Brass CL
Temperature range (K)	4.5 K to 300 K
Active length of HEX (m)	0.78
Design current (A)	5000
Maximum operating current (A)	10000
Shape factor (A/m)	1.52×10^6
LHe consumption (g/s) in standby, I=0	0.09
Total LHe consumption (g/s) at I=1.5 kA	0.14

♦ Experiment Test set-up

- Prototype MgB2/Brass CL installed at test set-up & paired with NbTi/Cu current lead using SC dummy link.

Fig 2: Test *set-up preparation*

♦ Performance Results & Analysis

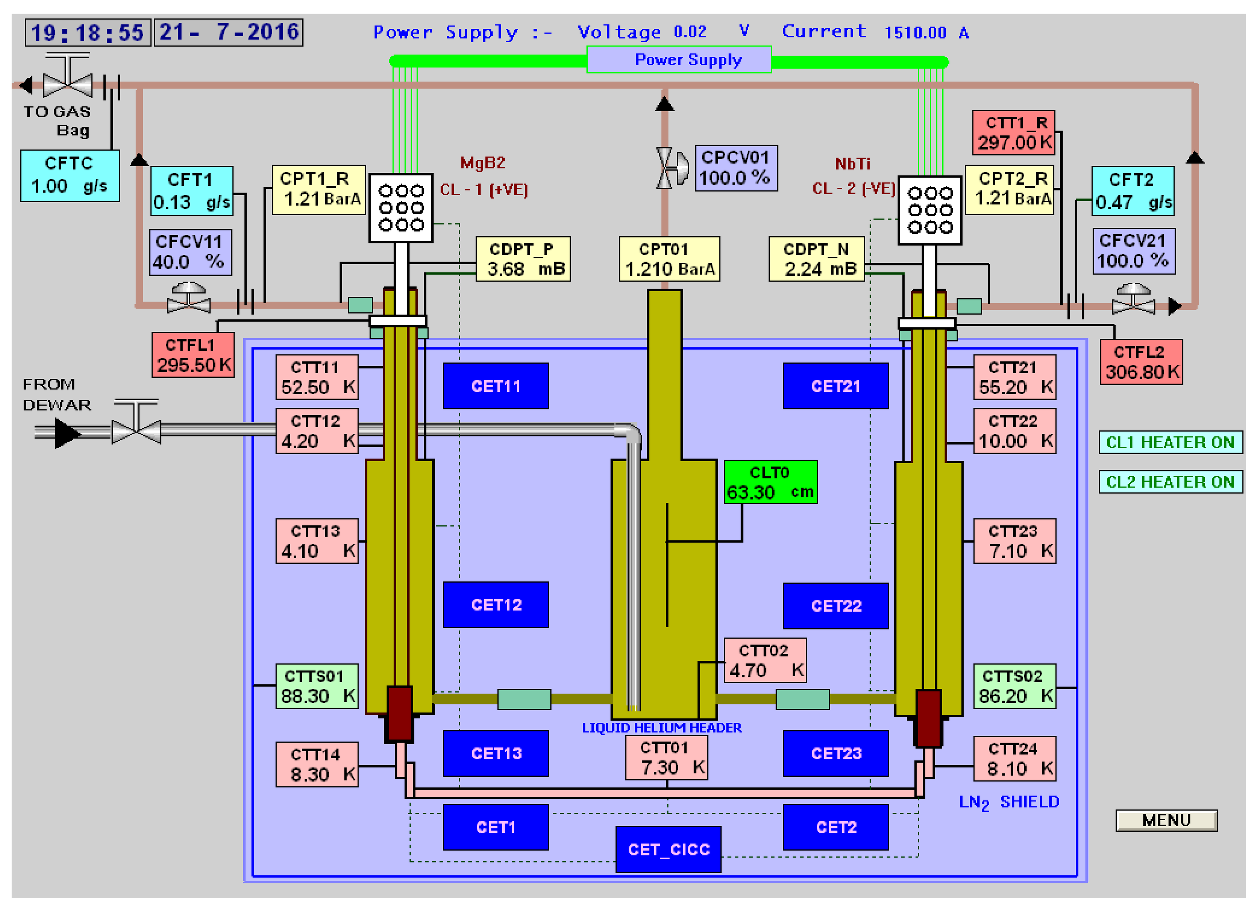

Fig 3: *Screen shot during experiment*

- 80 K shield cooled by LN2 and achieved better cryogenic stability during experiment
- Both VCCLs cooled and maintained at designed temperature gradient by collecting ~ 4.5 K LHe at the bottom of CLs
- SC dummy link cooled by conduction below its T_c
- Level of LHe and requisites temperatures monitored through sensors and controlled by manual operation
- Vacuum inside cryostat maintained 10^{-6} mbar
- On attaining all operational parameters, LHe flow recorded in stand-by as well as in excitation mode
- Initially, CLs charged from 250 A, 500 A, 1000 A for ~ 300 s
- Finally, transport current increased up to 1.5 kA for ~ 900 s

Table II: *Important experimental results*

Parameters	MgB2/Brass CL	NbTi/Cu CL
Temperature gradient (K)	4.5 K – 300 K	4.5 K – 300 K
LHe consumptions (g/s) at standby, I=0	0.1	0.38
Conduction Heat Load (W)	2.04	7.75
Total LHe consumptions (g/s) at I=1.5 kA	0.13	0.47
Total Heat Load (W) at I=1.5 kA	2.65	9.59

♦ Conclusion

- Estimation of HEX sizing & the requirement of LHe mass-flow have been carried out for MgB2/Brass CL
- Operating cryogenic cost may be saved notably ~3.5 X times over NbTi/Cu VCCLs
- If MgB2 CL cooled below T_c, saving factor further increased
- Using brass in HEX , VCCLs gets benefits of its overloading in pulse mode operations

♦ References

[1] Yukikazu Iwasa: Case Studies in Superconducting Magnets Design and Operational Issues, Kluwer Academic Publishers, e-Book ISBN 0-306-47062-4, Print ISBN 0-306-44881-5