## §10. Development of Superconducting Bus Line

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A flexible superconducting bus-line is proposed as an electrical feeder between the superconducting coils of the Large Helical Device (LHD) and the device's power supplies. The bus-line consists of superconducting cables and a cryogenic flexible transfer-line. A specially developed aluminum stabilized NbTi/Cu compacted strand cable satisfies requirements for large current capacity, high stability, high reliability and flexibility. A full-scale model with a length of 20 m was designed and constructed to investigate the feasibility and performance of the superconducting bus-line. Its fabrication, transportation, installation, cooling and excitation tests were successfully carried out.

Fabrication and installation of the full-scale model of the flexible superconducting bus-line were successfully carried out. Most parts of the superconducting bus-line were assembled in the factory. The assembled bus-line was then transported and installed at the experimental site.

The full-scale model was cooled down and excited successfully up to 40 kA without a quench. The measured minimum propagation current was larger than 32.5 kA. Thus, the bus line was fully stabilized at the rated current of 30 kA. A specially developed aluminum stabilized NbTi/Cu compacted strand cable was demonstrated to be sufficiently stable for the bus line. The measured current distribution of the nine-stand cable was quite uniform. The success of the full-scale model shows the feasibility and usefulness of flexible superconducting bus-lines for LHD and in other applications, too.

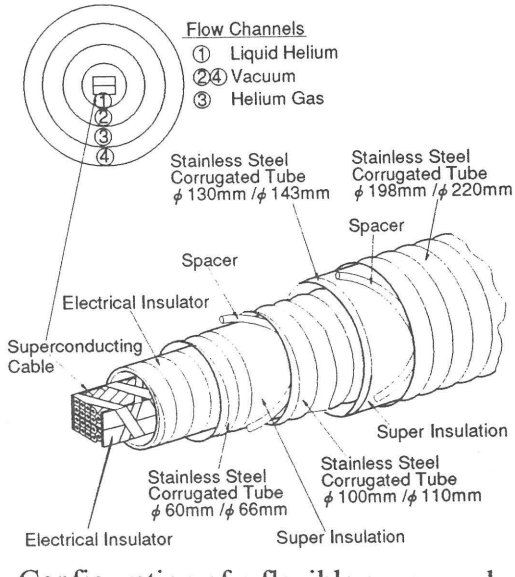


Fig. 1. Configuration of a flexible superconducting bus-line.

TABLE 1 Specifications of Bus-Lines for LHD and Full Scale Model

| | | For LHD (updated design) | Full scale model |
|---|---|---|---|
| 1. | Rated current | 13 kA - 31 kA | 30 kA |
| 2. | Breakdown voltage (in helium gas at 1 atm, 77K) | for Poloidal coil DC 5 kV for Helical coil DC 2 kV | DC 2 kV (design) > DC 5 kV (measured) |
| 3. | Length | 45 m - 65 m | 20 m |
| 4. | Conductor | Aluminum stabilized NbTi/Cu compacted strand cable | |
| 5. | Minimum bending radius | 1.5 m | 1.5 m |
| 6. | Transfer-line | Coaxial five-channel with 80K shield | Four-channel |
| 7. | Outer diameter | < 0.25 m | 0.22 m |
| 8. | Cooling method | Forced-flow of two-phase helium | |
| 9. | Heat load | | |
| | Liquid helium channel | < 0.2 W/m | < 0.3W/m |
| | Returning gas channel | < 0.2 W/m | < 3.5 W/m |
| | 80 K shield gas channel | < 3 W/m | - |

TABLE 2 Parameters of Superconducting Cable for Bus-Line

| | Aluminum Stabilized, Compacted Strand Cable | |
|---|---|---|
| 1. | Rated current | 30 kA at 1 T, 4.2 K |
| 2. | Critical current | 180 kA at 1T, 4.2 K |
| 3. | Size | 17.2 mm × 35.4 mm |
| 4. | Number of strands | 9 |
| 5. | Twist pitch of strands | 374 mm |
| 6. | Electrical Insulation | Polyamide paper (nomex) |
| 7. | Al sectional area | 500 $mm^2$ |
| 8. | Cooling ratio | 13 % of the cable surface |
| 9. | Minimum propagation current | 40 kA |
| | **Superconducting Strand** | |
| 1. | Outer diameter | 8.95 mm |
| 2. | NbTi/Cu insert diameter | 2.91 mm |
| 3. | Al:Cu:NbTi ratio | 8.4:0.5:0.5 |
| 4. | Twist pitch of filaments | 60 mm |
| 5. | Filament diameter | 30 μm |
| 6. | NbTi/Cu critical current density | 6000 $A/mm^2$ at 1 T, 4.2 K |
| 7. | Al resistivity | $3 \times 10^{-11}$ Ωm at 1 T, 4.2 K |

References

1) Mito, T. et al. "Conceptual design and development of a superconducting bus-line for the Large Helical Device." *Fusion Engineering and Design*, Vol. 20, 1993, pp.113-120.

2) Mito, T. et al. "Development and tests of a flexible superconducting bus-line for the Large Helical Device." Proceedings of MT-13 to be published.