

# **Development of a three phase 10.5kV/1.5kA HTS power cable**

Yinshun WANG

Institute of Electrical Engineering, CAS

Jun. 24, 2004

# Content

- **Status of HTS Power Cable in IEE**
- **Research on Homogeneity of HTS tape**
- **Development of 10m 10.5kV/1.5kA three phase HTS cable**
- **Progress in 75m 10.5kV/1.5kA three phase HTS Cable**
- **Conclusions**

# 1m , 1kV/1kADC HTS cable



## 1998年 中国十大 科技进展

钱学森、吴阶平、周光召、朱光亚、路甬祥、张存浩等 587 院士评出

### 5. 研制出我国第一根 铋系高温超导电缆

我国第一根由铋系高温超导材料制成的输电电缆，在北京研制成功，通电实验无阻电流达到 1200 安培，接触电阻小于 0.06 微欧。这使我国成为世界上少数几个掌握这一技术的国家，将极大地推进我国高温超导技术的实用化进程。

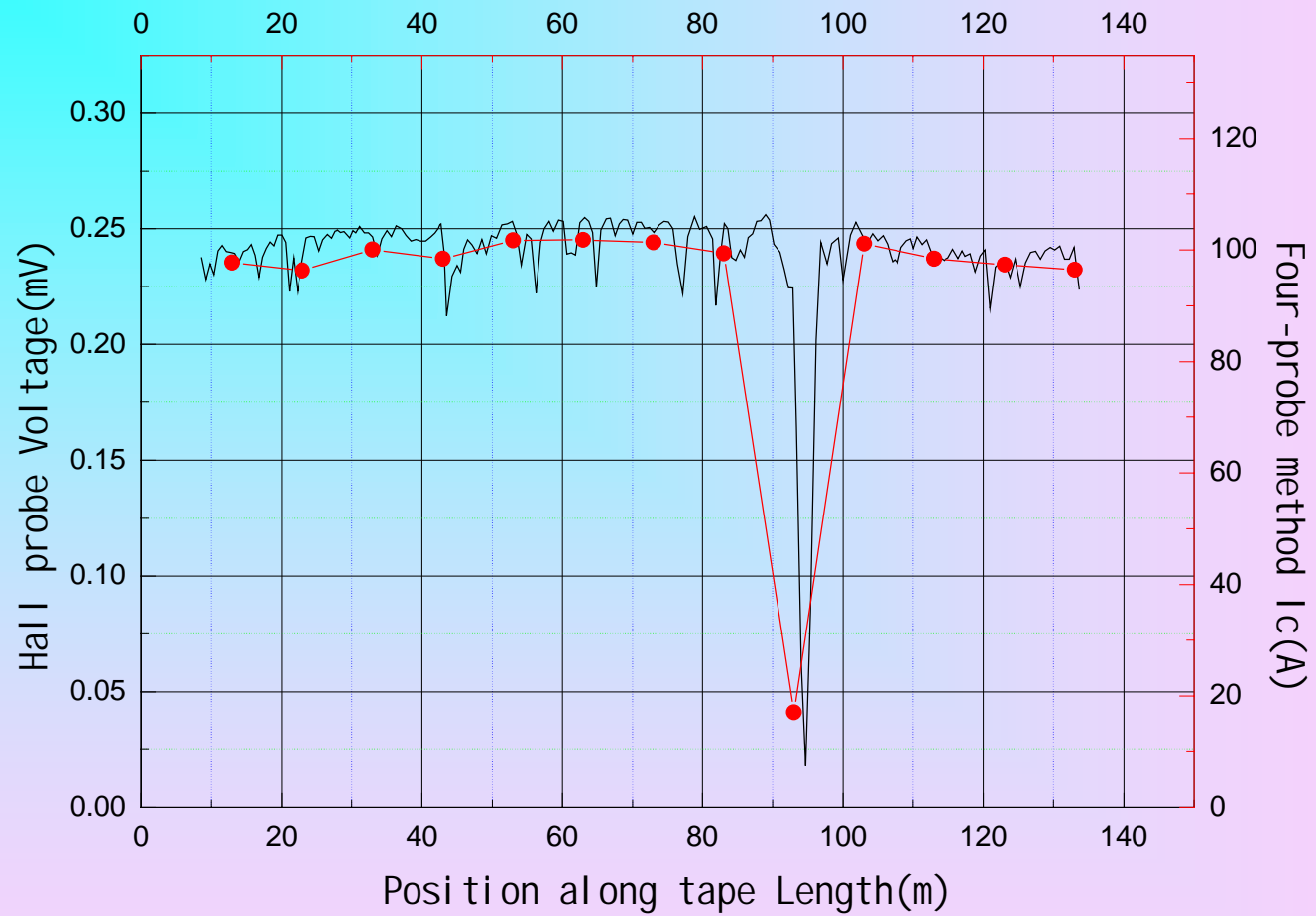
铋系高温超导输电电缆是当今各国在高温超导技术强电应用研究领域的首选项目，被国家超导专家委员会列入“863”高技术“九五”重要攻关项目。这个项目由北京有色金属研究总院和西北有色院负责超导材料研究和提供电缆用材，由中科院电工研究所负责输电电缆设计和绕制。

# 6m , 2kV/2kA DC HTS cable



# Measurement system of practical long HTS tape by contact-free method





# Overview of 10m HTS cable system

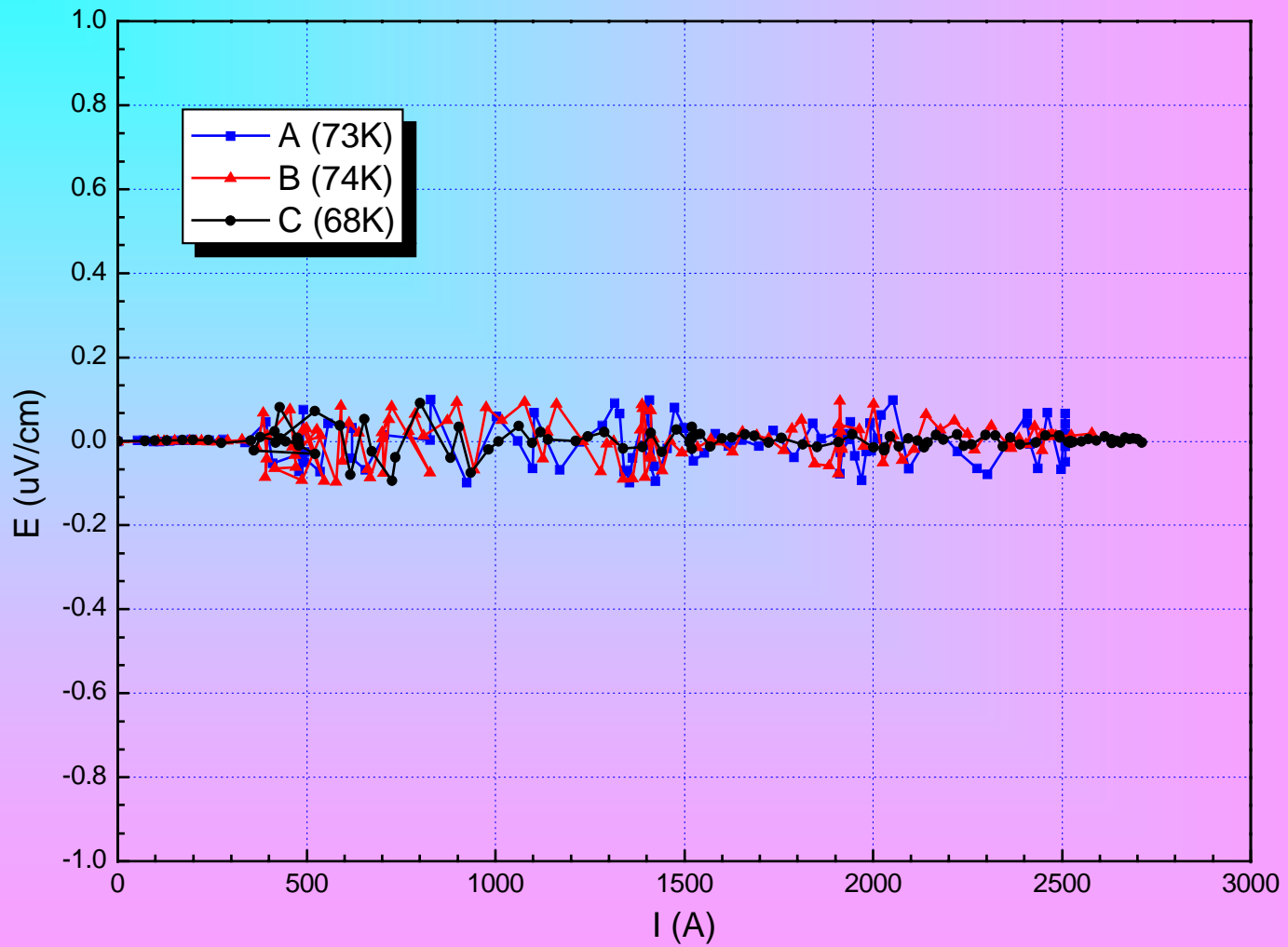


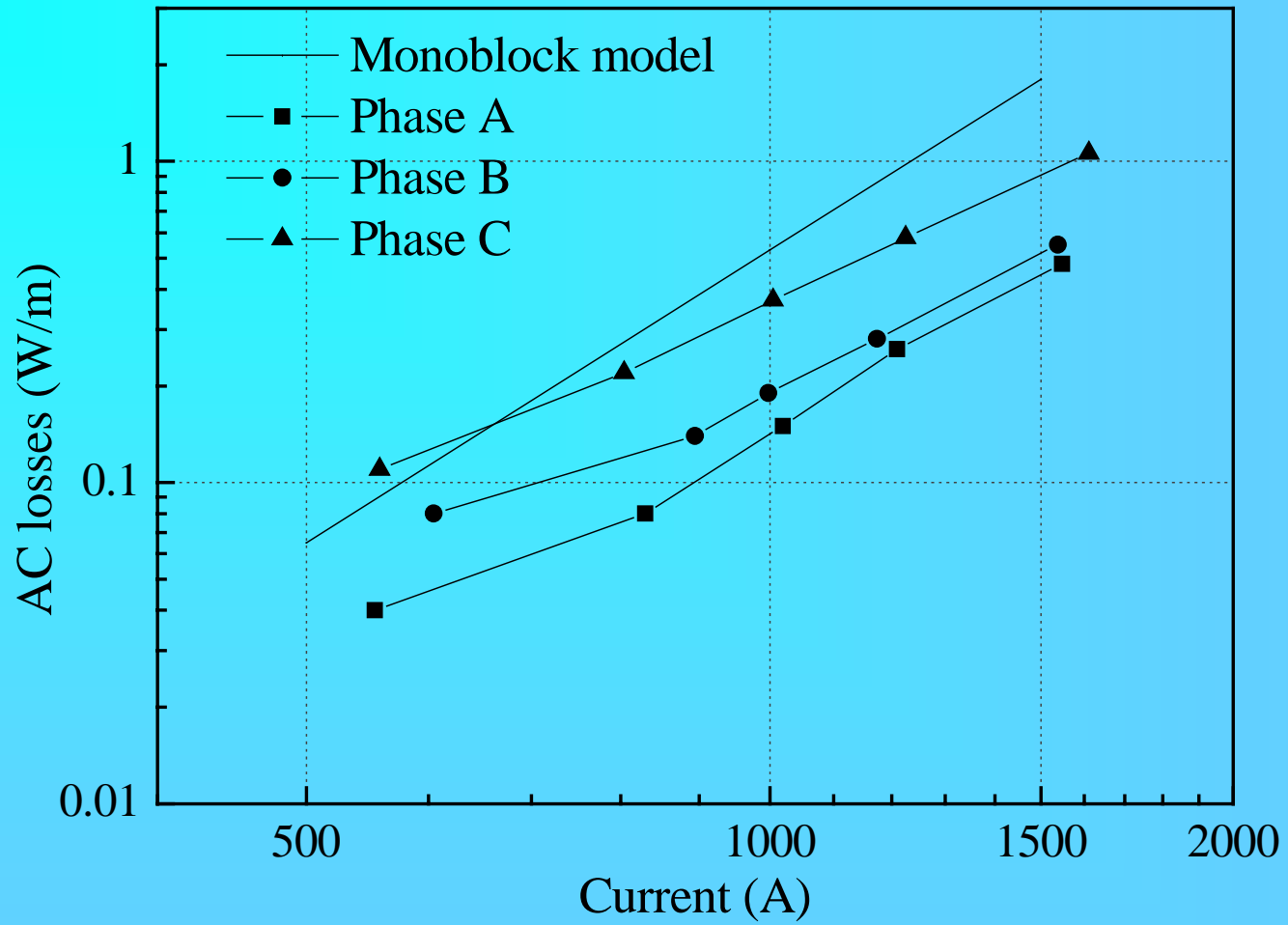
# Container, termination, leads and insulation of the HTS cable

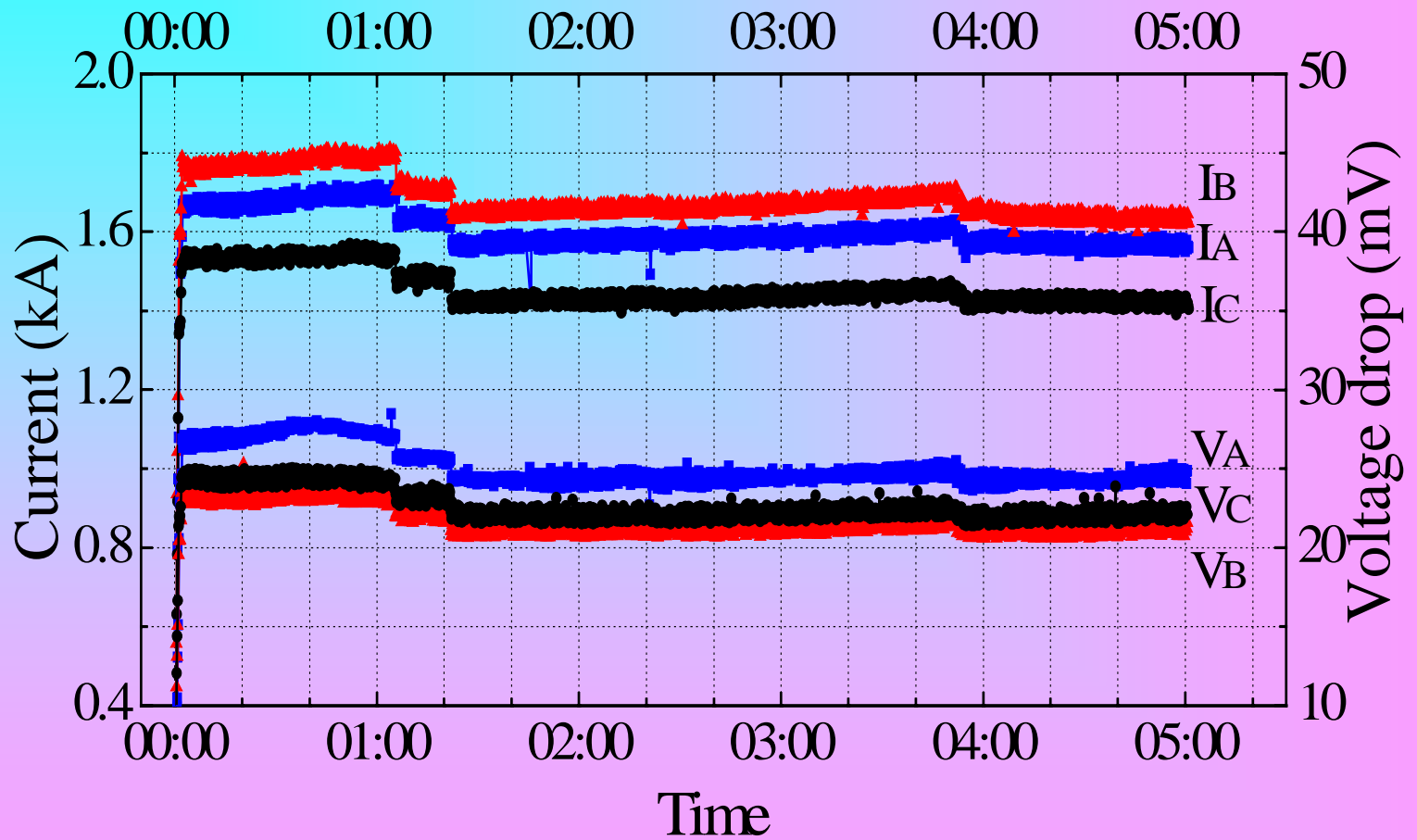


# Overview of Cryogenics System









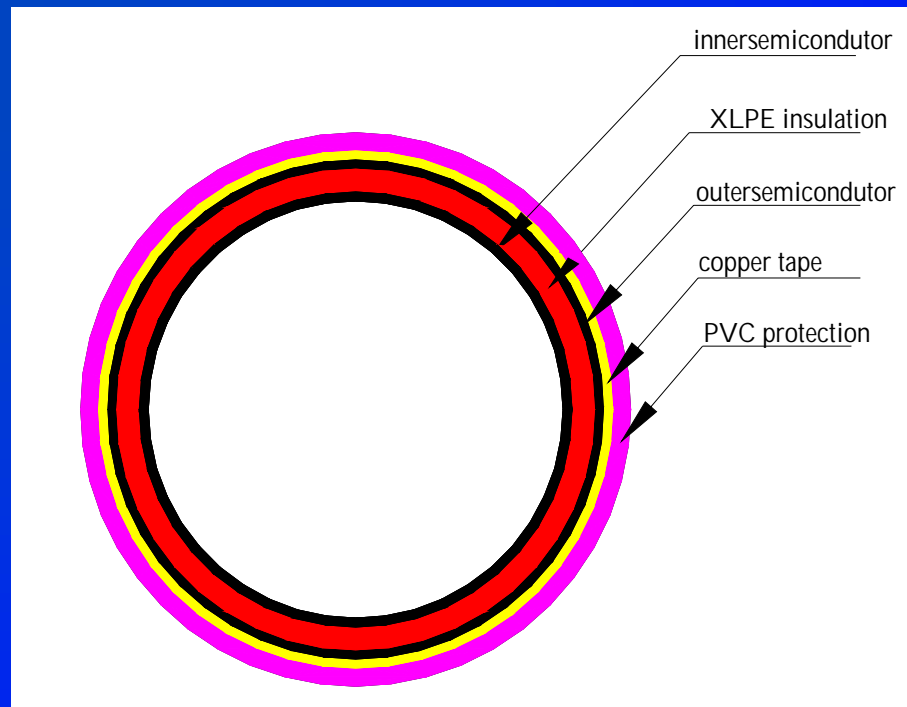
# Progress in 75m 10.5kV/1.5kA three phase HTS Cable

- ➔ Design of HTS conductor ;
- ➔ High voltage insulation and shielding at low temperature ;
- ➔ Container, termination, current leads
- ➔ Cryo-cooling System ;

# Main parameters

- AC loss less than  $1.0 \text{ W/kA.m/phase}$  ;
- Heat leakage in current leads smaller than  $45 \text{ W/kA}$  ;
- Other properties of HTS cable satisfy Electrical standard

# Insulation and shielding (RT)



Inner semiconductor shielding layer + Insulation layer +  
outer semiconductor shielding layer + Cu tape shielding  
layer + PVC protection layer

# Results of high-voltage insulation in HTS cable

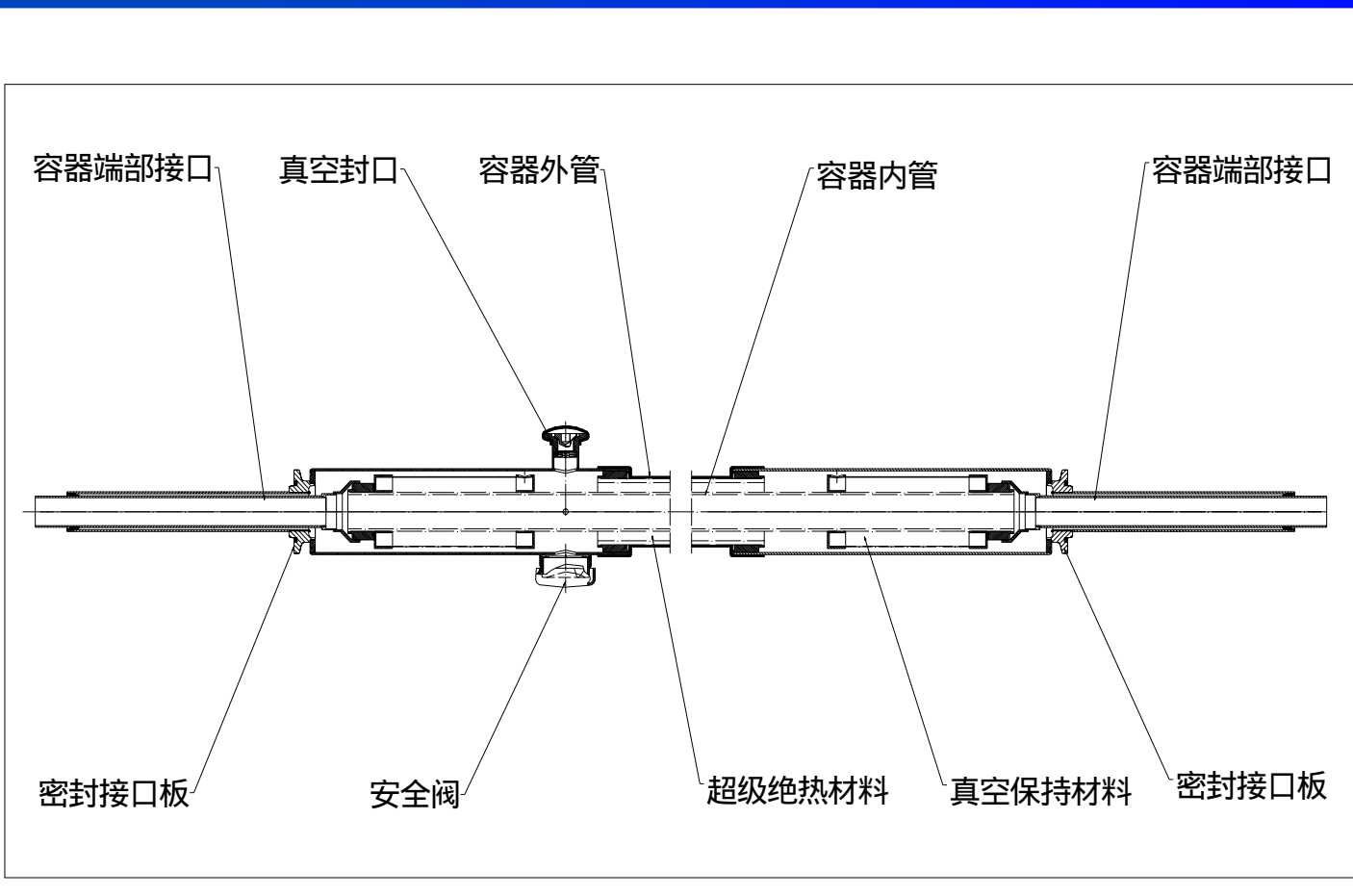
Test items	Test value	results
AC high-voltage test at power frequency	35 kV	No breakdown
Radius of bending	0.9 m	No Destructive
AC High-voltage at power frequency test after bending test	35 kV	No breakdown

# Design of HTS cable container and termination

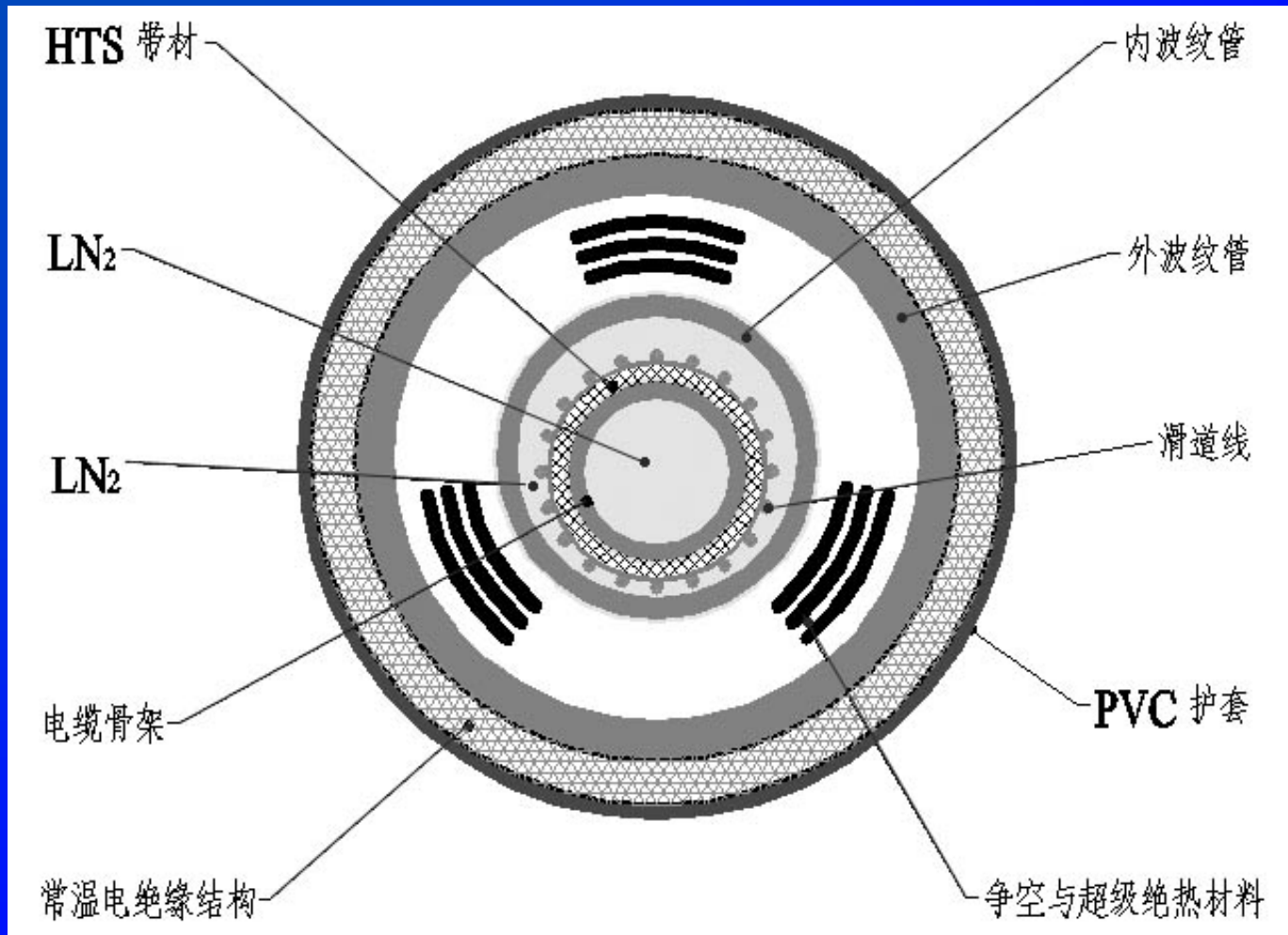
## Design requirement

- **Volume small, low heat-leak , loss less than 1.5W/m.**
- **Can be bended and wound on spool for easy transportation, bending radius <1.2 m.**
- **Rated voltage of container insulation 10.5 kV.**
- **Operation pressure in container 1-10bar.**
- **Inner radius of container 50mm for conductor going through easily.**
- **Outer radius of container 92mm for insulation fabricating.**
- **Easily installation and disassembly.**

# Schematic Structure of cable container



# Schematic cross-section of HTS cable container



# Container parameters

items	unit	parameters
Inner dia.	mm	50
Outer dia.	mm	92
Outer dia. ( including insulation )	mm	115
Withstand voltage	kV	10.5
Operation pressure	MPa	0.1-1
Min. bending radius	mm	1200
Operation temperature	K	67-77
Loss	W/m	<1.5
Vacuum	Pa	$<1 \times 10^{-2}$

# Inner and outer parameters of container

items	Inner dia. (mm)	Outer dia. ( mm )	Bending radius (m)	Weight (kg/m)	Permissi ble pressure (Mpa)
Inner tube	50	61.5	>0.5	1.6	2.5
Outer tube	76.5	90	>0.5	2.2	1.5

# Insulation structure

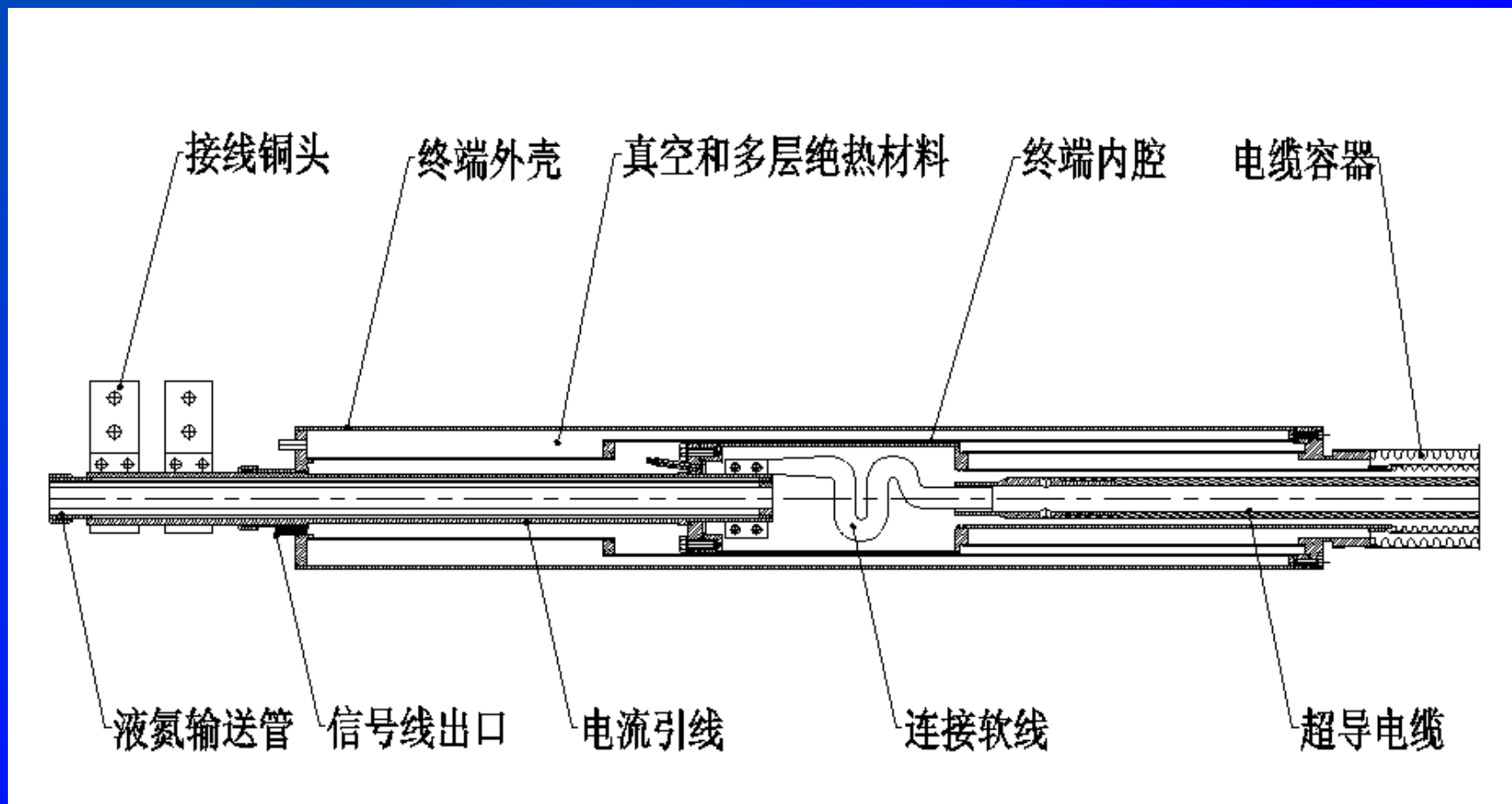
Technology Order	items	Thickness ( mm )
1	Inner shielding	1
2	insulation	4.5
3	Outer shielding	1
4	Cu tape layer	0.2
5	Protection layer	4

# Termination of HTS cable

## Design requirement

- Operation current 1500A. Current leads are fetched out from termination, loss of single current lead  $<45\text{W/kA}$ .
- Rated voltage 10.5kV.
- Connection between termination and container disassemble.
- There are inlet and outlet in termination which can be regulated in order to meet single and 3-phase operation.
- Small heat leak, loss/phase  $<100\text{W}$ .
- Compensate the effect of length difference in container on HTS cable operation at different pressure operation.

# Schematic structure of termination



# Design of current lead

$$Q < 43 \text{ W/m}$$





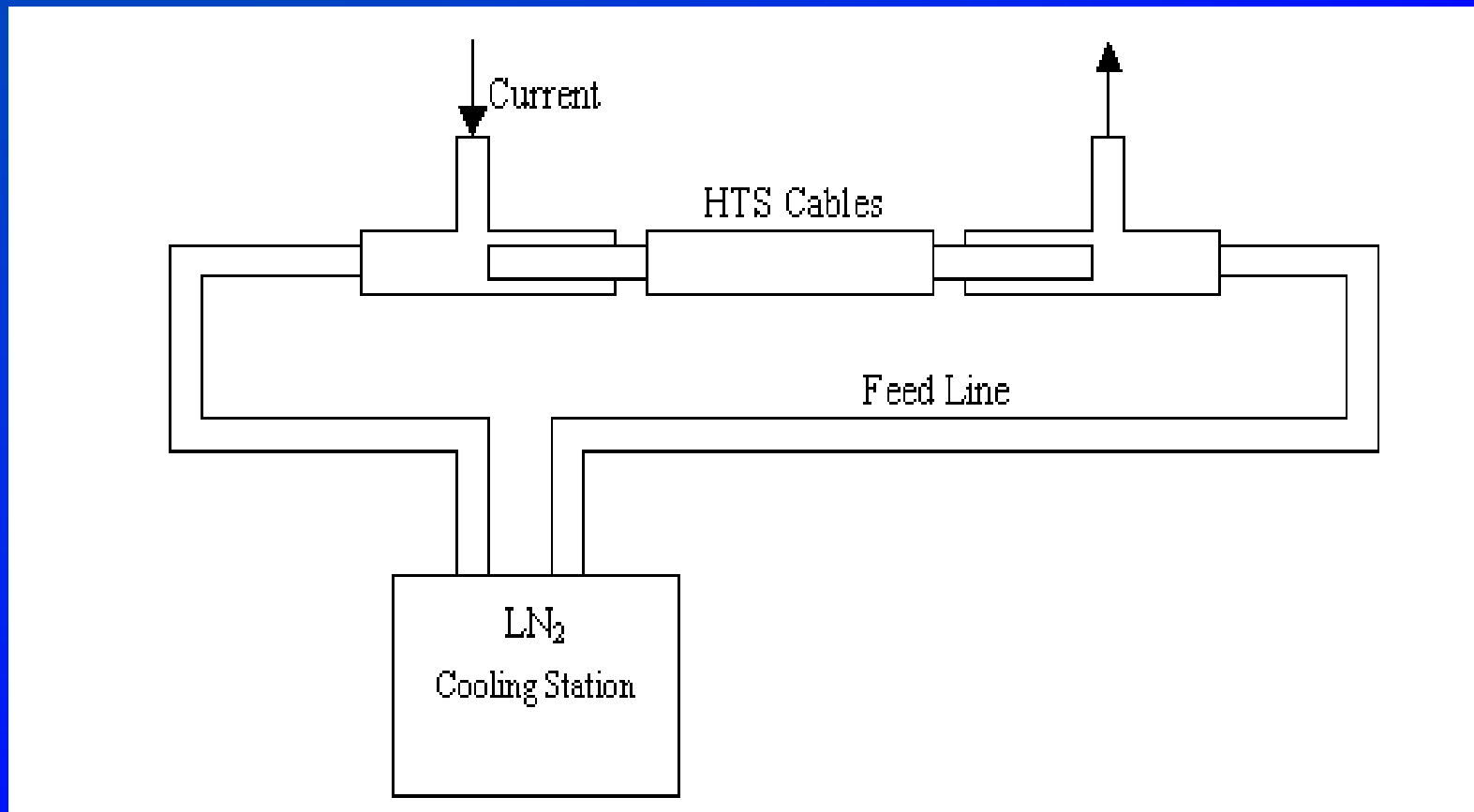
# Cryo-cooling system of HTS cable

# Technology requirement

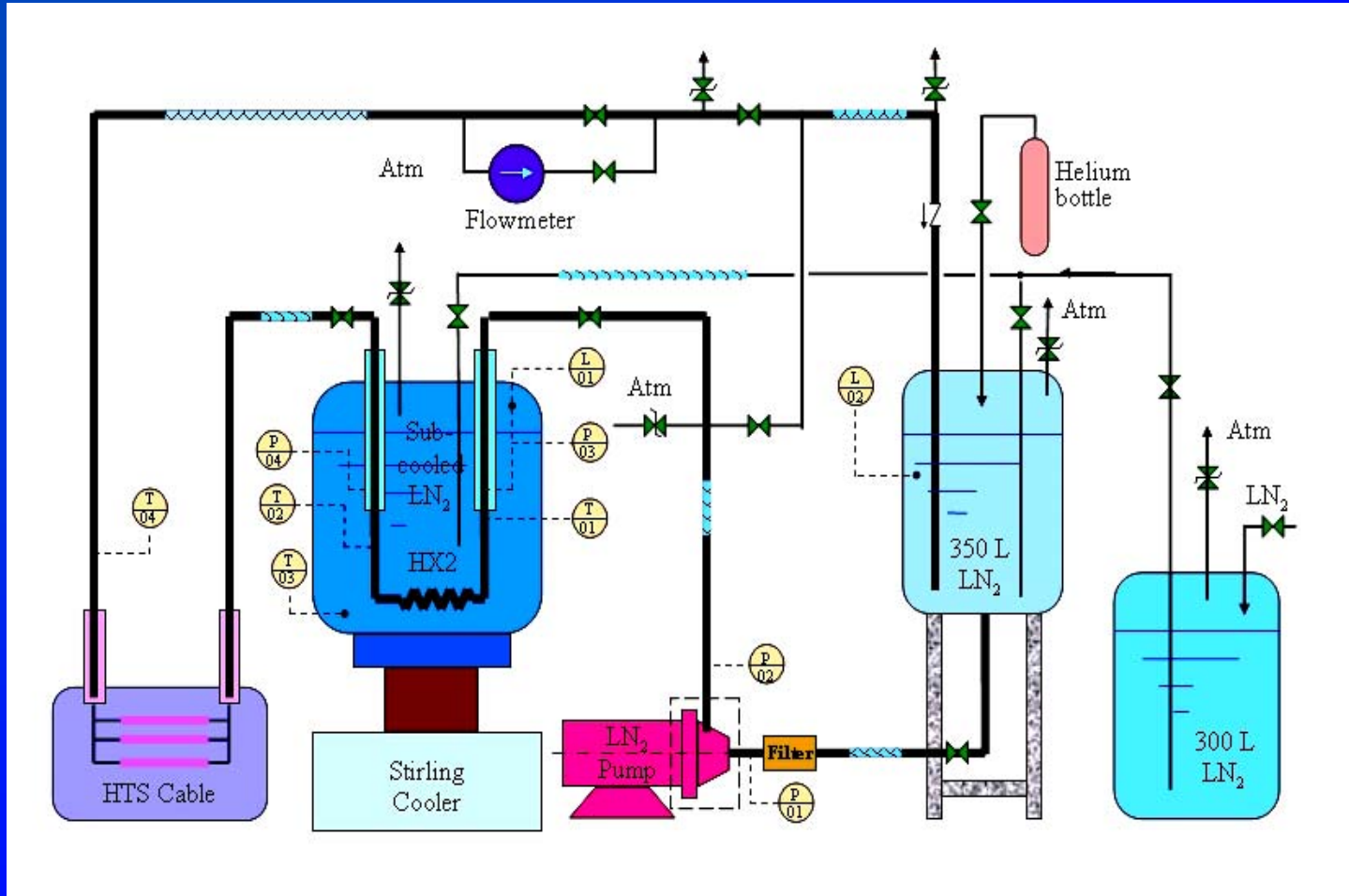
<b>Medium</b>	<b>Liquid nitrogen</b>
<b>Flowing mass</b>	<b>400 ~ 1200L/h</b>
<b>Temperature at load inlet</b>	<b>&lt;66K</b>
<b>Temperature at load outlet</b>	<b>&lt;76K</b>
<b>Operation pressure</b>	<b>0.1 ~ 1.0Mpa</b>
<b>Max. coolingb power</b>	<b>3000W@70K</b>

Connecti on pi pel i ne	3 Soft tube , 2 inlet , 1 return one , inner di a. 20 mm , loss<1.2 W/m.
Controlling mode	Controlling, collecting and displaying by computer , data including temperature at inlet and outlet, pressure, flowing mass, level of LN <sub>2</sub> and its loss.

# Principle view of LN<sub>2</sub> cooling cable



# Flow-chart of HTS cable system cooled by crocooler



# Conclusion

- Critical current of the HTS cable is more than 2800 A .
- Long-time operation and thermal cycle tests indicated that the performance of the cable is stable.
- The joint resistances and ac losses of cable conductors are very low.
- The reliable data and practice got from the development and tests of the 10m cable can be used for development and operation of the 75m, 10.5kV/1,5kA HTS power cable.
- Design 75m 10.5kV/1,5kA HTS power cable.

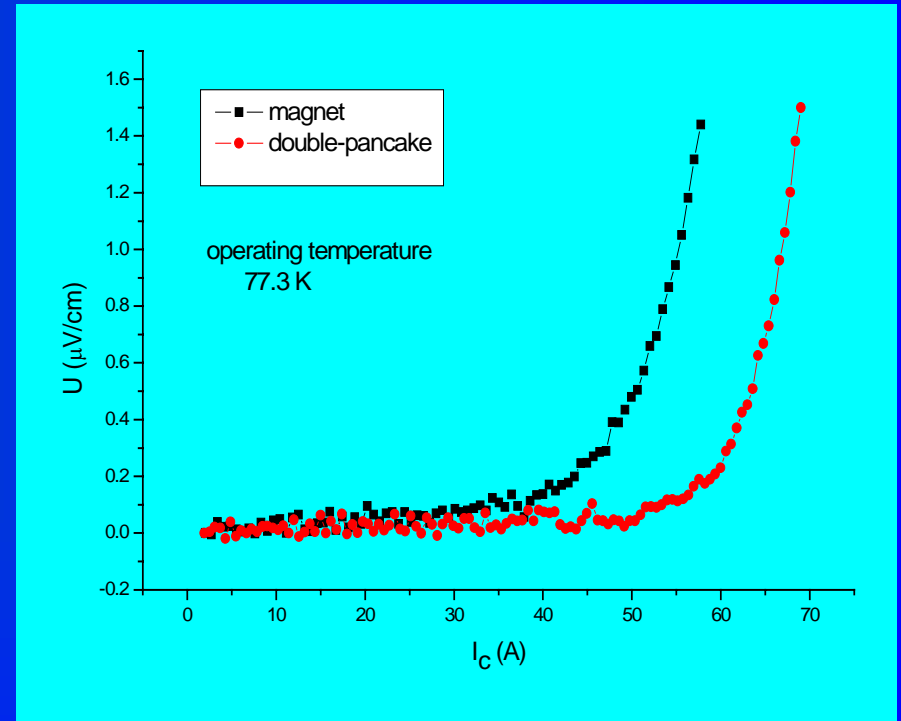
# Application of HTS cable depending on cryogenics

- **The Superconductivity technology solved in HTS cable;**
- **Restriction of Cryogenics**
- **Maintenance of cooling system;**
- **Save energy, but not economical;**

# Other HTS application research in IEE

# IEE—Improved Bridge-type SFCL



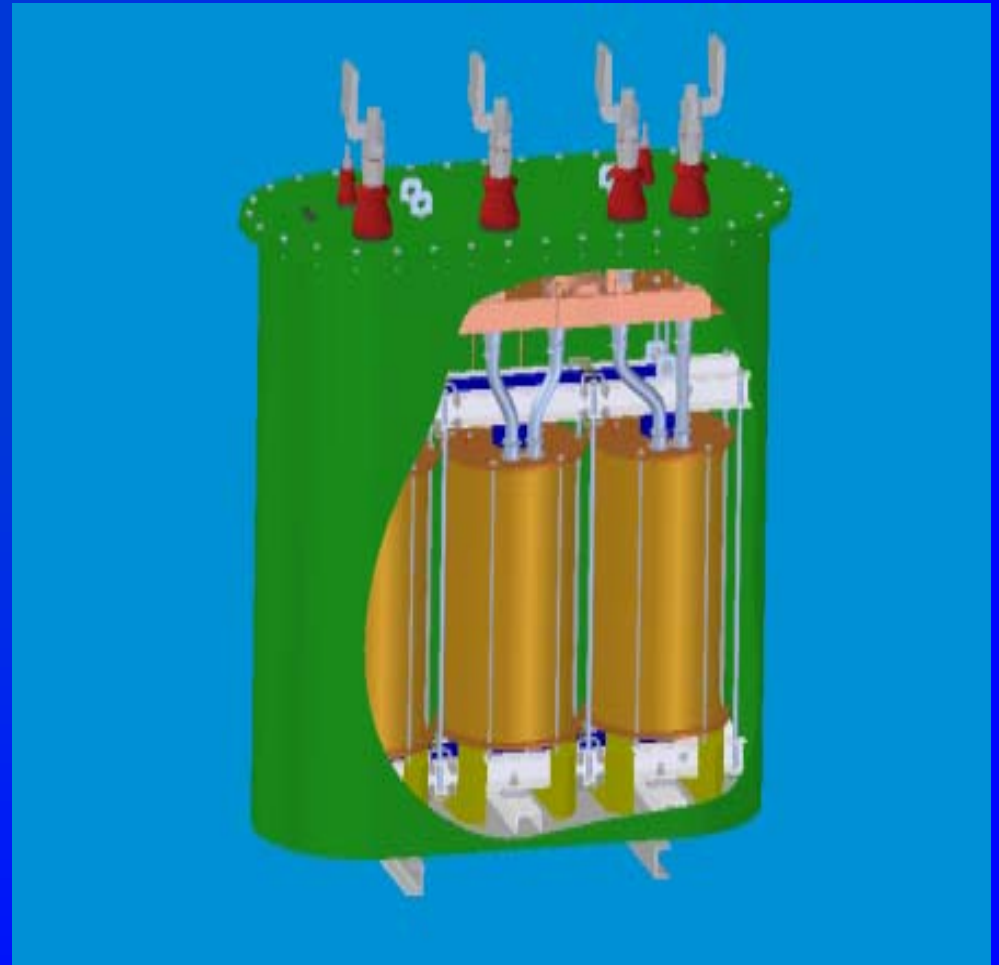
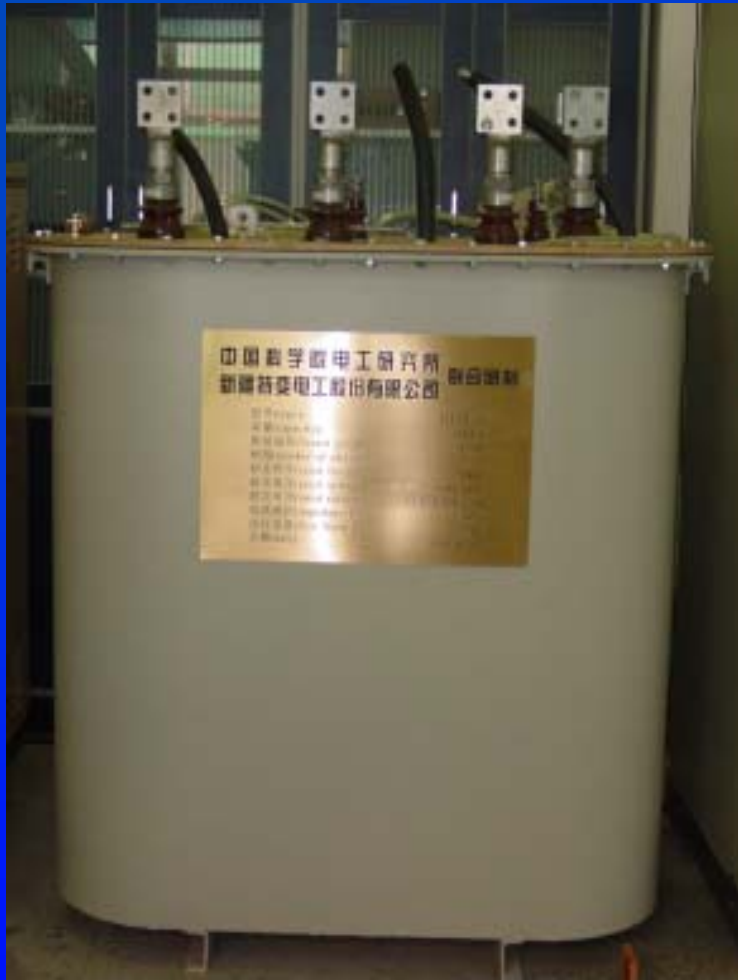


## HTS coil for a 380 V/25 A FCL demonstrator of the new design

# Future Plan

- ➔ 10.5 kV/1.5kA 3-phase HTS FCL in this year or beginning of next year.

# 26 kVA/400V/16V 3-phase HTS Power Transformer





# Future Plan

- ➔ 630 kVA, 10.5 kV/400 V 3-phase Transformer will be finished and tested in TEBA Company at the end of 2004;

# Acknowledgment

Many thanks to:

- Ministry of Sci. & Tech., P.R.China
- Inst. Of Phys. & Chemi. Tech., CAS
- Gansu Changtong Cable Company
- Hebei Baofeng Group Company
- Shenzhen Woer Company

Thank you !