IASS Workshop
@2011/05/13, Potsdam

Experiment of the 200-meter DC superconducting power cable and Perspectives of DC Superconducting power transmission and distribution

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and

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Today's Talk

1) Results of the 20-meter Cable Experiment
2) Design & Construction of the 200-meter Cable Test Facility
3) Results of the 200-meter Cable Experiment
4) Future Projects & Comments

20-meter Cable Experiment

Laboratory in Nov., 2006

Parameters

current > 2.5 kA
voltage > 20 kV
length ~ 20 m
Sumitomo Bi-2223 cable

coolant; LN_2

equipped with pump and
cryogenic cooler
72 K - 77 K

Measurement system

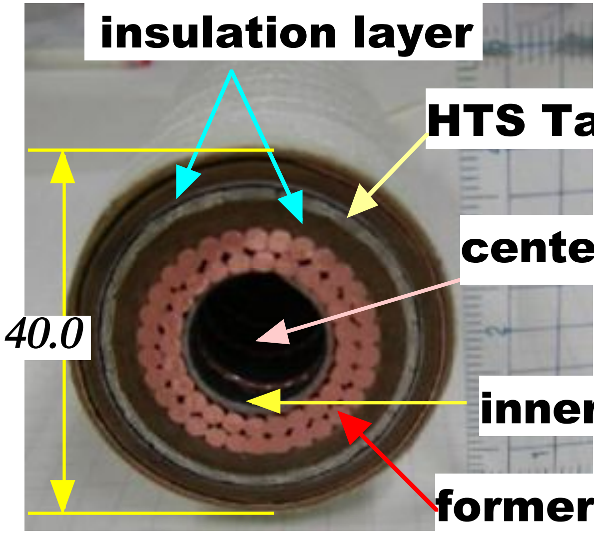
~ 500 CH by LabView

First Experiment of HTS DC Cable System in the World

Structure of 20-meter Cable

20-meter cable

single core
(2 layers, 39 tapes)
Ic ~ 100A @77K
> 3kA@77K



30kV insulation by PPLP

Center hole: LN2 return path for circulation
measurement cable path

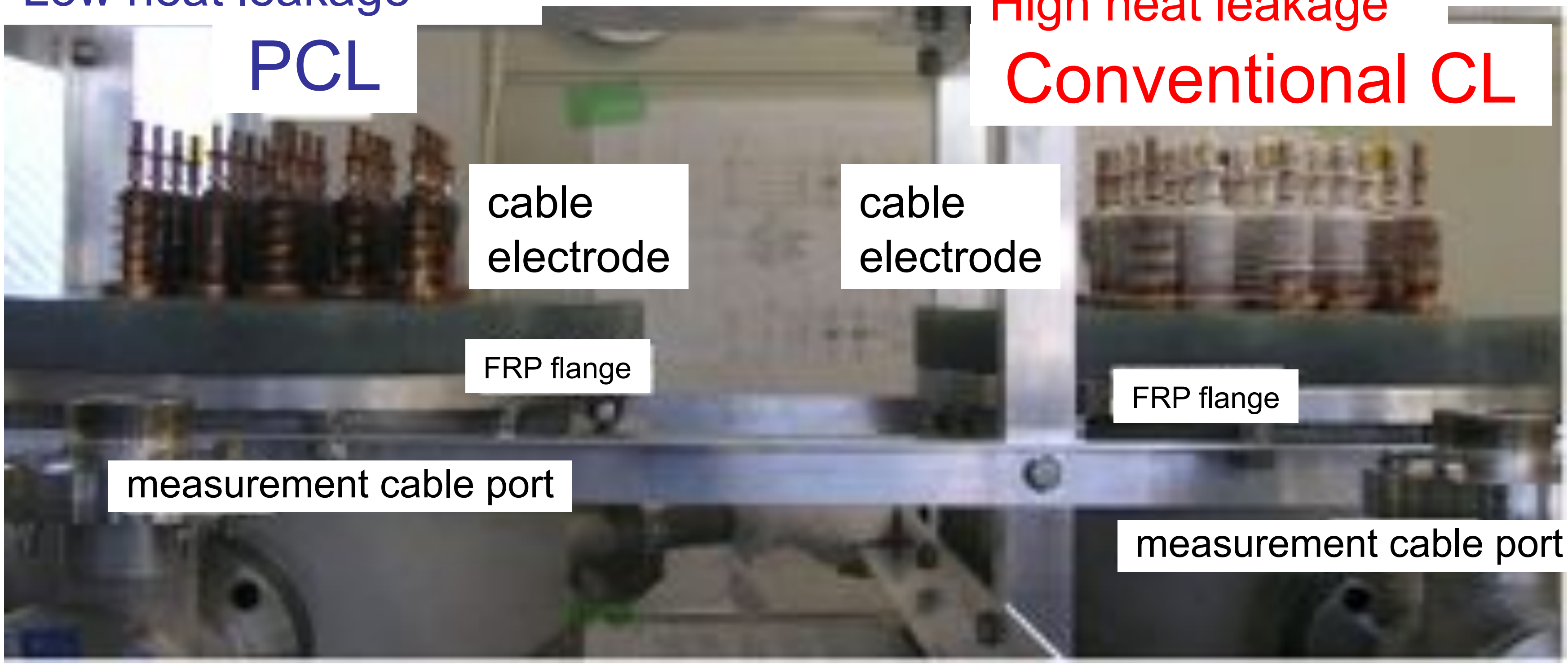
Price ~ 50,000US$,
but the first estimated price ~ 200,000US$

Made by Sumitomo

Results of PCL@20m cable

No frozen of electrode
↓
Low heat leakage

Frozen of electrode
↓
High heat leakage

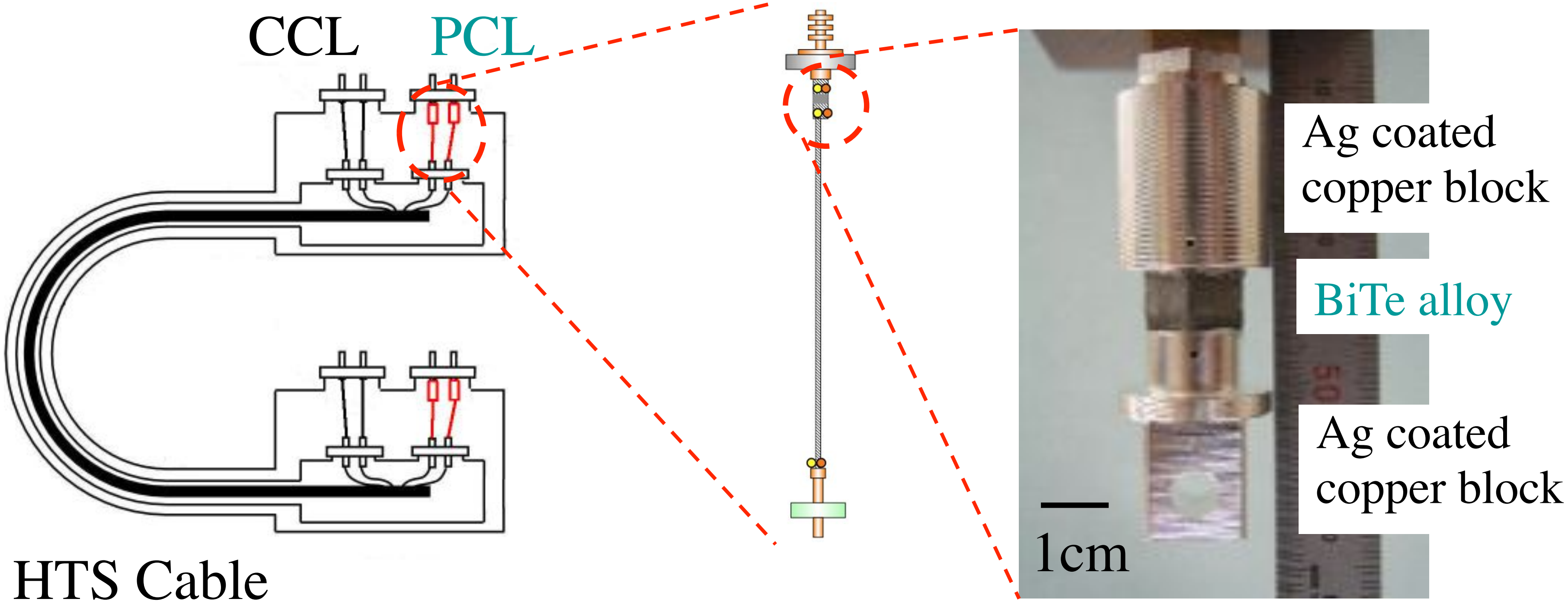


S. Yamaguchi et al, "Research activities of DC Superconducting Power Transmission Line in Chubu University", J. Physics: Conference Series, **97**(2008)012290.

Results of PCL@20m cable

CASER-1

Reduction of Heat Leak from Current Lead



Whole Current Lead　　Peltier part

Results of PCL@20m cable

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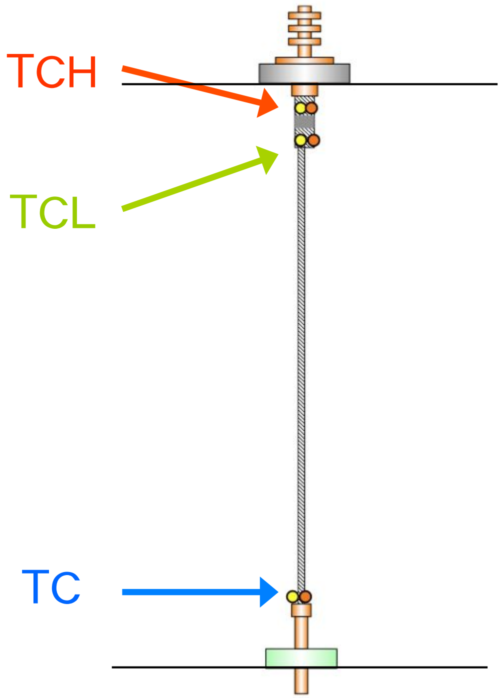
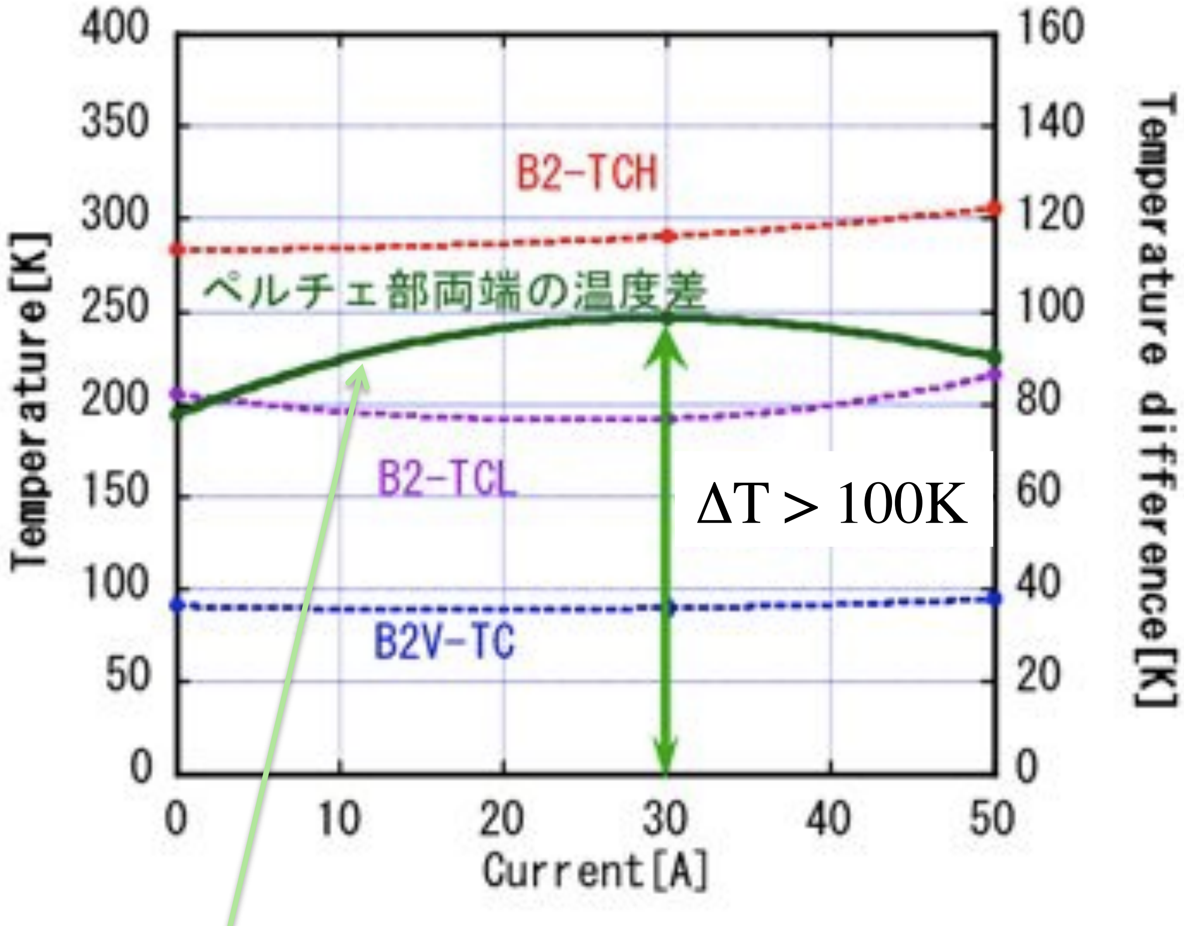




Temp. difference is larger than 100 K @current of 30A

Performance of PCL

Heat Leakages of PCL and Conventional current lead (CCL)

	f = 0	f = 1
CCL	42.5	23.3
PCL	26.7	18.6

Heat Leak from 300K to 77K
unit (W/kA)

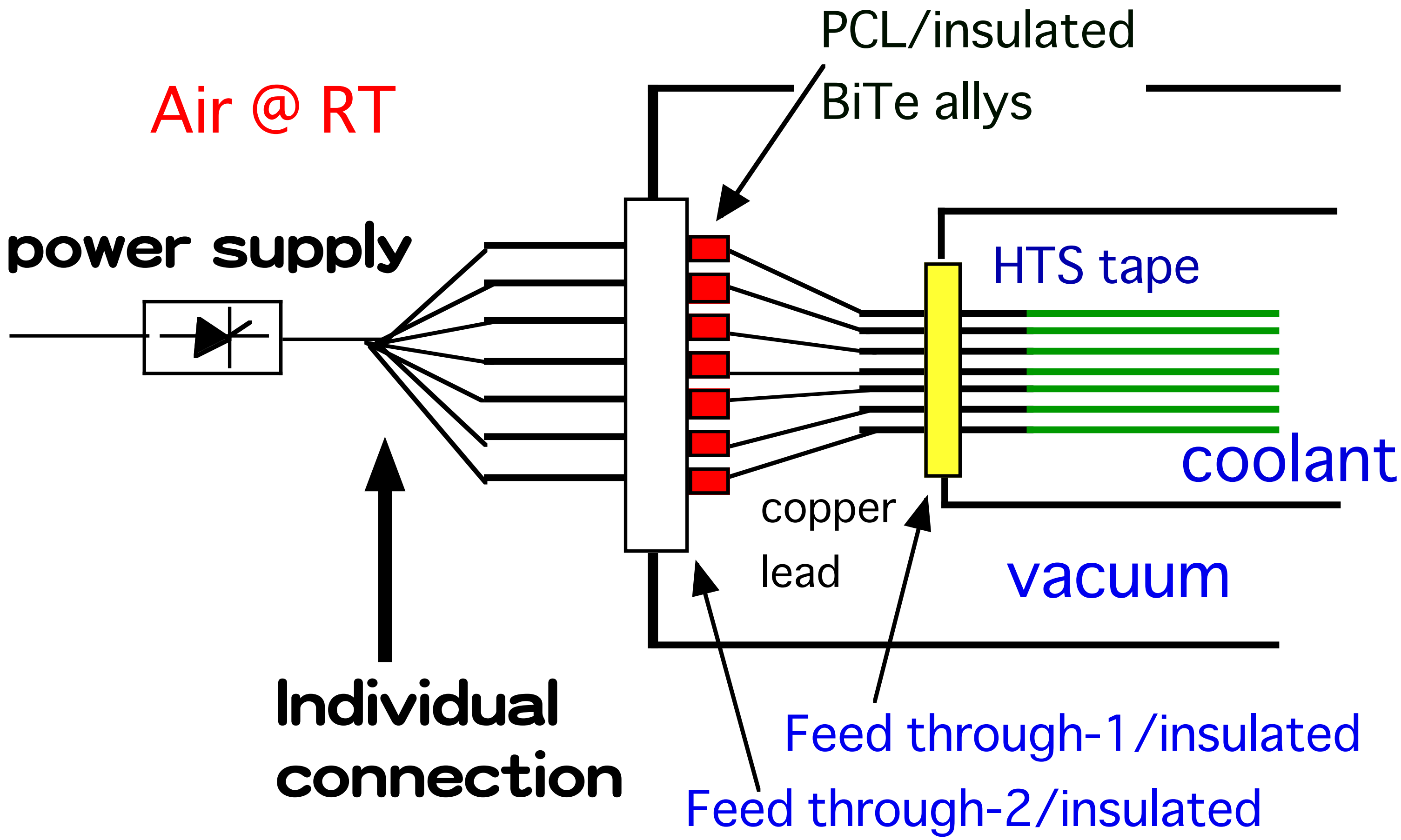
Energy balance of PCL (for Bi-Te alloys)
For 100A current lead
Difference of Heat Leakage between CCL – PCL (f = 0)
4.25 – 2.67 = 1.58 [W]
If we use refrigerator of COP = 0.067 (Sterling cycle) Saving Power = 1.58/0.067 = 23.6 [W]

Additional Loss of PCL
Voltage of PCL = 52mV → 52mV x 100A = 5.2 [W]

S. Yamaguchi et al, "Peltier current lead experiments and their applications for superconducting magnets ", RSI, **41**(2004)207.

➽ advanced PCL: gas-cooled PCL & Multi-stage current lead

Terminal connection@20m cable



Important Structure to avoid the current imbalance of HTS tape for longer cable (> several km)

N. Koizumi et al, "Experimental results on instability caused by non-uniform current distribution in the 30 kA NbTi demopoloidal cpo;)DPC-U) conductor", Cryogenics, **34**(1994)155-162.
S. Yamaguchi et al, "A small-scale experiment demonstrating the current lead resistance method of preventing a current imbalance", Cryogenics, **38**(1998)875-880.

Current of each HTS Tape@20m cable

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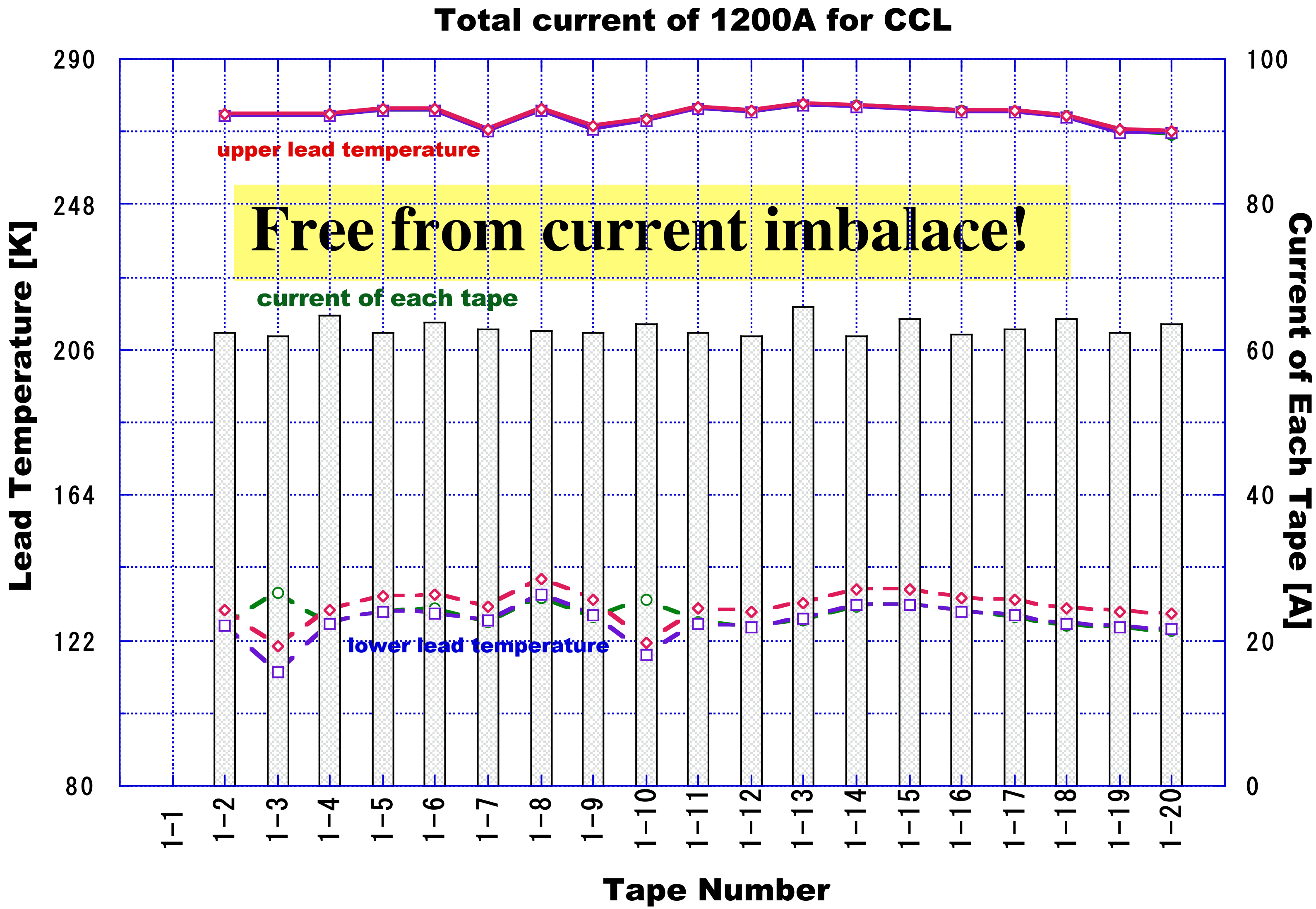
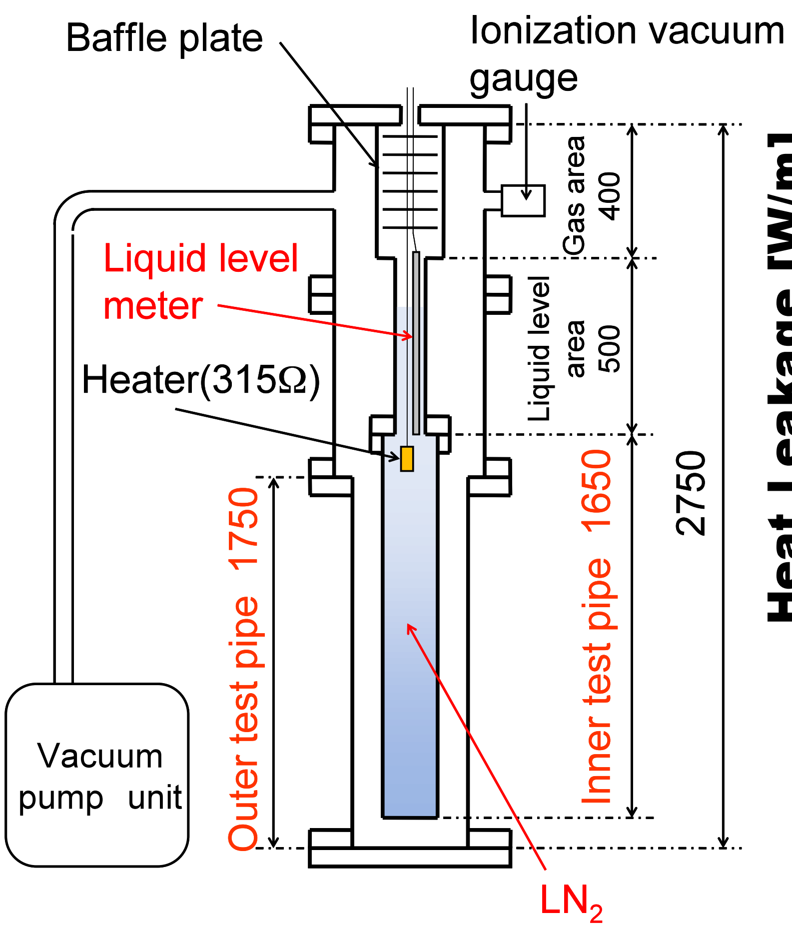
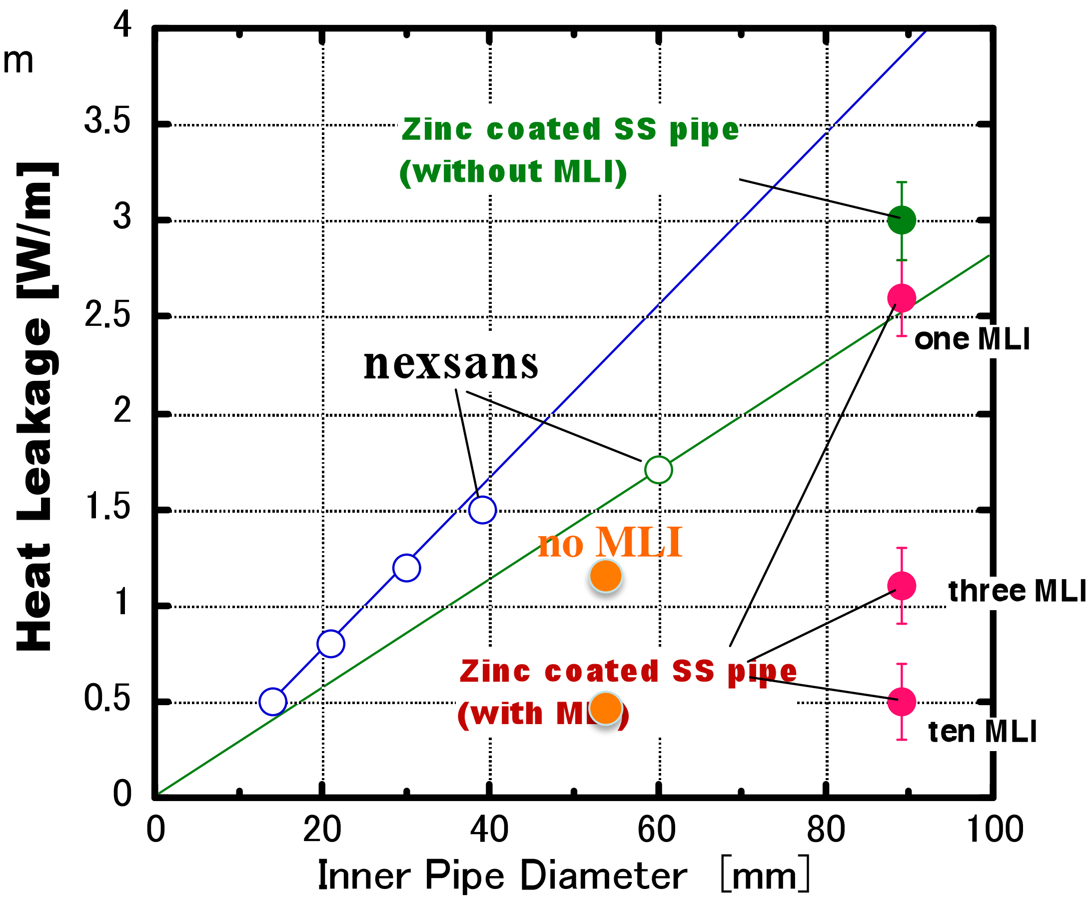


S. Yamaguchi et al, "Research activities of DC Superconducting Power Transmission Line in Chubu University", J. Physics: Conference Series, **97**(2008)012290.

Heat leak of Cryo-pipe@Test Stand

Low Heat Leakage even for Fewer MLI
Use low cost Iron pipe

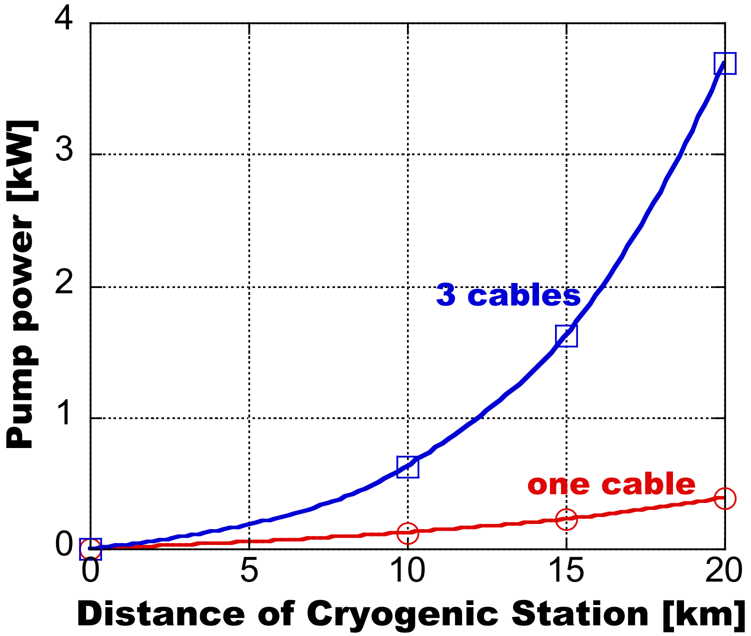


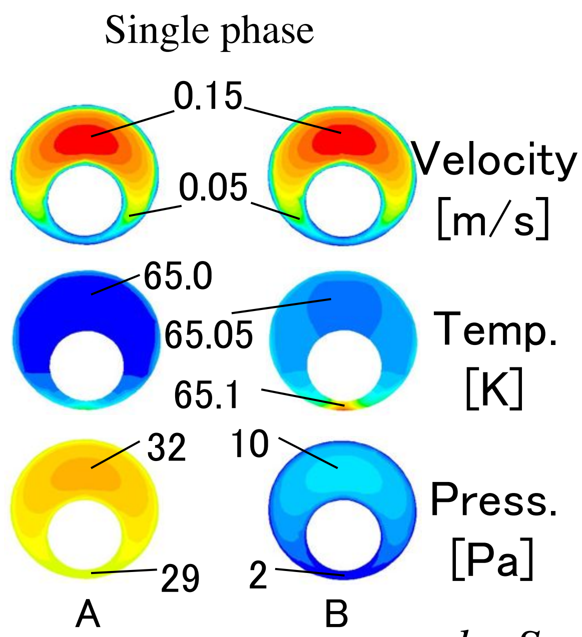


M. Hamabe et al, "Measurement on Thermally-Isolated Double-Pipe for DC Superconducting Power Transmission ", Advances in Cryogenic Engineering, **53A**(2008)168-173.

Numerical Fluid Dynamics@20m cable

Computational Fluid Dynamics (CDF by *Fluent* ®)





by Sasaki et al

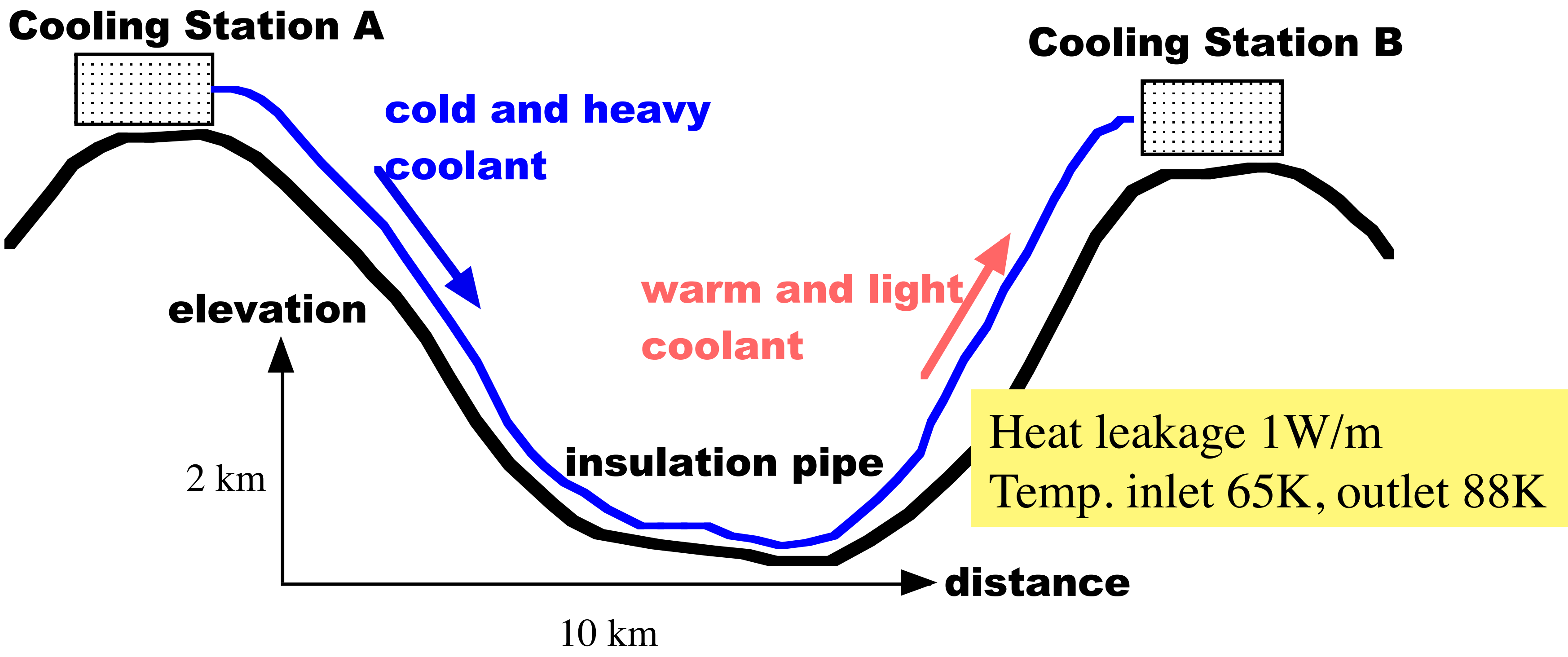
DC pressure drop (**one cable**) << AC (10 times higher, **three cables**),
But, in the actual design (**pressure drop > 100 times**)

Experiment is need in long cable! ⇒ 200 meter cable

A. Sasaki et al, "Cryogenic Fluid Dynamics for DC Superconducting Power Transmission Line", *IEEE Trans. Appl. Supercond.* **17** (2007) 1748-1751.

How to set Cryo-station

How to reduce pump power, Use Siphon!

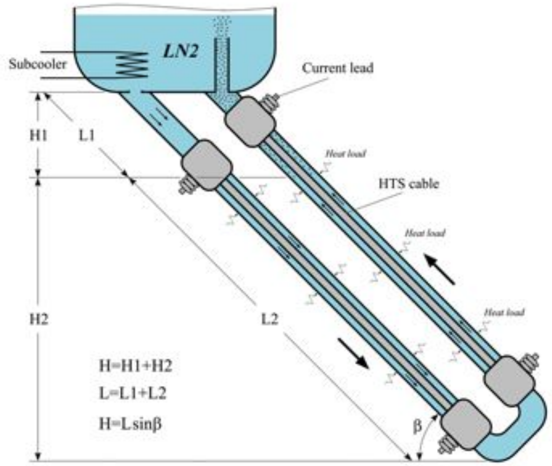


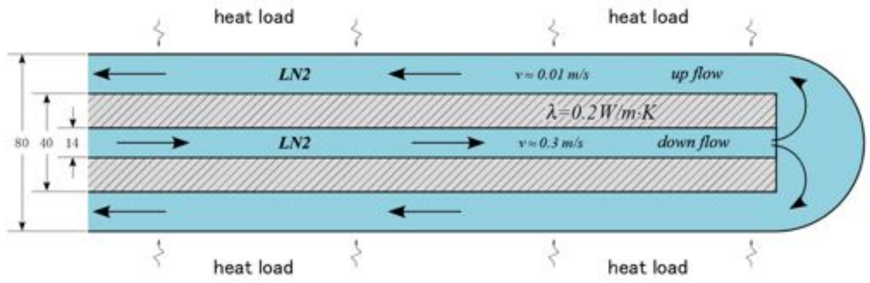
Analysis of experimental data should be included,
⇒ 200-meter cable experiment

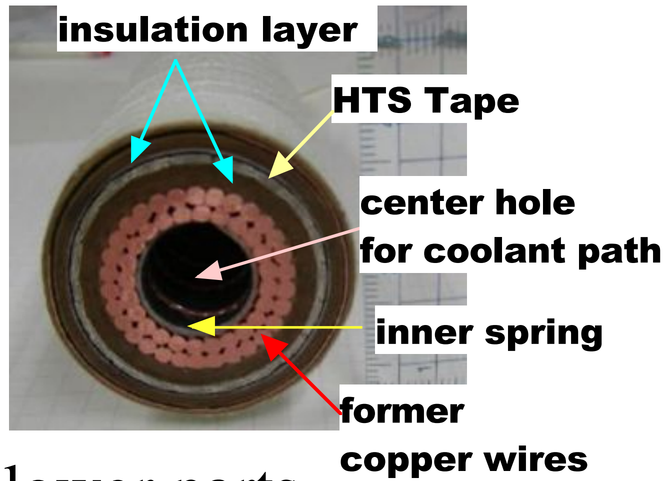
Y. Ivanov et al, "A compact cooling system for HTS power cable based on thermal siphon for circulation of LN2", *Adv. Cryogenic Eng.*, **55** (2010) 865-870.

LN_2 circulation System

Model and Equations







for upper parts

$$
\begin{cases}
\dot{m}C_{pl}\dfrac{dT_1}{dx} = k(T_2 - T_1) \\
\dot{m}\left[(1-\chi)C_{pl} + \chi C_{pg}\right]\dfrac{dT_2}{dx} + r\dot{m}\dfrac{d\chi}{dx} = k(T_2 - T_1) - q \\
\dfrac{dp_1}{dx} = \rho_l g \sin\beta - \dfrac{2 f_1 G_1^2}{\rho_l D_{h1}} \\
\dfrac{dp_2}{dx} = \left(\dfrac{\chi}{\rho_g} + \dfrac{1-\chi}{\rho_l}\right)^{-1} g\sin\beta + \dfrac{2 f_2 G_2^2}{\rho_l D_{h2}} \dfrac{1+\left(\rho_l/\rho_g - 1\right)\chi}{\left[1+\left(\mu_l/\mu_g - 1\right)\chi\right]^{0.25}} \\
T_2 = T_{sat}(p_2)
\end{cases}
$$

for lower parts

$$
\begin{cases}
\dot{m}C_{pl}\dfrac{dT_1}{dx} = k(T_2 - T_1) \\
\dot{m}C_{pl}\dfrac{dT_2}{dx} = k(T_2 - T_1) - q \\
\dfrac{dp_1}{dx} = \rho_l g \sin\beta - \dfrac{2 f_1 G_1^2}{\rho_l D_{h1}} \\
\dfrac{dp_2}{dx} = \rho_l g \sin\beta + \dfrac{2 f_2 G_2^2}{\rho_l D_{h2}}
\end{cases}
$$

Y. Ivanov et al, "A compact cooling system for HTS power cable based on thermal siphon for circulation of LN2", *Adv. Cryogenic Eng.*, **55** (2010) 865-870.

LN_2 circulation System

Calculation Results

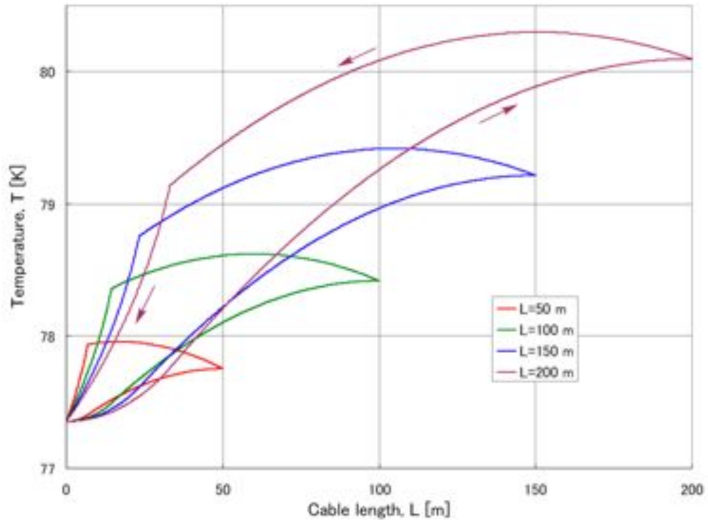


Fig.3 *Temperature profiles for 50, 100, 150 and 200 m cables (sinβ = 0.2)*

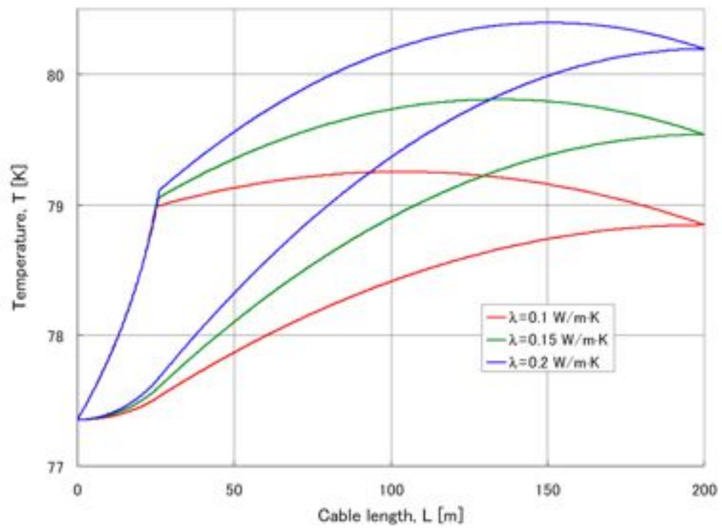


Fig.4 *Temperature profiles for 200 m cable (sinβ=0.25) as a function of heat conductivity of electrical insulator*

It is effective for circulation to use Thermal siphon!

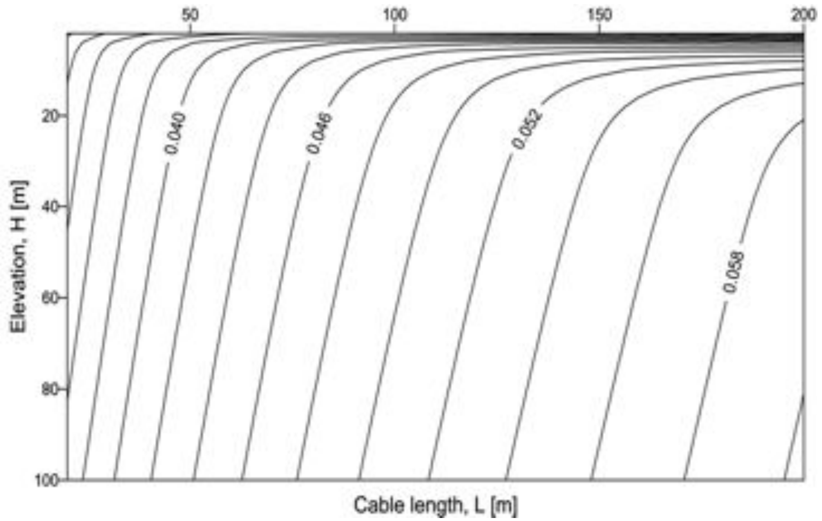
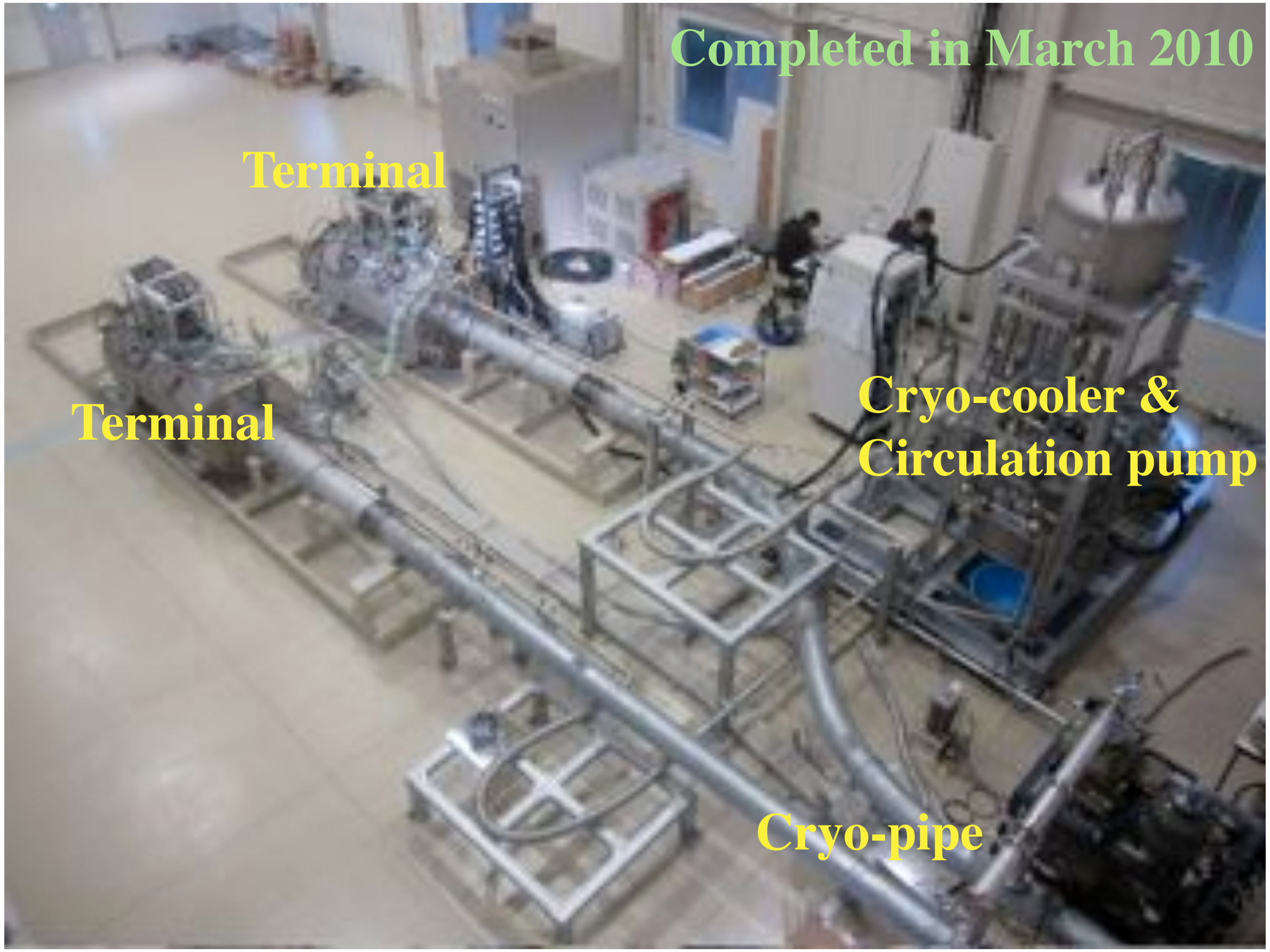


Fig.5 *Mass flow [kg/s] versus cable length and elevation*

Y. Ivanov et al, “A compact cooling system for HTS power cable based on thermal siphon for circulation of LN2”, *Adv. Cryogenic Eng.*, **55** (2010) 865-870.

200-meter Cable Test Facility



CASER-2

Construction at site:
Aug. 2009 to Jan. 2010

1st cooling down: Jan. 2010
2nd cooling down: Aug. 2010

Insulation = ±10kV
Current = 2 kA @77K

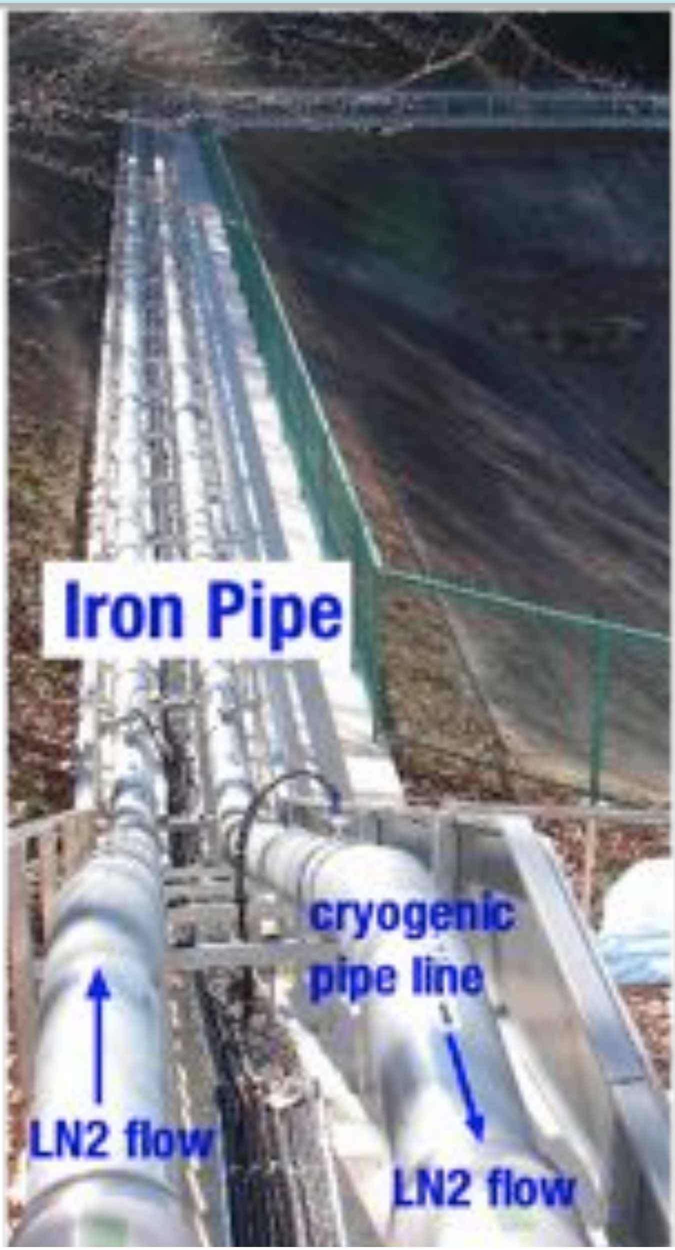
Cryo-cooler = ~1kW@77K
Circulation = ~10L/min

Monitor ~ 600CH

S. Yamaguchi et al, "**DESIGN and CONSTRUCTION of 200-meter HTS DC Power Cable Test Facility in Chubu University**", CEC-23/ICMC 2010, Poland July 2010.

Total budget ~ 5MUS$(included labor cost of researchers)

Design of Cryogenic Pipe



20-meter cable experiment

200-meter cable experiment
Iron Straight Pipe for outer pipe
SS pipe for inner pipe

S. Yamaguchi et al, "**DESIGN and CONSTRUCTION of 200-meter HTS DC Power Cable Test Facility in Chubu University**", CEC-23/ICMC 2010, Poland July 2010.

Cryo-cooler & Cryogenic Tanks

Cryo-cooler ~ 1kW@77K

operation temperature = 72K – 82K

Low pressure drop for circulation,
Not connect the pump directly

Upper tank & lower tank system
1) pump does always not work
2) slush N2 experiment available
Operation ΔP = 10kPa – 30 kPa

S. Yamaguchi et al, "**DESIGN and CONSTRUCTION of 200-meter HTS DC Power Cable Test Facility in Chubu University**", CEC-23/ICMC 2010, Poland July 2010.

Small diameter cable

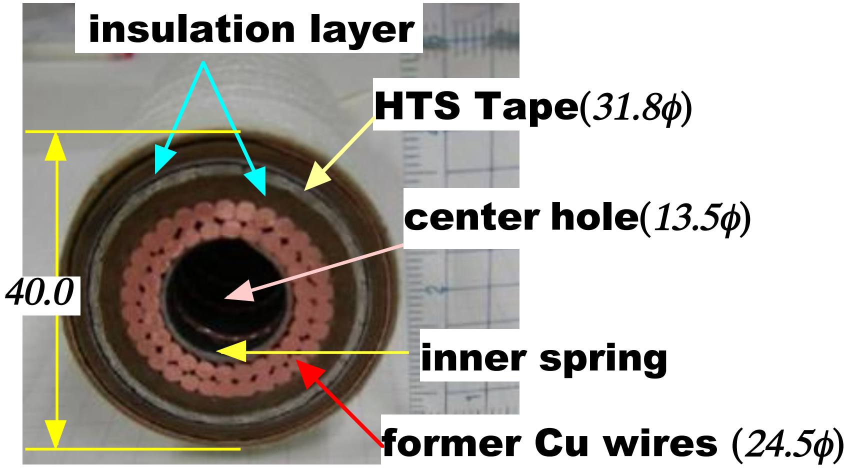
20-meter cable

Single wire

(2 layers, 39 tapes)

30kV insulation

>3 kA @78K



Made by Sumitomo

200-meter cable = co-axial

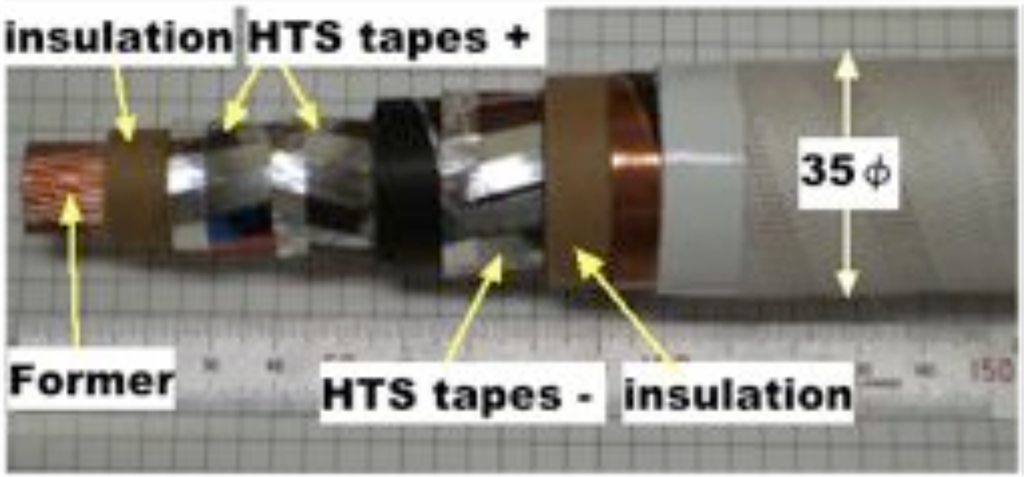
Inner (2 layers) = 23 tapes

Outer (1 layer) = 16 tapes

Insulation = ±10kV

Current = 2 kA @78K

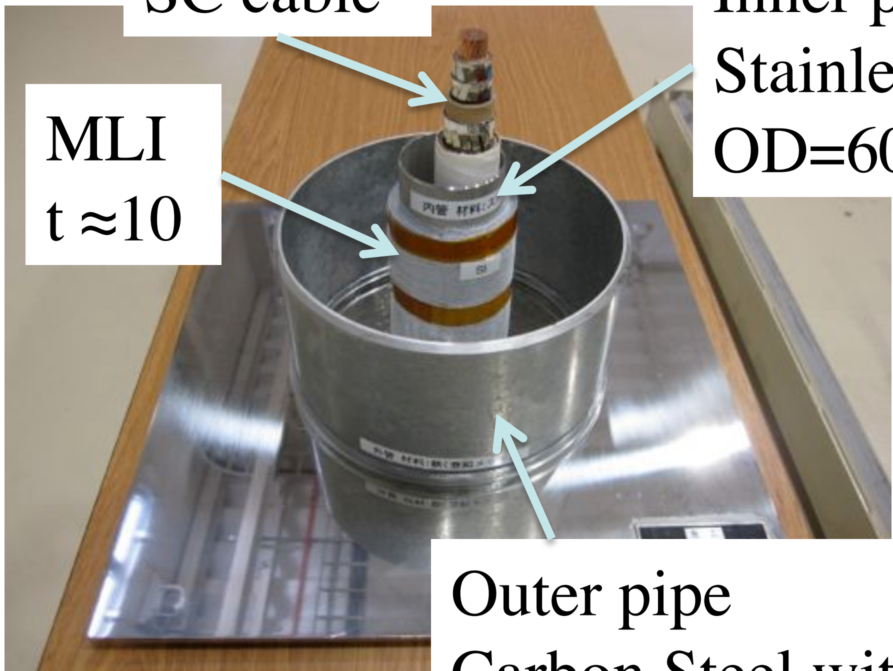
Copper former = 14ϕ



Structure of Cryogenic Pipe & Cable

Vacuum pumping is a key subject for long pipe,
1st Priority of the Design is wider space for vacuum pumping.

→ H. Watanabe et al, SAP-9, ISS2010
H. Watanabe et al, 22A-PS-3, ICEC23/ICMC2010
H. Watanabe et al, "超伝導送電用長距離断熱配管の真空排気", 1P-p16, CE Japan



Data is not enough for the vacuum pumping design.

The vacuum system for CASER2

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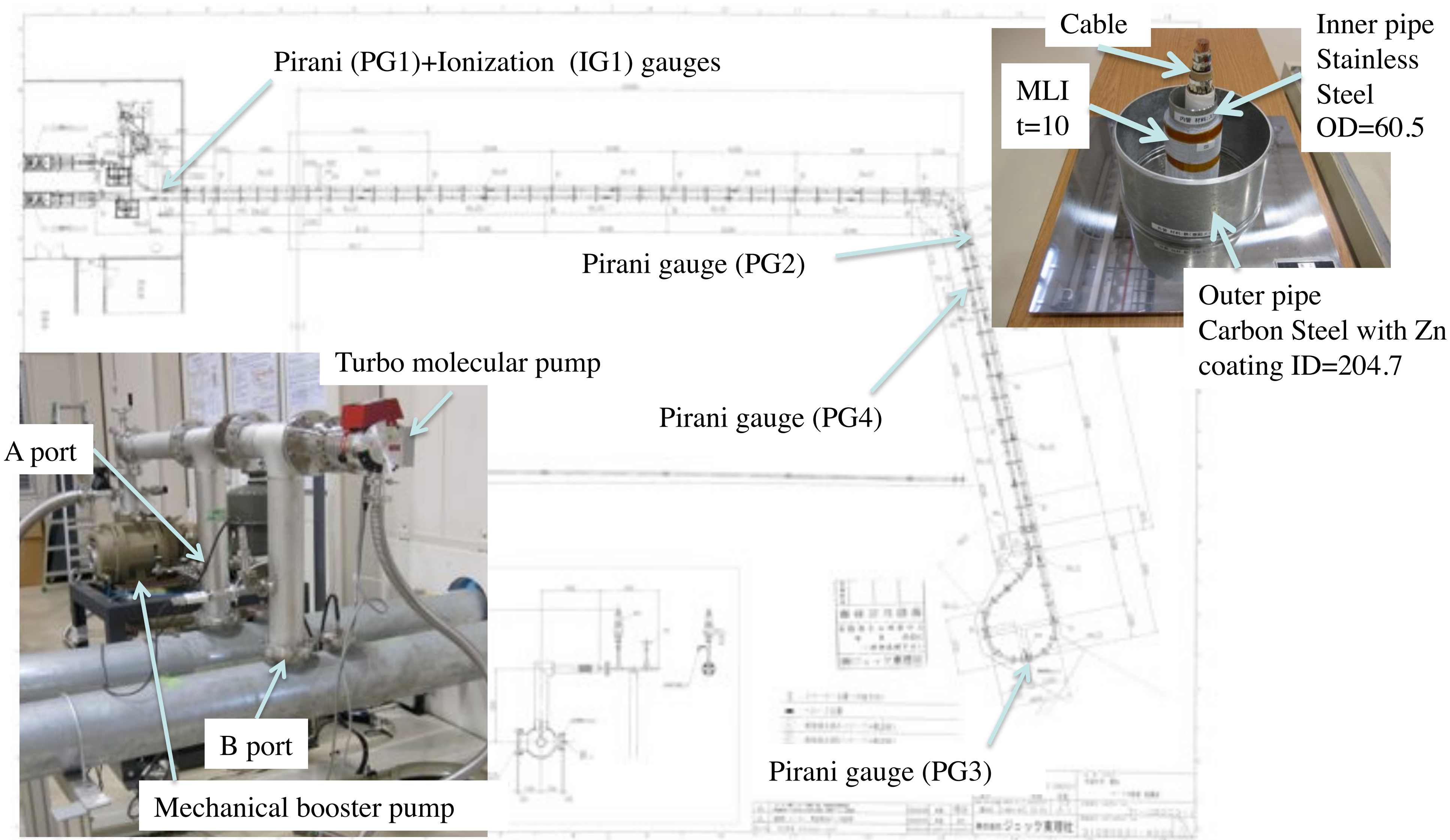
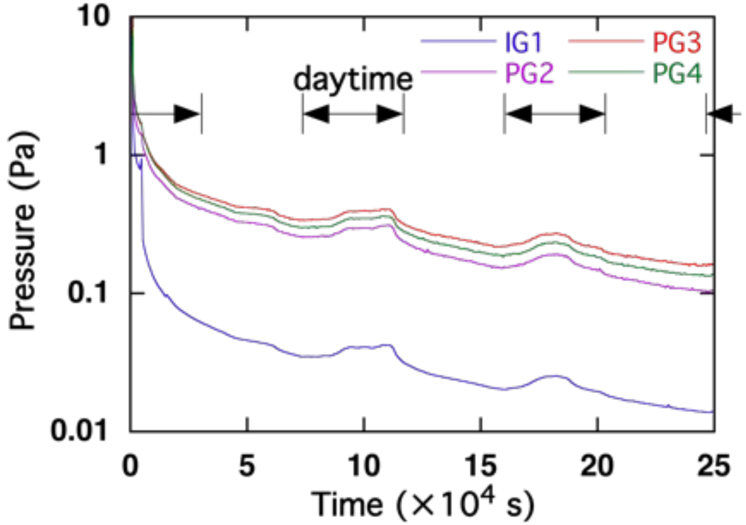
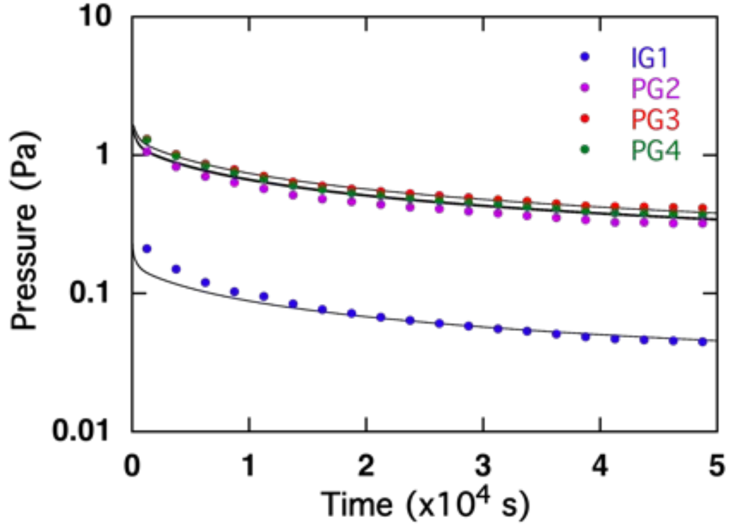


Evacuation for vacuum insulation





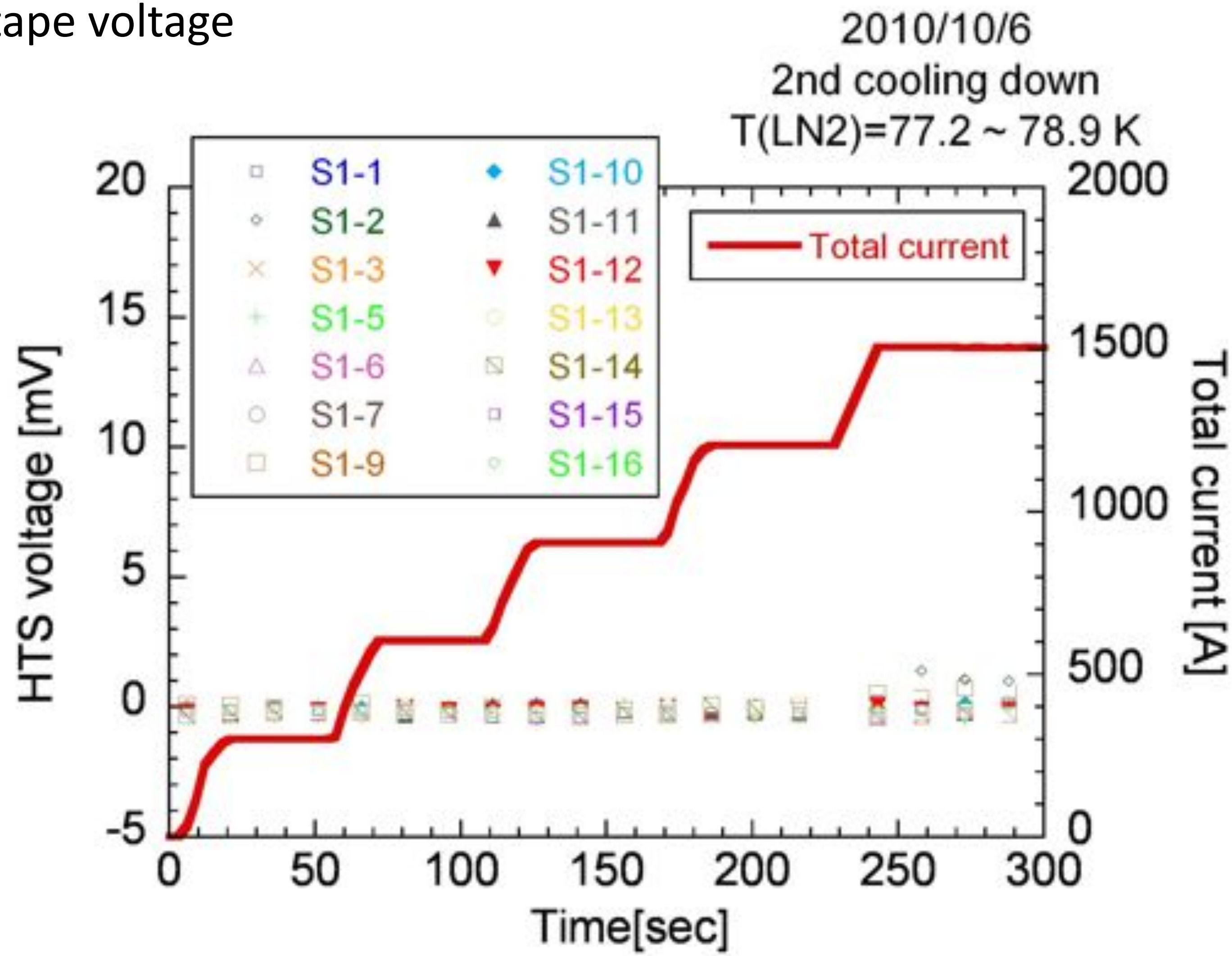
Evacuation time obtained by simulations with different conditions

Vacuum degree	Present situation	Pumping speed 50% reduction	Out-gasing rate 20% reduction	Conductance 50% increase
0.1 Pa	9days	10days	6days	4days
0.05 Pa	37days	41days	23days	18days

A 200m cryogenic pipe is evacuated at the middle with a TMP of 260 l/s. The conductance of 300l･m/s and the outgassing rate of $6.8t^{-0.5}$Pa･l/(s･m^2) are supposed to obtain the result “present situation”.

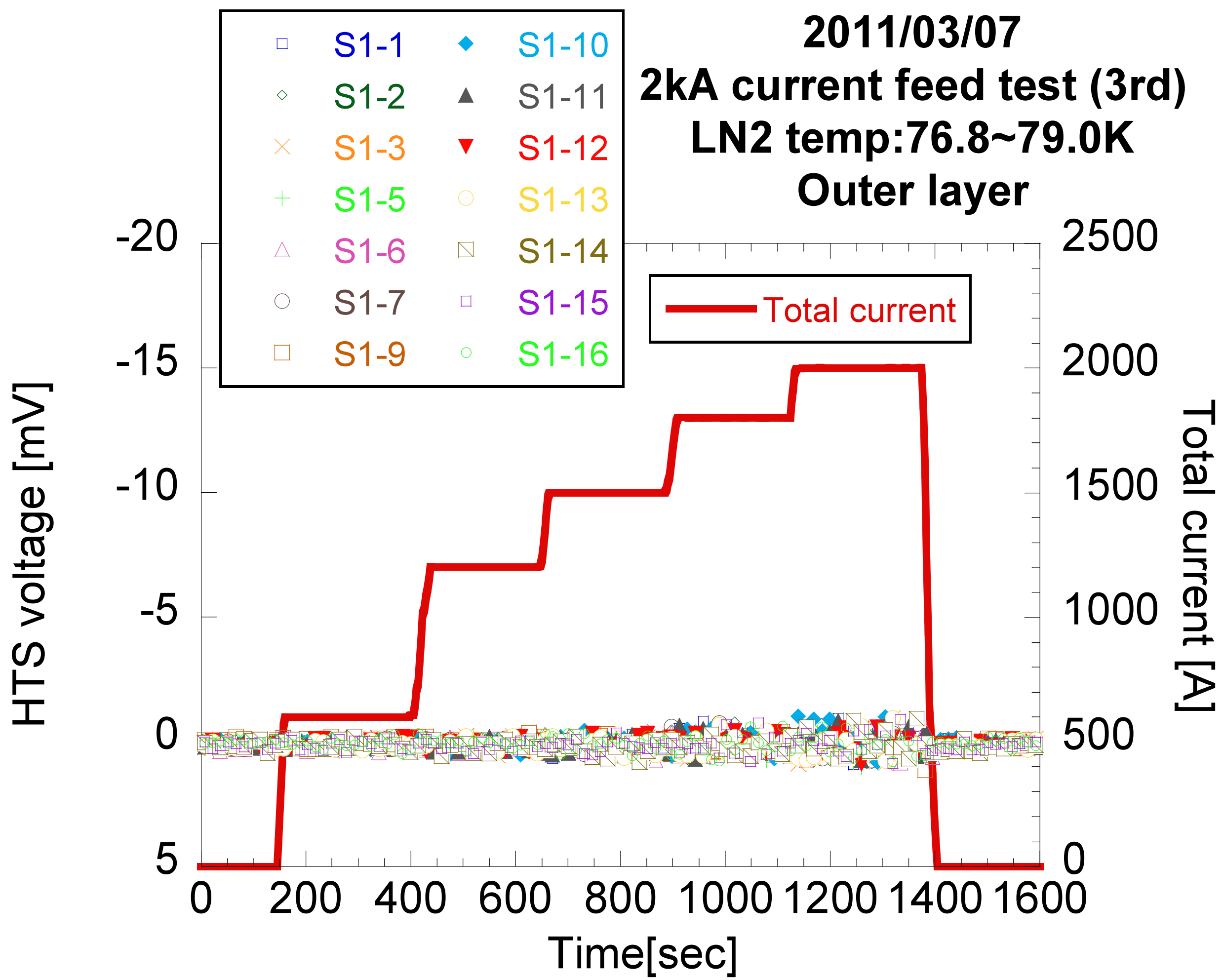
Excitation of DC Cable

Current > 1500 A @Oct, 2010
Each HTS tape voltage



Outer layer of cable.

Current feeding test up to 2 kA



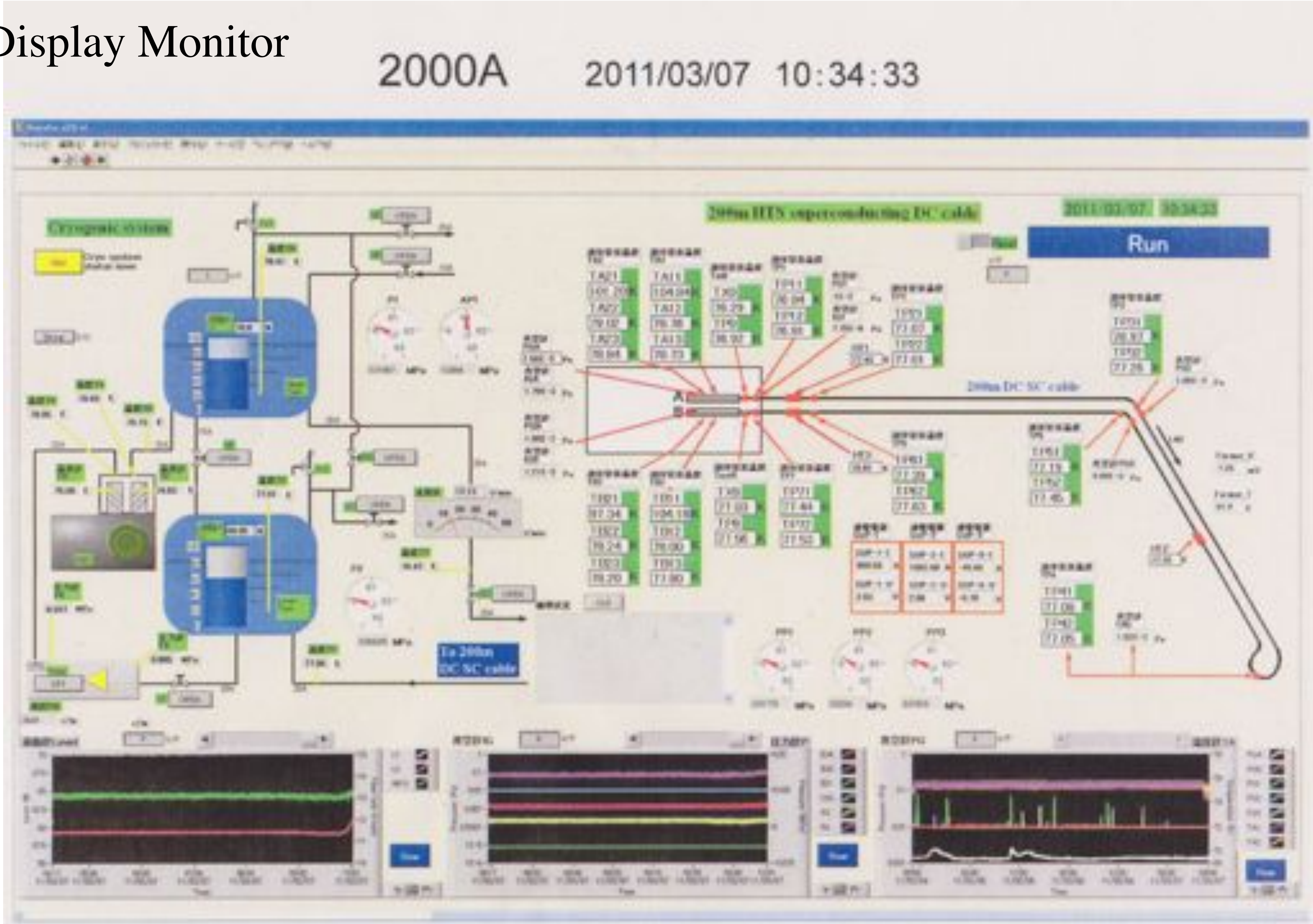
We adjusted the length of each power cable between DC power supply and HTS tape by several mΩ

Current imbalance between HTS tapes can be suppressed

Operation up to 2 kA has succeeded.

Current feeding test up to 2 kA

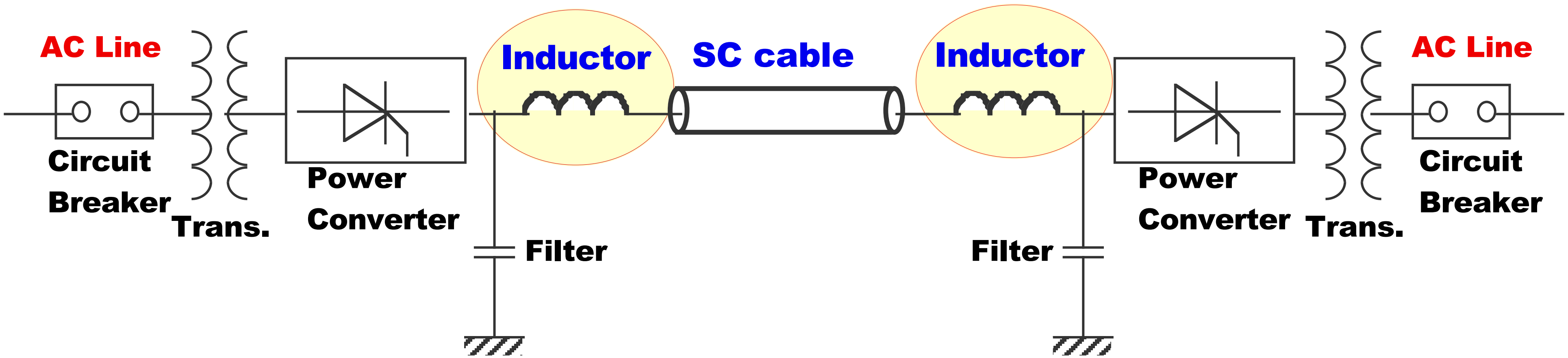
Display Monitor



Inductor in Transmission Line

DC Transmission Line needs Larger Inductors
to reduce the ripple of current & short circuit current.

System of **Iron pipe + Single core cable**



Energy Storage like SMES!?

S. Yamaguchi et al, "Iron-steel cryogenic pipe for DC superconducting power transmission line", ASC2010, Washington DC, USA August 2010.

Inductance of DC Cable

Energy Storage by Grid

L = 0.37 mH for 100m cable measured at the current of 400A,
Higher inductance depends on Iron material of outer pipe.

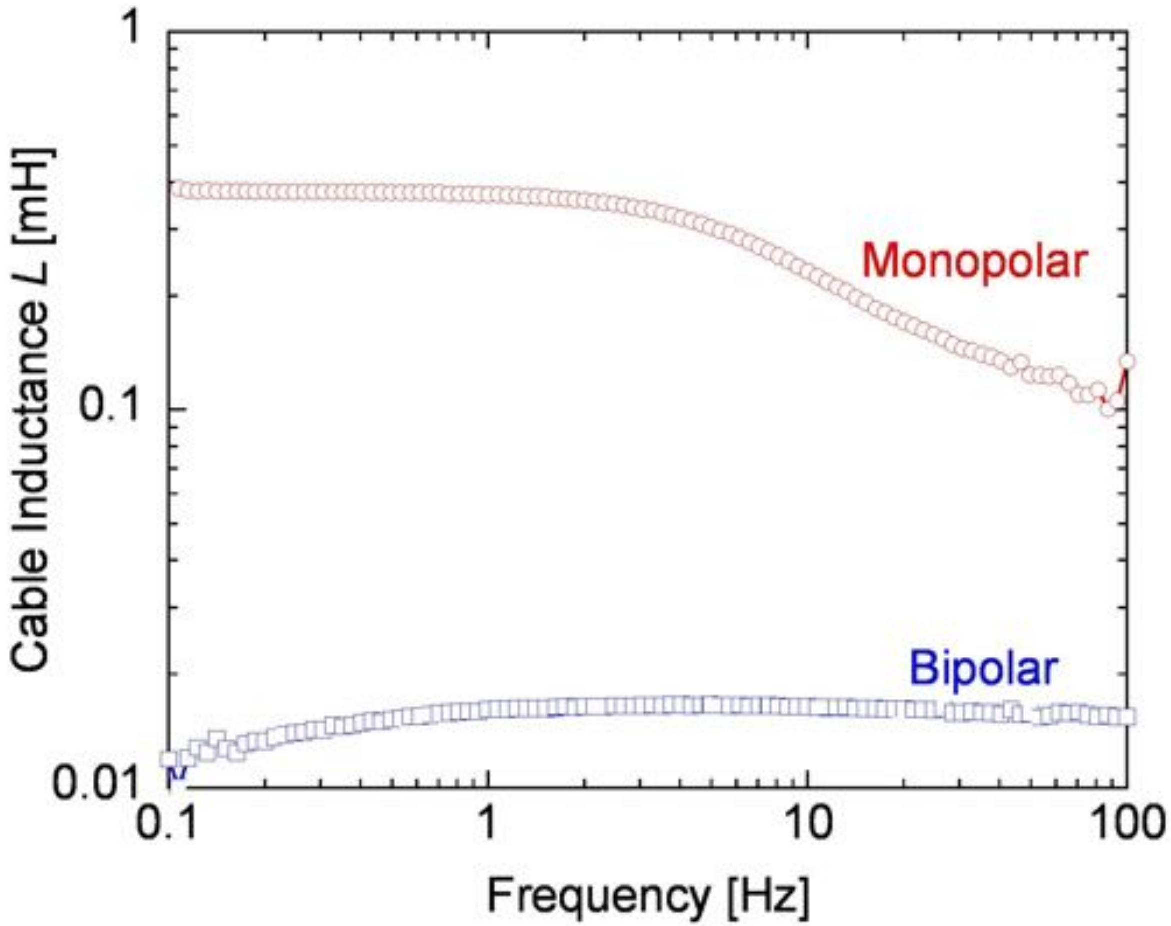
→ M. Hamabe et al, SAP-10, ISS2010

If current = 50kA &
length = 100 km

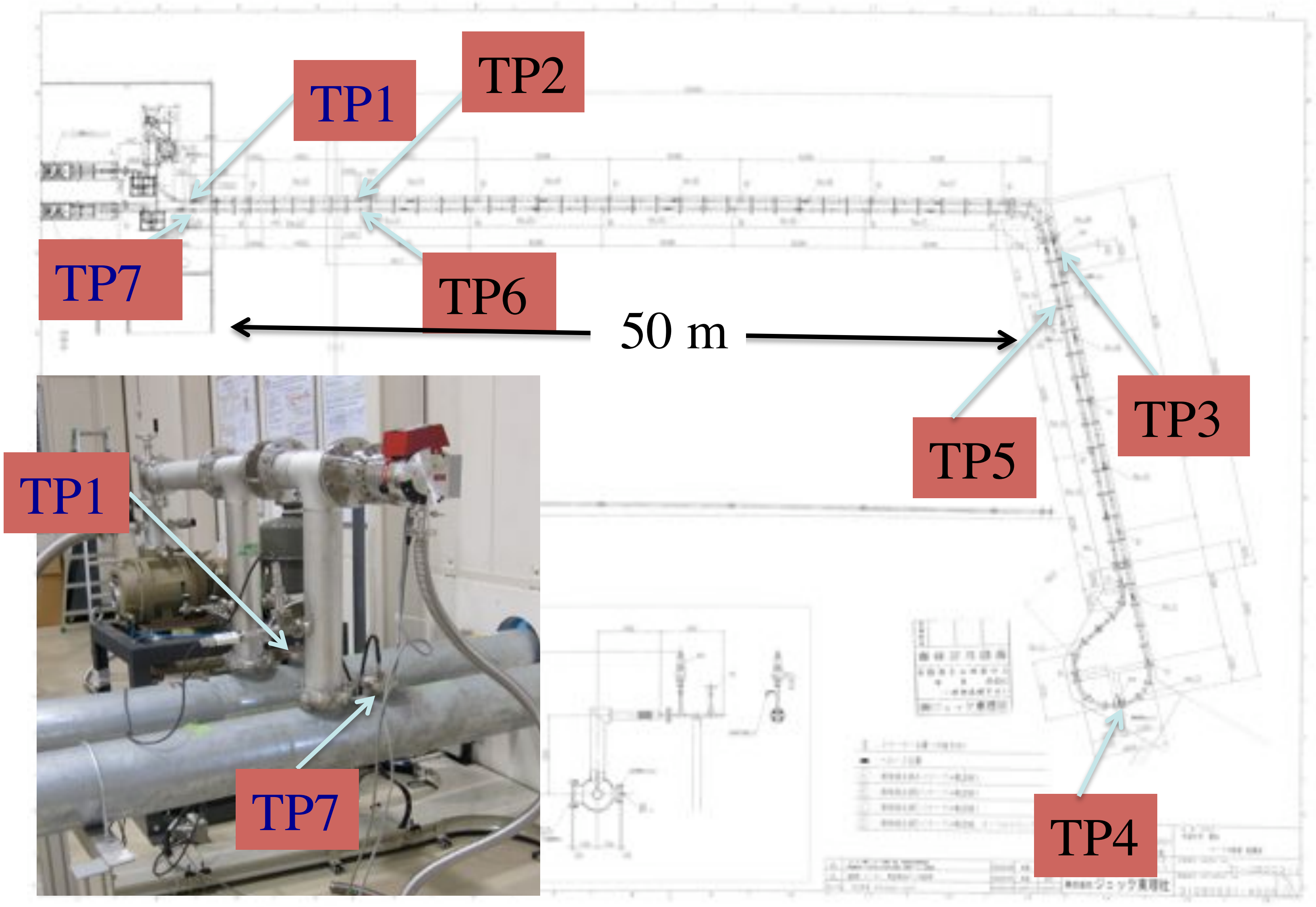
↓

L **= 0.37 H (SC magnet)**
Stored Energy = 462 MJ

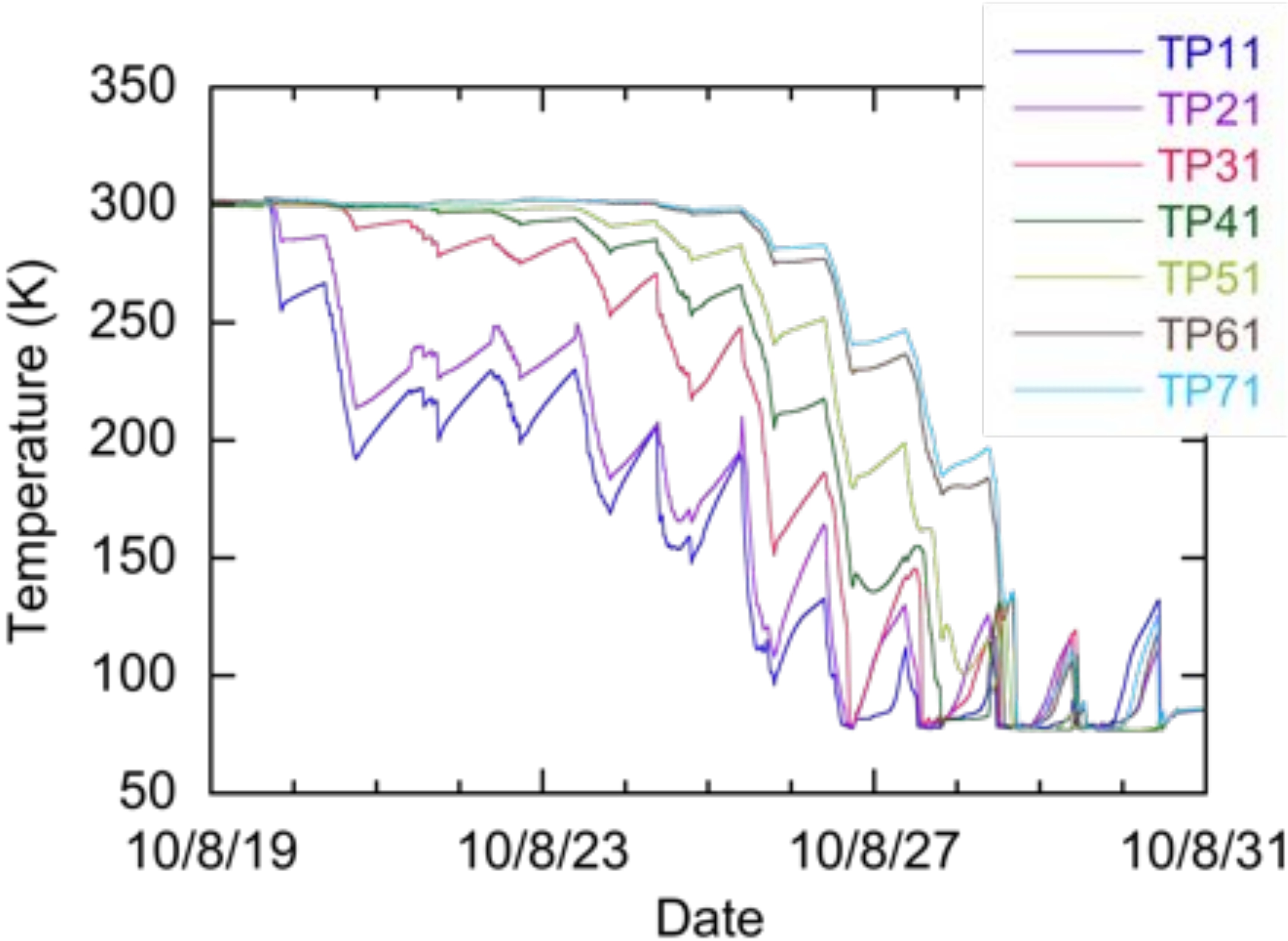
Present SMES ~ 20MJ



Thermometer positions



2nd Cooling Down



Thermal expansion & Support Structure

nexans

CRYOFLEX(flexible, vacuum insulated cryogenic envelopes consist of two concentric, corrugated tubes. The tubes, together with their associated terminations and hardware, are assembled, leak tested and evacuated at the factory.

Design:
Helically corrugated and longitudinally welded stainless steel tubes
Diameter range from 10 to 300 mmrom 10 to 300

http://www.nexans.com/eservice/Navigate.nx?navigationId=142392

Water pipe structure

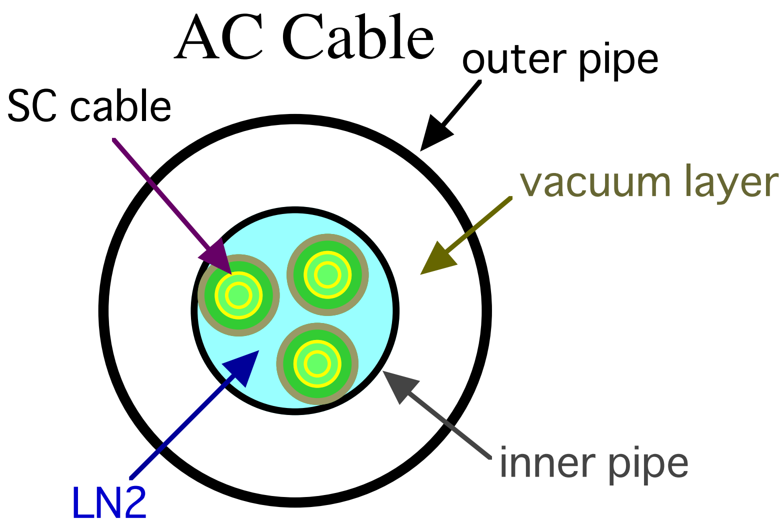
Chubu Univ. & LHC/CERN

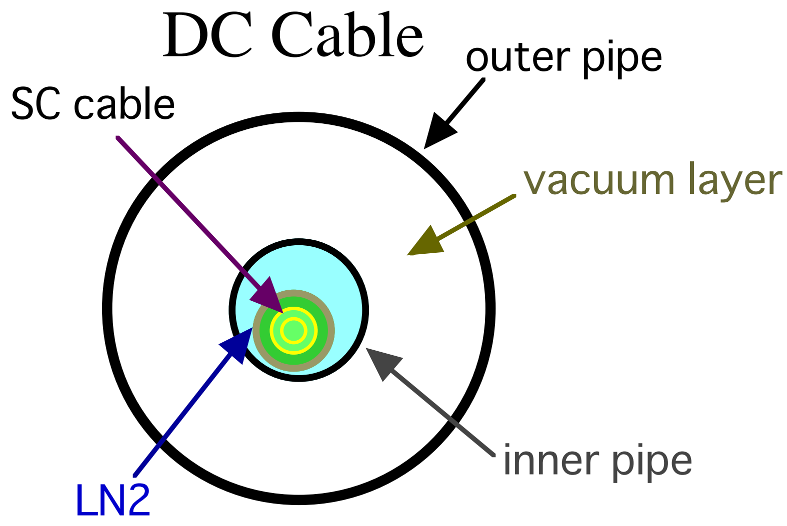
Straight & Bellows Pipes

1) High Strength
2) Cheap
3) **Low pressure drop**
4) the other reasons

How to absorb HTS tape thermal shrinkage?

Difference of DC & AC Cable





1) One Cable for DC,
   Three Cables for AC

2) Smaller cryo-pipe for DC
   Low Heat Leakage &
   Low Pressure Drop

→

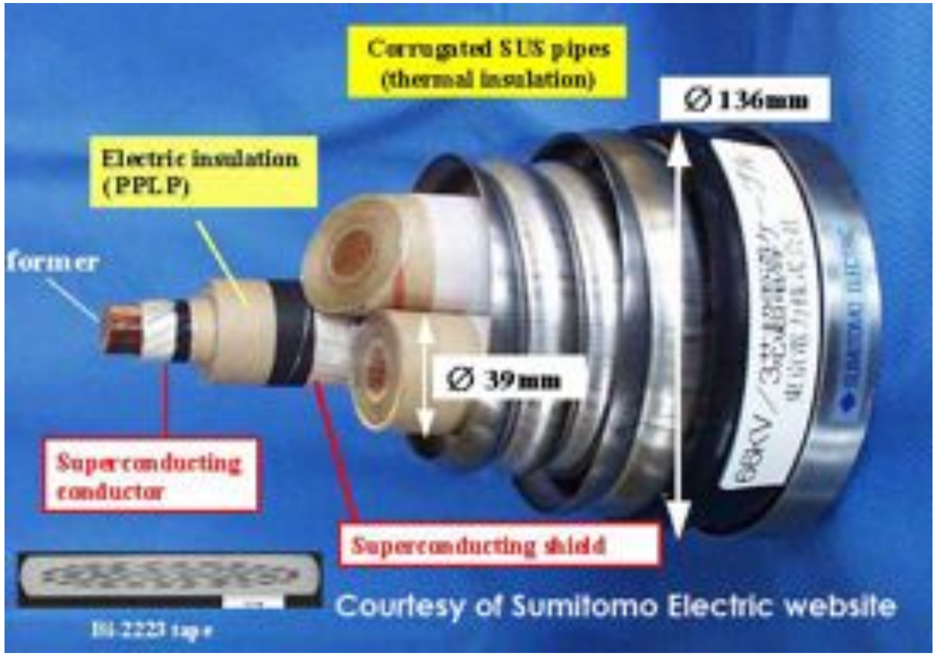
DC Cable is Cheaper & High Performance
even if ac losses are zero

We should confirm experimentally!

Lying Cable Method

**Previous Method: compose Cable & cryo-pipes in factory at first,
Install Cable with cryo-pipe in site**

Merit: Easy installation for short distance



Sumitomo et al

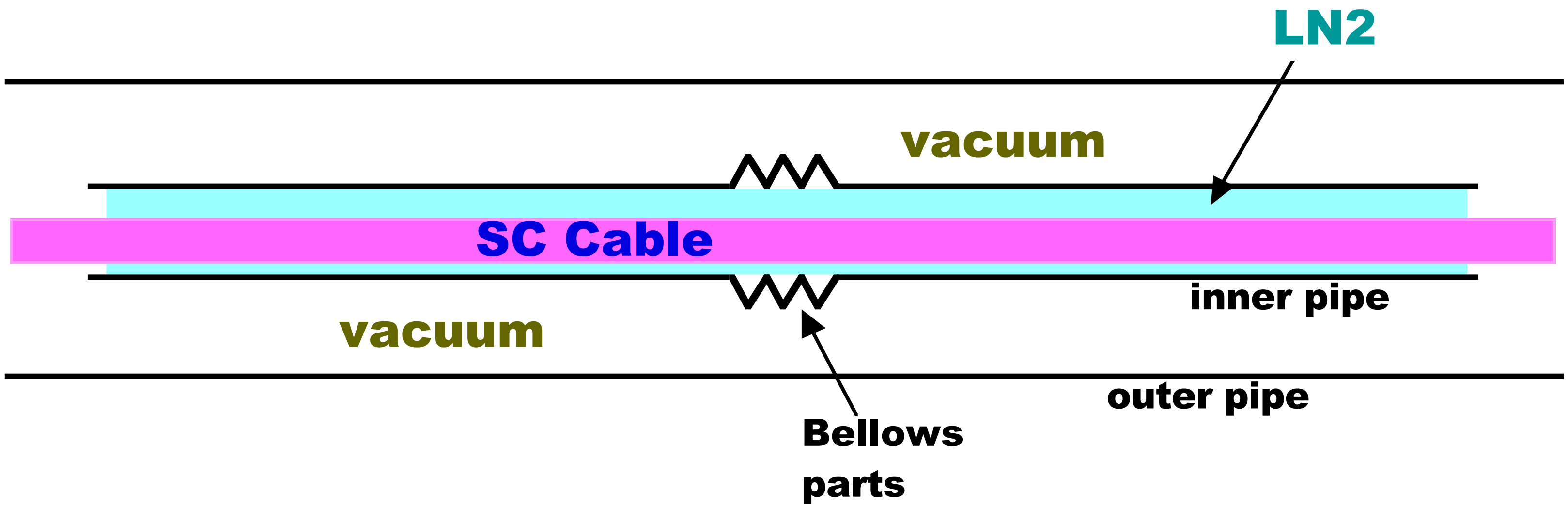
▲三心一括型超電導ケーブル

However, many connection parts for long distance

High Cost of connection + Cabble Accidents will increase!

Support Structure of Cable & Pipe

**New Method: Install Cryo-pipe in site at first,
Insert SC Cable into Cryo-pipe later**



Outer pipe: Straight Pipe (Iron pipe coated by Zinc)

Inner pipe: straight pipe & bellows pipe

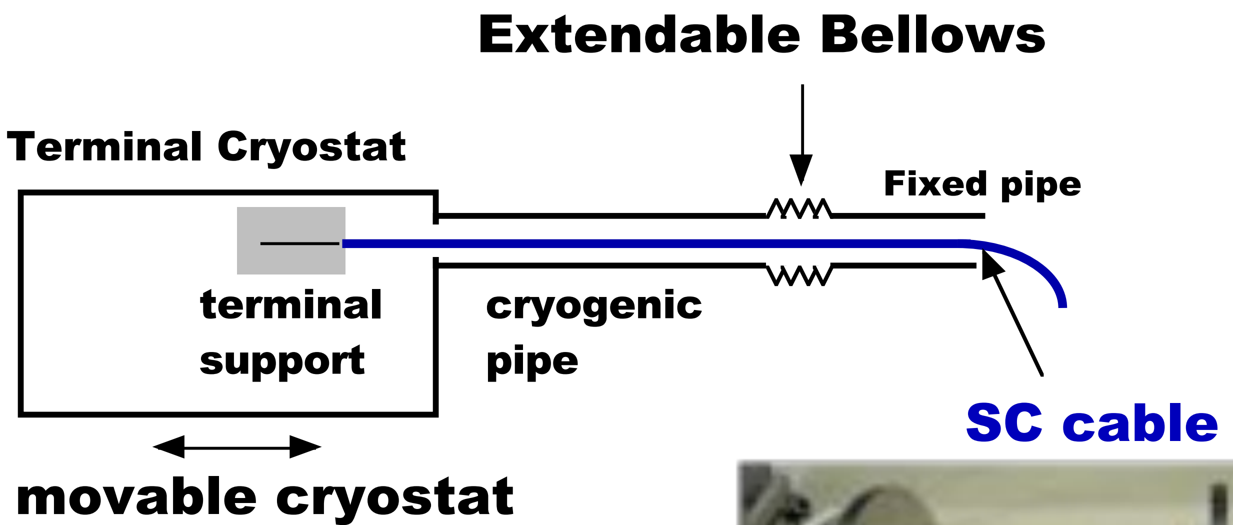
Thermal shrinkage of inner pipe ~ 600mm & bellows pipe will absorb.

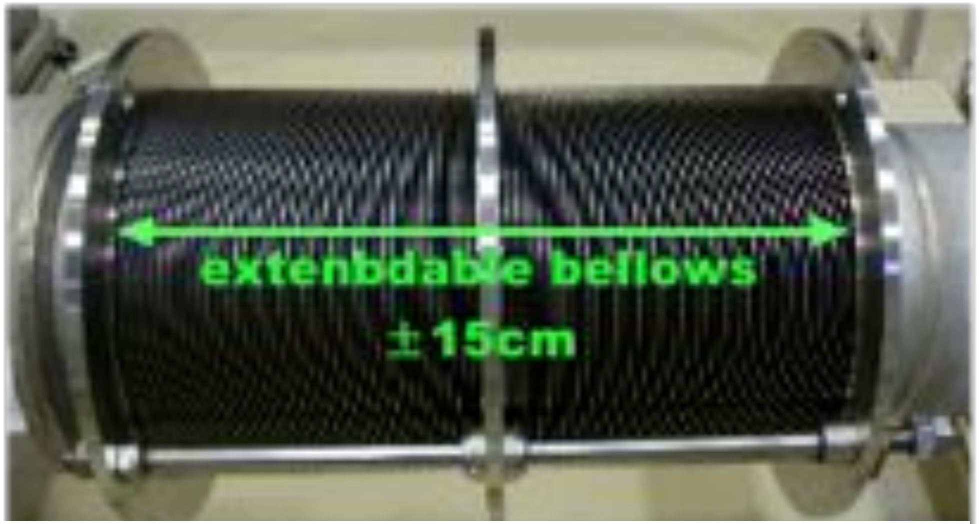
S. Yamaguchi et al, "**DESIGN and CONSTRUCTION of 200-meter HTS DC Power Cable Test Facility in Chubu University**", CEC-23/ICMC 2010, Poland July 2010.

Cable support at Terminal Cryostat

Reduction of thermal stress of HTS tape is important!

M. Sugano, K. Shikimachi, N. Hirano and S. Nagaya, Supercond. Sci. Technol., **23**(2010)085013.



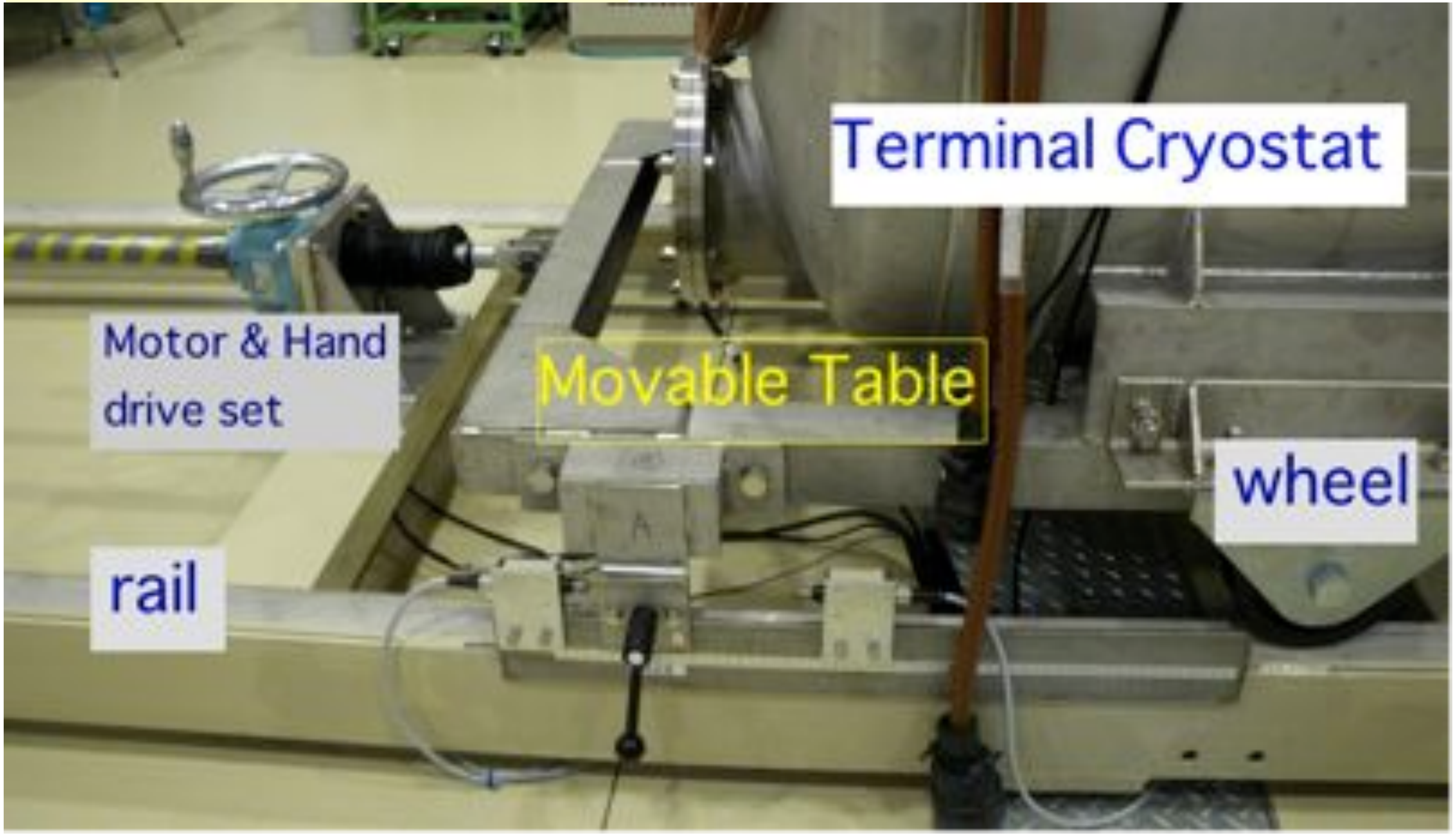


Absorb the thermal contraction and expansion of SC cable, **Movable cryostat** & **Extendable bellows** are used.

S. Yamaguchi et al, "**DESIGN and CONSTRUCTION of 200-meter HTS DC Power Cable Test Facility in Chubu University**", CEC-23/ICMC 2010, Poland July 2010.

Movable Cryostat

Computer control system



S. Yamaguchi et al, "**Experiment of 200-meter Superconducting DC cable system in Chubu University**", accepted in publication in *Physica C*.

Experimental Result of Movement

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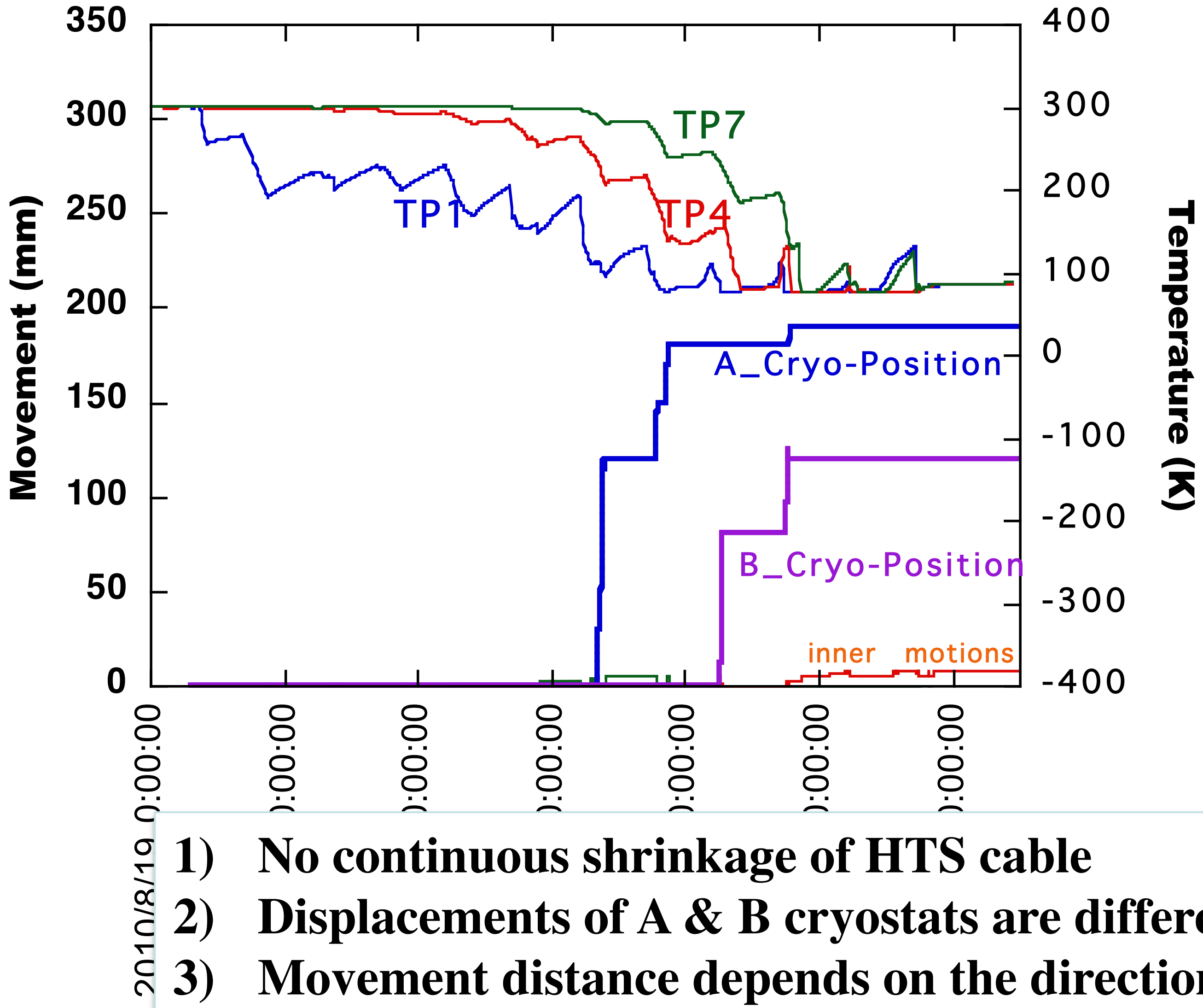
2nd cooling down experiment



1) **No continuous shrinkage of HTS cable**
2) **Displacements of A & B cryostats are different**
3) **Movement distance depends on the direction of cooling start**

S. Yamaguchi et al, "**Experiment of 200-meter Superconducting DC cable system in Chubu University**", accepted in publication in *Physica C*.

Summary of Cryostat Motions

Cryostat positions of 1st, 2nd and 3rd Experiments

	Cryostat A [mm]	Cryostat B [mm]
After Construction	0.0	0.0
1st Cooling Down	-163	-299
1st Warming up	+28	-181
2nd Cooling Down	-162	-294
2nd Warming up	+7	-100
3rd Cooling Down	-207	-238
3rd Warming up	+6	-99

Since the cables are not fixed to the cryostat,

1) **These displacements are not real length of Cables**
2) **Movements are not constant for cooling down & temperature rise**

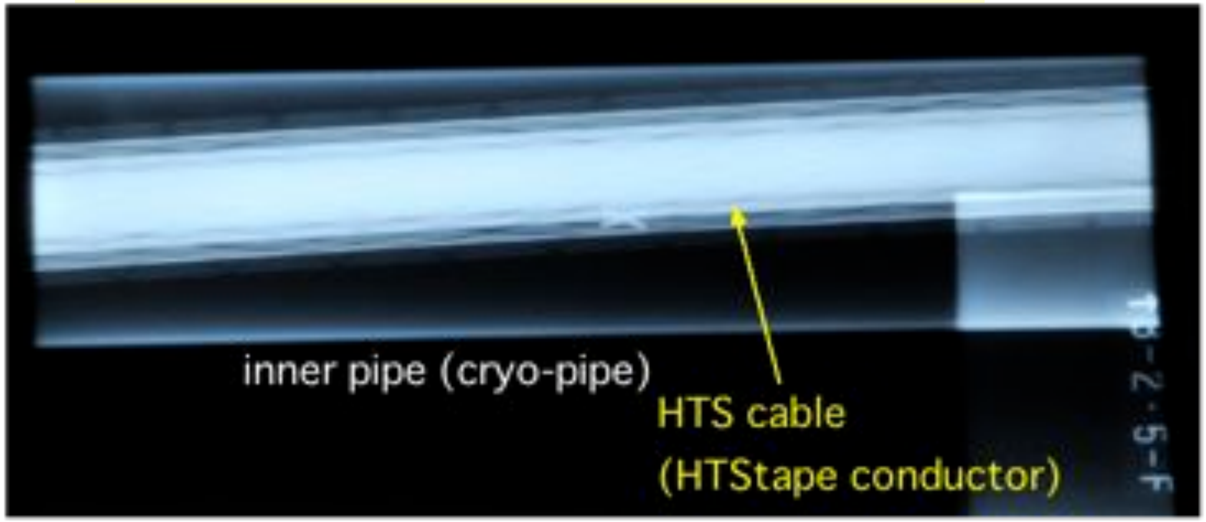
↓

X-ray Photos

S. Yamaguchi et al, "**Experiment of 200-meter Superconducting DC cable system in Chubu University**", accepted in publication in *Physica C*.

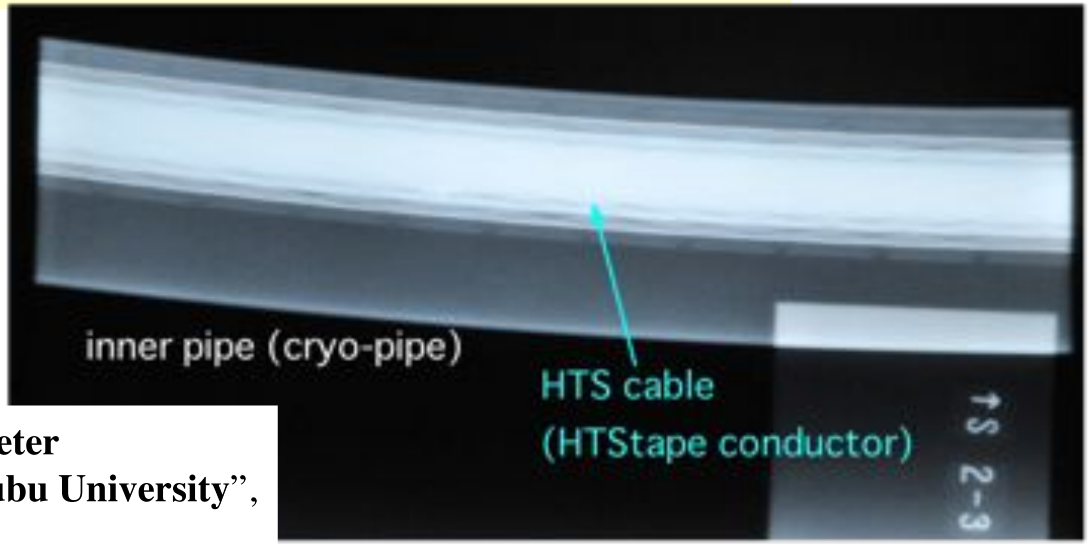
X-ray photos of cryo-pipe & cable

1st temperature rise (~@300K)



helically twisted way

2nd cooling down (~@77K)

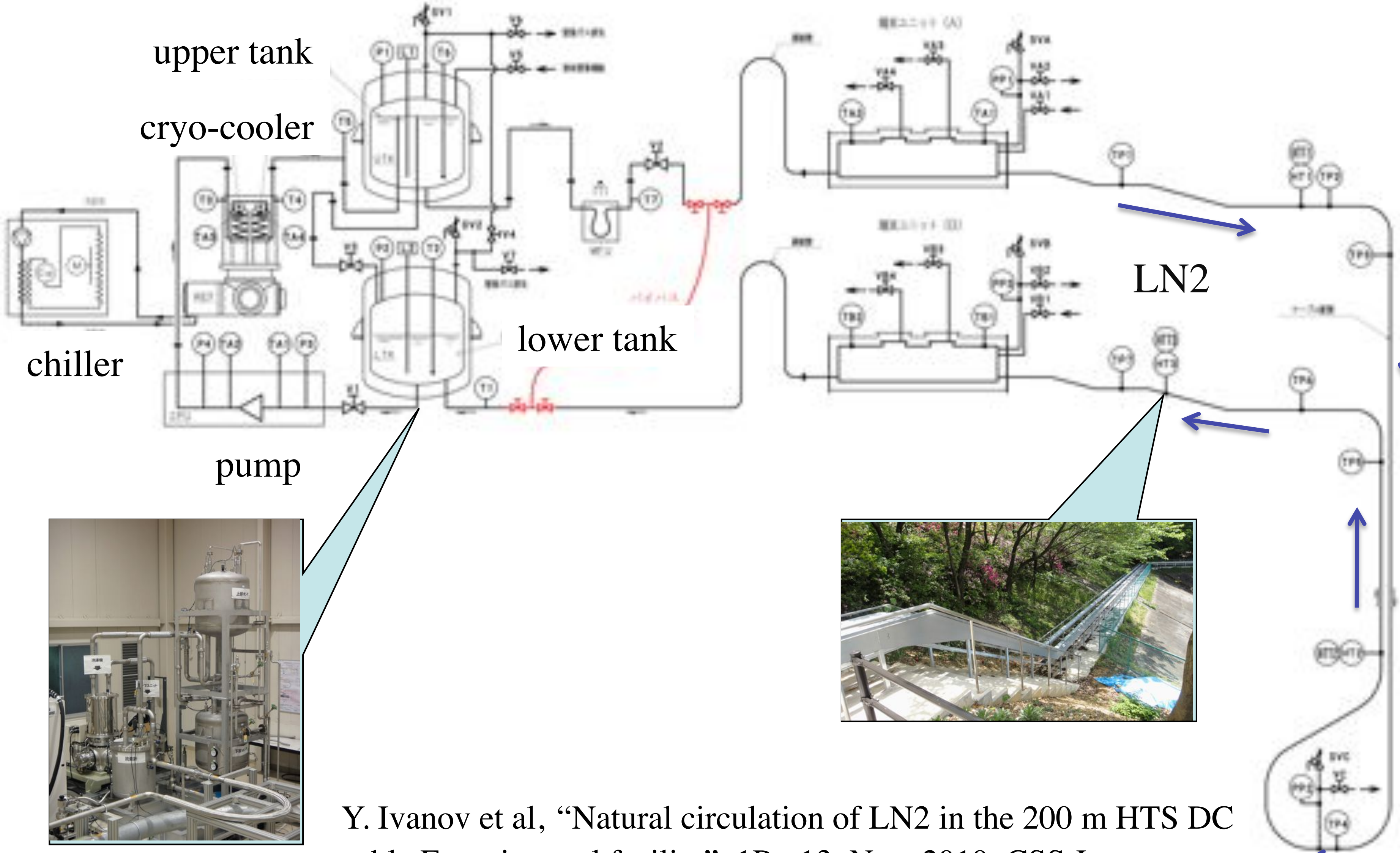


side up to
inner pipe

S. Yamaguchi et al, "**Experiment of 200-meter Superconducting DC cable system in Chubu University**", accepted in publication in *Physica C*.

Circulation of LN2

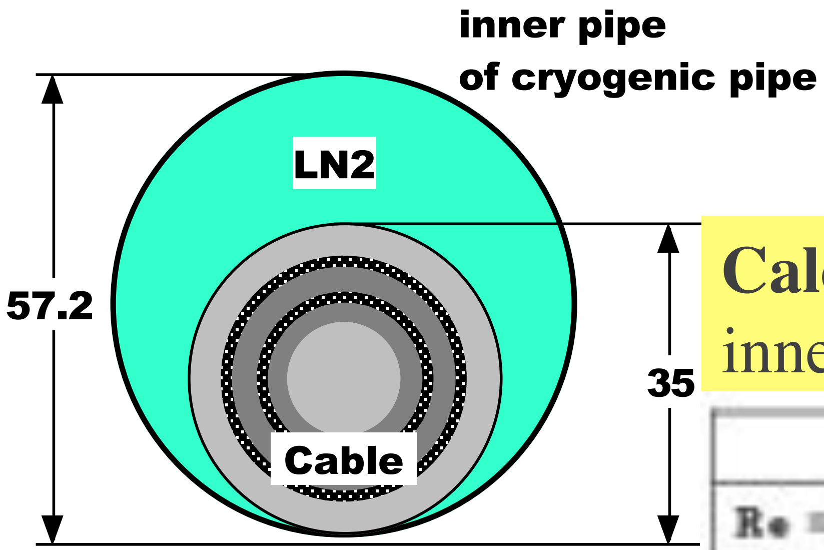
Setup of circulation path



Y. Ivanov et al, “Natural circulation of LN2 in the 200 m HTS DC cable Experimental facility”, 1P-p13, Nov. 2010, CSS Japan.

Cryogenic Circulation Design

Configuration of inner pipe & cable



Calculation

inner straight SS pipe with bellows pipe (<5%)

Formula	
$Re = \rho v D_h/\mu$	$\Delta P = 2f\rho v^2 L/D_h$
Re: Reynolds number	ΔP: pressure drop [Pa]
ρ: density [kg/m^3]	L: length of pipe [m]
v: flow velocity [m/s]	
D_h: hydraulic diameter [m]	
(for circular pipe, $D_h = D_2 - D_1$)	$\Delta T = q_w L / v A_h \rho C_p$
μ: viscosity [Pa·s]	ΔT: temp. difference [K]
$f = 0.0791/Re^{0.25}$ (Re>2000)	q_w: heat leak [W/m]
f: pipe friction factor	A_h: cross section [m^2]
	C_p: specific heat [J/(kg·K)]

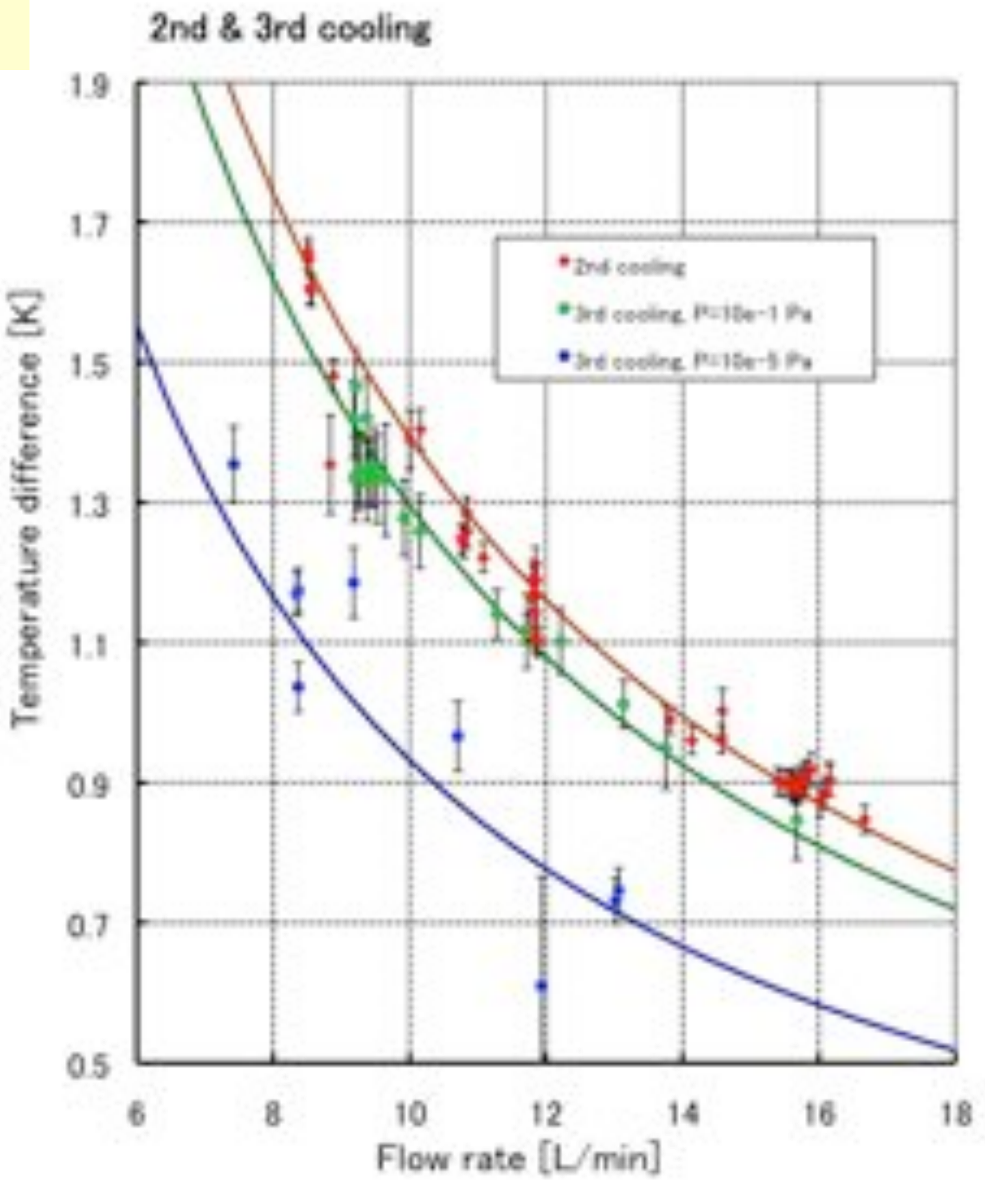
Experimental Result of LN2 Circulation

Flow rate & Temp. Difference

1) Vacuum degree is important to keep low heat leak.
2) Flow rate ~ 4L/min – 17L/min

↕

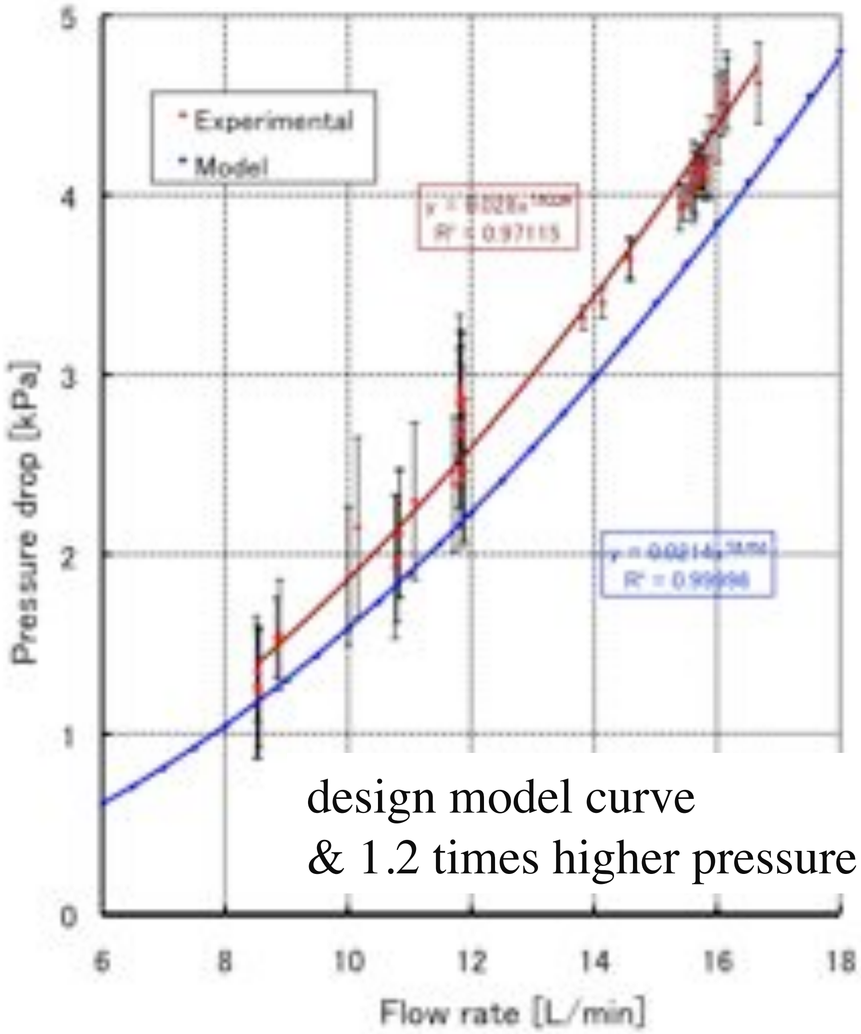
Flow rate ~ 50L/min – 200L/min
In AC cable experiment



Experimental Result of LN2 Circulation

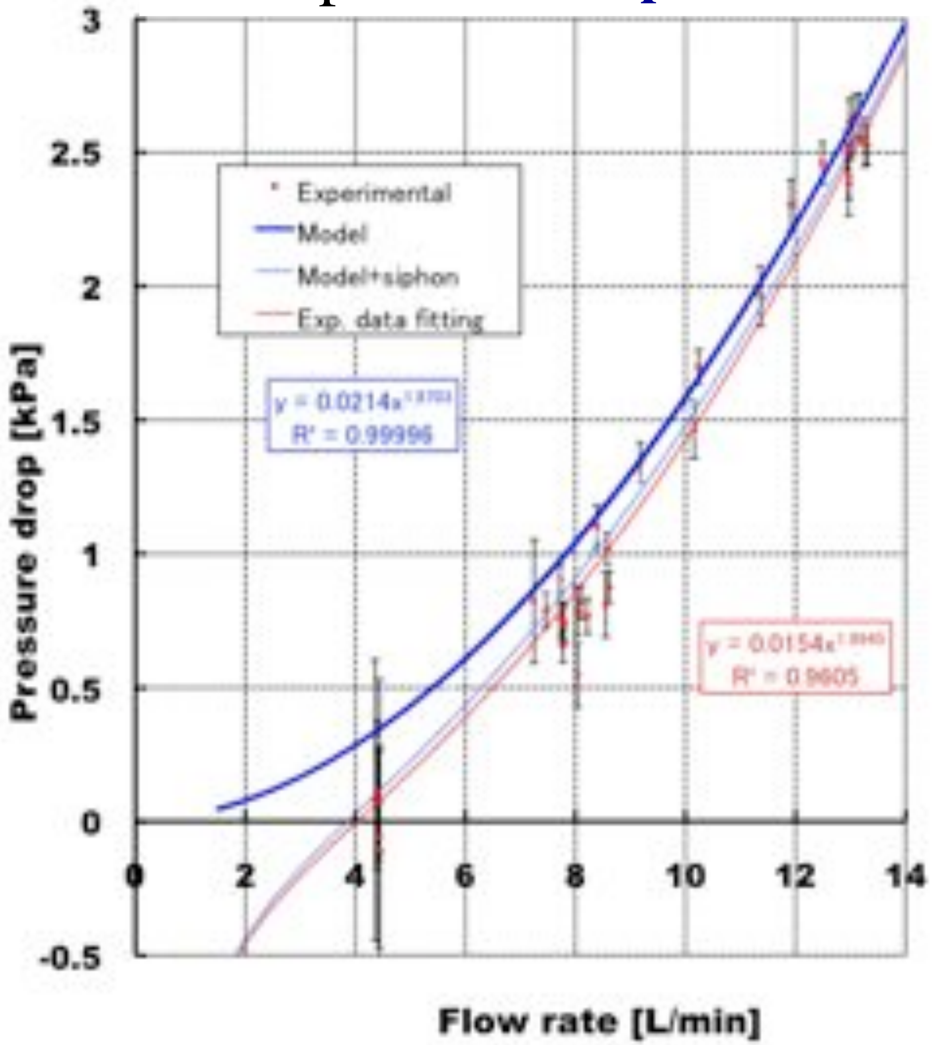
Pressure Drop & Flow rate in 2nd & 3rd Experiments

2nd Experiment



design model curve
& 1.2 times higher pressure

3rd Experiment / **siphon effect!**



Estimation for Long LN2 Circulation

Pressure drop = $L^{2.75} \sim \underline{L^{3}}$

Distance :	200 m	➜	2 km	➜	20 km
ΔT:	1.5 K	➜	1.5 K	➜	1.5 K
Pressure :	1.5kPa	➜	1.5MPa	➜	1.5GPa
Flow Rate:	10 L/mim	➜	100 L/min	➜	1000 L/min

ΔT ➜ 5 K (70 K→ 75 K) for 2 km

Flow rate ➜ 30 L/min

Pressure ➜ 135 kPa

If heat leak will be half,
the flow rate is 15 L/min & the pressure drop is 33.8 kPa

⬇

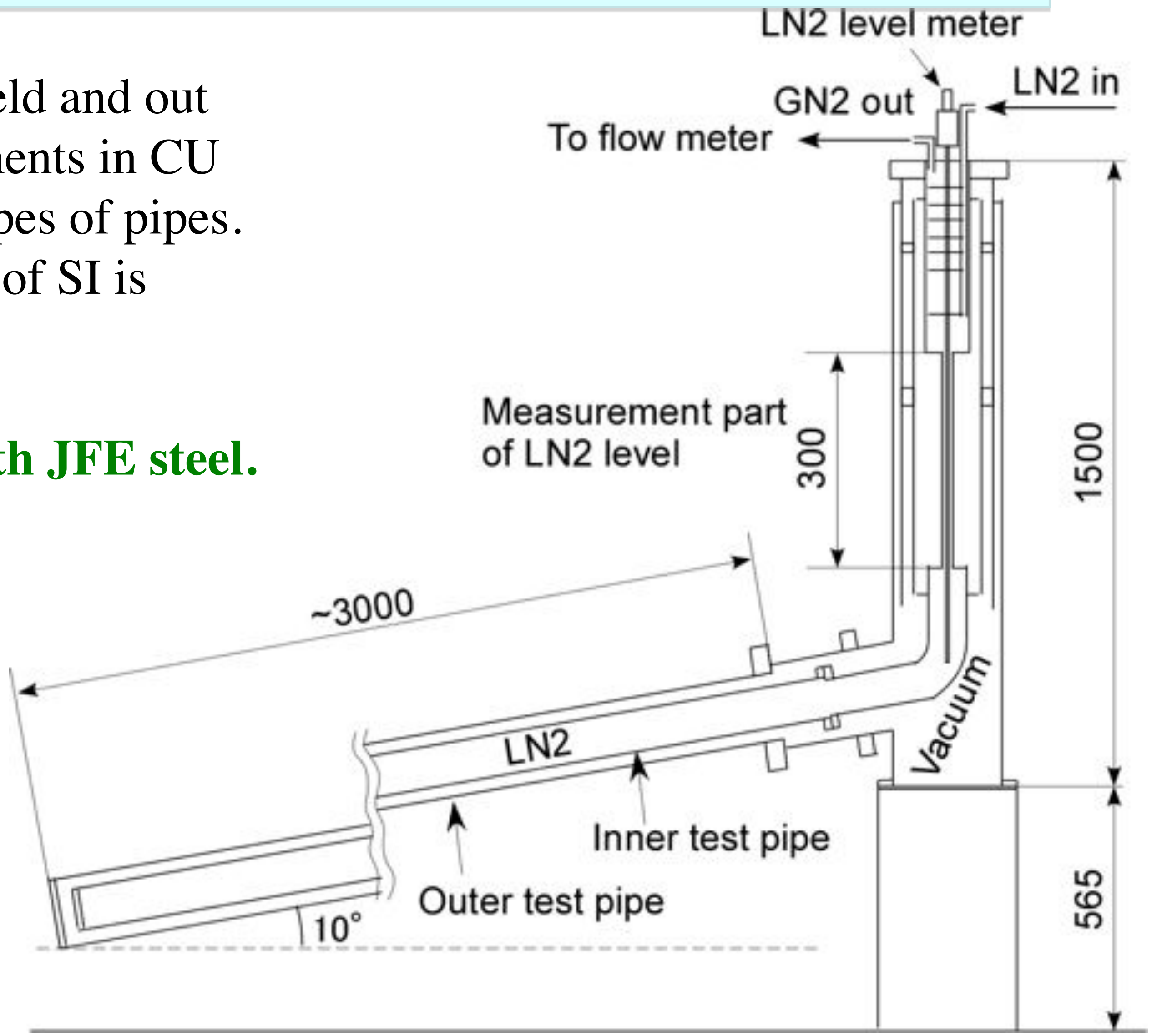
Available in the Present Instruments till 2 km!

New Test Bench for Heat Leakage

New test bench for accurate measurement
Main loss is heat leak of cryo-pipe for long transmission

1) Radiation shield and out gas measurements in CU for various types of pipes.
2) Improvement of SI is needed.

Collaboration with JFE steel.



Perspectives for R&D

20m cable
single core,
30kV, 2kA
@2006

→

200m cable
co-axial cable,
±10kV, 2kA
@2010

: in Chubu University, Japan

High Power Transmission

GW class
200kV, 10kA, single core

Long Cable (>10 km)
~ 2km for next experiment

Target @IASS workshop

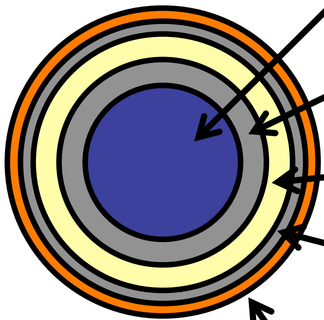
Medium to Low Power Transmission

2MW – 100MW class
1kV – 5kV, 2kA
Thin cable for
actual application

actual cable length ~ 2km

Cable Design of DC200kV/±10kA/4GW

- Structure of cable: Single-core, coaxial, and mono-pole cable.
  SC tape is for main line and Cu tape is for return line
- DI-BSCCO (Ic=200A) is employed as superconducting tape .
- Electric insulation is based on the results of previous DC insulation test, not confirmed.



Parameter	CASE 1	CASE 2
Former	ϕ14mm	ϕ35mm
SC layer (Forward line)	6 Layers / 70 SC tapes Ic=12500A	3 Layers / 64 SC tapes Ic=12500A
Insulator	PPLP：t=17mm	PPLP：t=13mm
Copper layer (Return line)	Copper tape	Copper tape
Protecting layer	ϕ60mm	ϕ70mm

Collaboration with Sumitomo

Price of Bi-2223 tape ~ 10 Yen/A･meter in 2011.

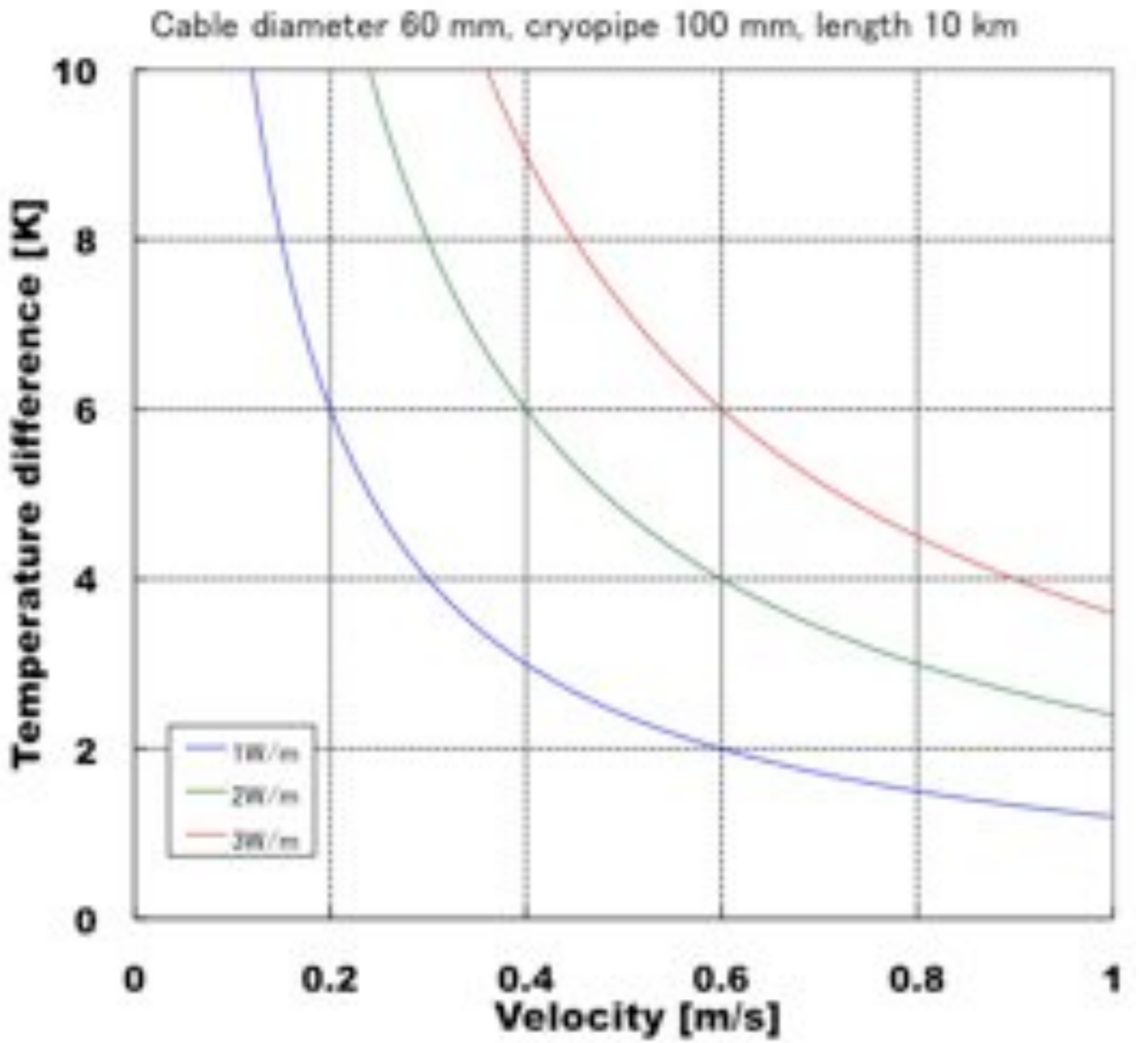
Test of SC-DC cable (proposal)

IASS Workshop
@2011/05/13, Potsdam

	Parameter	Target	Content and outline	Description	
Typical test	Bent test	30m Cable + accessaries	Tested at the bent radius by IEC standard	Ic degradation is not observed.	CIGRE
	Load cycle test		8 hours operation, 16 hours non-operation by 20 cycles First 10 cycles: 1.8U0/Last 10cycles: -1.8U0	Positive voltage is sufficient for monopole cable.	CIGRE
	Polarity switching test		+-1.4U0, reversed at every 4 hours for 10 days	Not necessary for monopole cable	CIGRE
	Impulse withstand voltage test		-U0+ positive switching surge, 10 times +U0+ negative switching surge, 10 times		CIGRE
			-U0+ positive lightning impulse, 10 times +U0+ negative lightning impulse, 10 times		
	Ic test		Similar to specified value		SC
	Heatleak of cryopipe		Similar to specified value		SC
Pre-shipment test	High voltage test	Total length	1.8U0, 15 minutes	Total length test is hard for SC cable and sample test is advisasble.	CIGRE
	Conductor resistance	Sample	Similar to specified value	Ic test sbstitutes in SC cable	CIGRE
	Cable capacitance	Sample	Similar to specified value		CIGRE
	Ic test	Sample	Similar to specified value		SC
	Bent test	Sample	Tested at the bent radius by IEC standard.	Ic degradation is not observed	SC
Completion test	Voltage immpression	Total length	1.4U0, 15 minutes		CIGRE
	Ic test	Total length	Similar to specified value		SC
	Heatleak of cryopipe	Total length	Similar to specified value		SC

U0: rated voltage

Cooling for High Power and Long Cable



LN2 circulation for DC200kV/10kA cable

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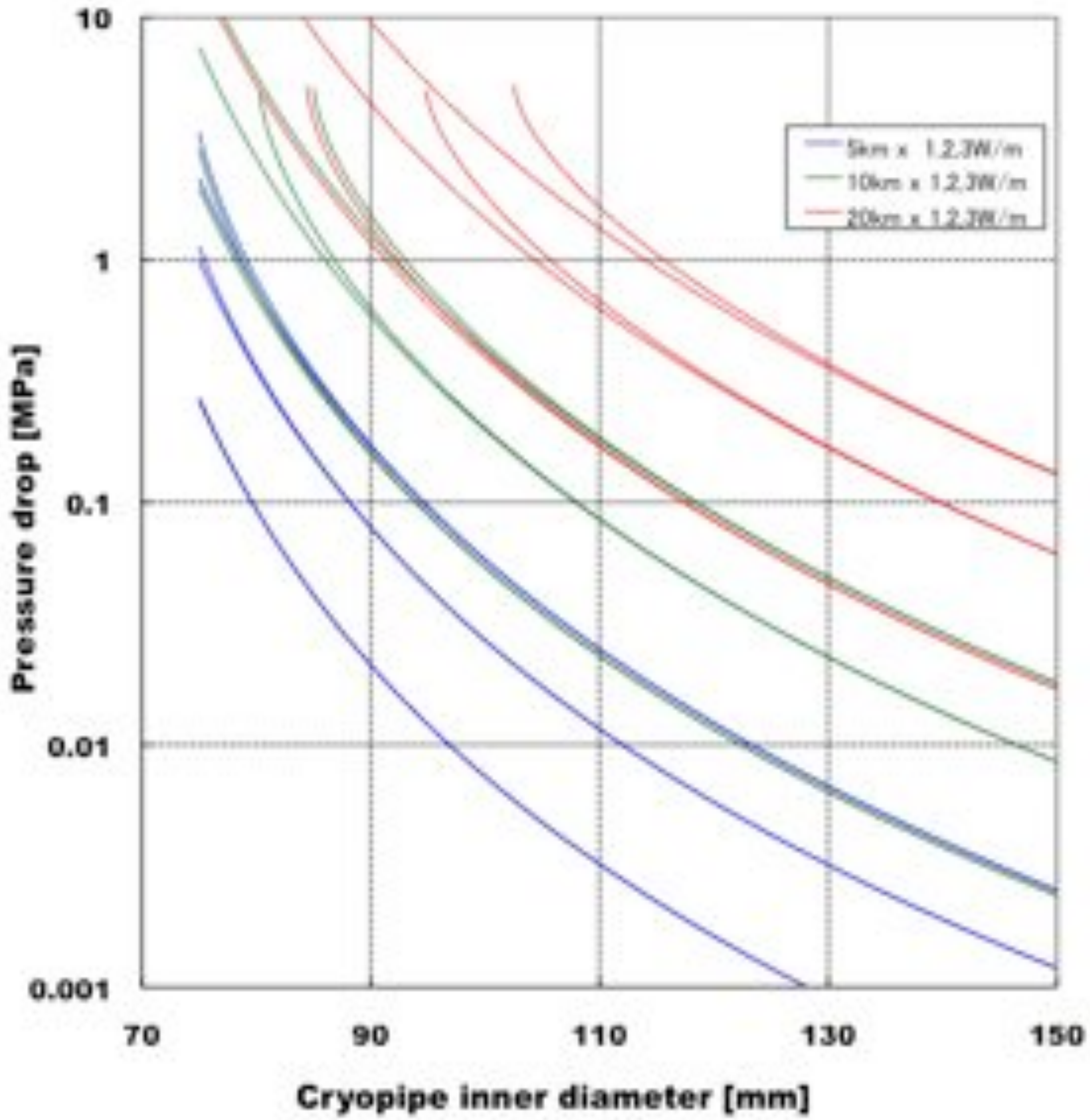
Inner pipe diameter
~ 150ϕ for 20 km
~ 110ϕ for 10 km

↓

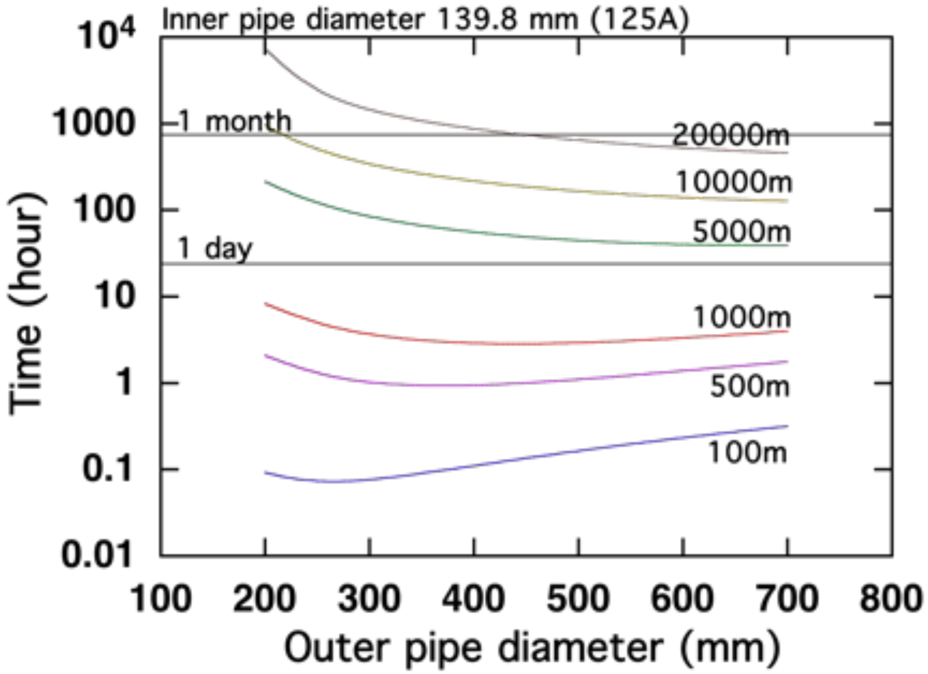
ΔP ~ 0.1 MPa

Cable diameter = 60 mmϕ



Vacuum pumping for long cryogenic pipe

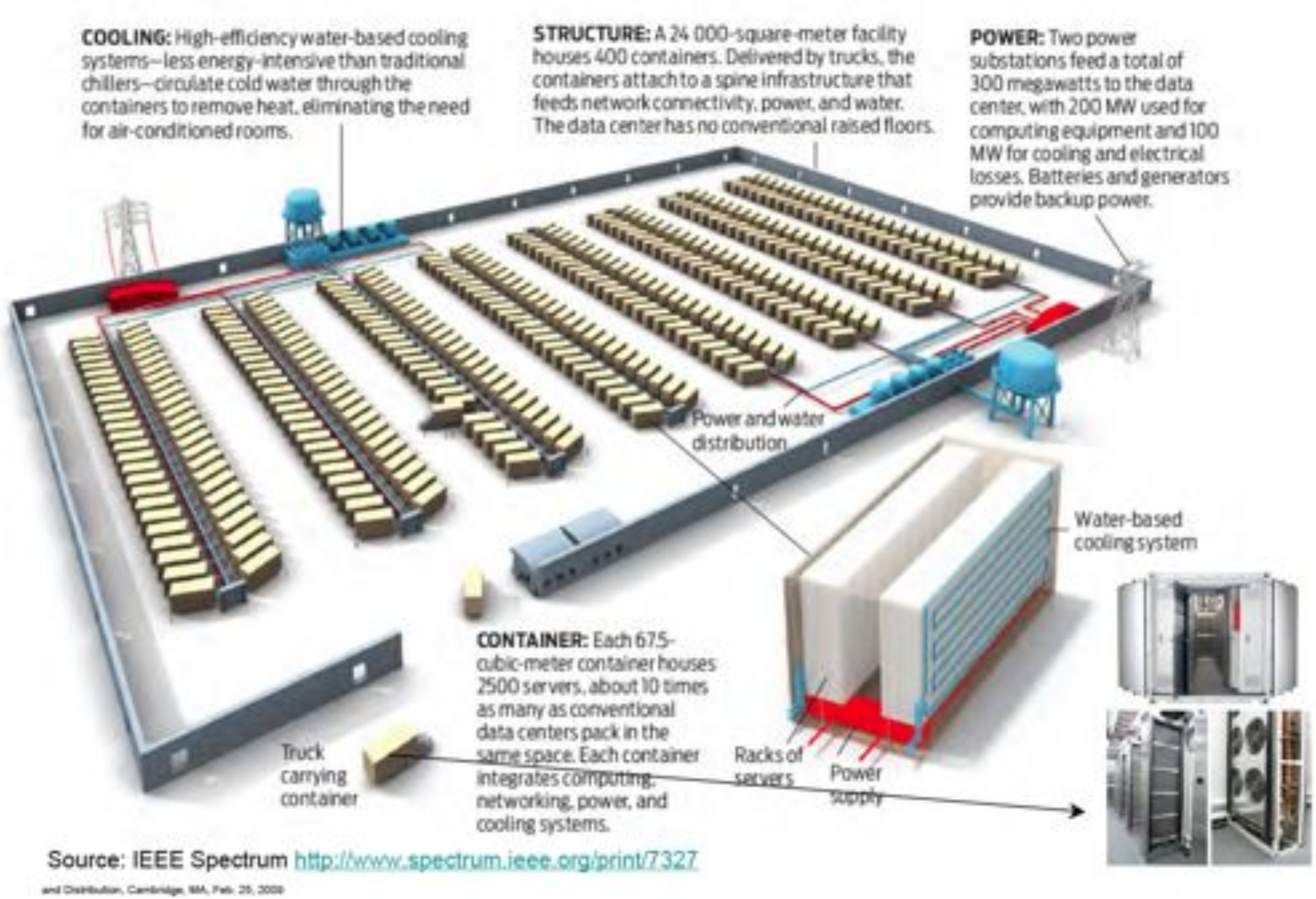
Evacuation time obtained by simulations
for outer pipes with different diameters and lengths



A cryogenic pipe is evacuated at the middle with a TMP of 100 l/s from 1 Pa. The out-gassing rate of $2x10^{-5}t^{-0.28}$Pa・l/(s・m^2) is supposed. This improved out-gassing rate was obtained during the 3rd cooling down experiment.

Diameter ~ 600ϕ for vacuum pumping.

Application for Data Center



We must learn how to manage the DC SC transmission from Short Distance

Comparison with CV cable

Loss of CV cable

Electric Power = 40MW
voltage = DC400V
current = 100kA
cable length = 250m

Resistivity = 0.02 μΩm
Current density = 1A/mm^2

↓

Number cable = 308 (325mm^2/cable)

Loss = 6.5 W/m for one cable

Total Loss = 308 x 2 x 250 x 6.5
= 1.0 MW

Loss of SC Cable

COP of Ref. = 0.1 @70K
Terminal heat leak = 25W/kA
Heat Leak of Cryo-pipe = 1W/m
cable length = 250 m

↓

Loss of terminal = 25 x100 x 4 x 10
= 100 kW

Loss of Cryo-pipe = 1 x 250 x 10
= 2.5 kW
Others = 20 kW

Total Loss =100 + 2.5 + 20 = 122.5 kW

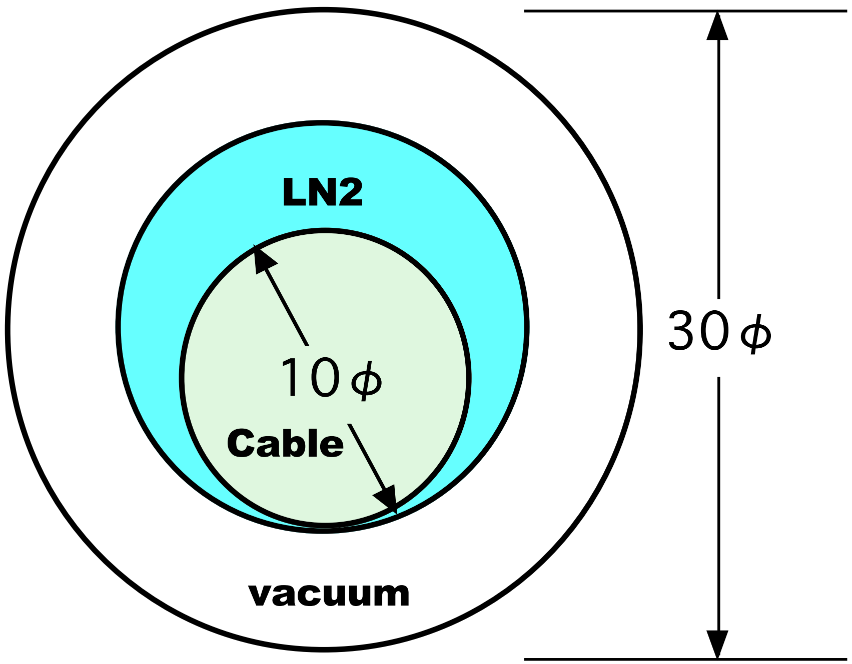
Low heat leak Terminal

Type of Terminal	Heat Leak	comments
copper lead	~50W/kA	Common use in the present time
Peltier current lead (PCL)	~25W/kA	R&D phase for commercial use
Gas-cooled PCL	12 ~18W/kA	Start the experiment in CU
New current lead	5 ~ 10W/kA	Theoretical estimation based on the performance of the present commercial instruments

If heat leak of 5 - 10 W/kA is achieved in the terminal, we can find wide applications because several companies started to develop high COP refrigerator (COP ~ 0.1 @70K).

Low voltage DC_SC Cable

Design Study for iDC, Electric Train, Steel Mill



DC bi-pole cable :

400V ~ 1.5kV ~ 4kV

1.0kA ~ 2.0kA

> 1MW

Cryo-pipe

outer ~ 30ϕ – 50ϕ

short distance

↓

Cheaper than copper wire?

But lower losses.

LN2 or LNG transfer tube is available!

(heat leak < 0.5W/m)

Transfer tube cost is higher than cable's!

Subject for discussion – 1 (cost)

200-meter cable experiment for 2.5 years construction & operation

Total budget ~ 5MUS$(included labor cost of researchers)

cable cost ~ 20% (included R&D in Sumitomo)
HTS cost ~ 6% (200US$/kAm)
Researcher ~ 20% (5 persons)
overhead ~ 5% for University

↓

If we use HTS @6K, HTS cost is less than 10US$/kAm.
Is it cheap or not for NbTi wire?

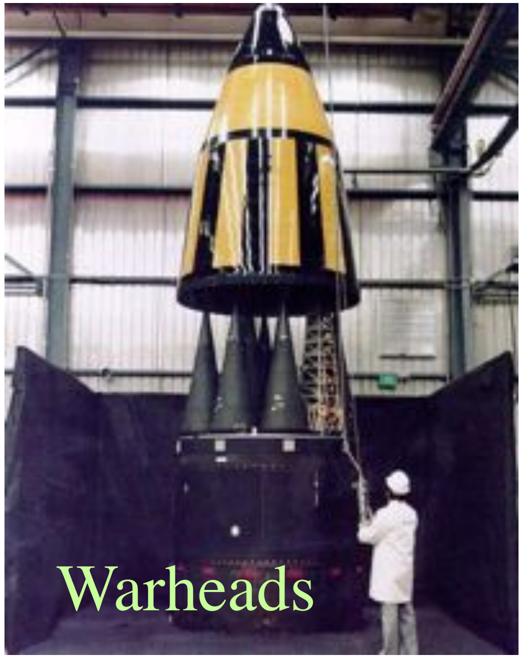
NEDO target ~ 30US$/kAm @70K in Japan,
therefore 3US$/kAm @6K?

Subject for discussion – 2 (application)

	HTS	NbTi
LN2 (T~ 70K)	**10 MW** – **10GW** applications	no use
LHe (T~ 5K)	**new subjects** for CERN because of LHC++ or ITER?	~ GW applications available

ICBM is Peace Keeper in Cold War

Deterrent Theory:
Intercontinental Ballistic Missile could keep Peace in cold war.



Specifications and Performance

Weight	88,450 kg
Length	21.6 m
Diameter	2.34 m
Range	Over 11,000 km
Speed	24,000 km/hr; 6.7 km/sec
Ceiling	805 km
Throw Weight	3950 kg; PBV weight 1365 kg; Net warhead load 2585 kg
Accuracy (CEP)	100 m

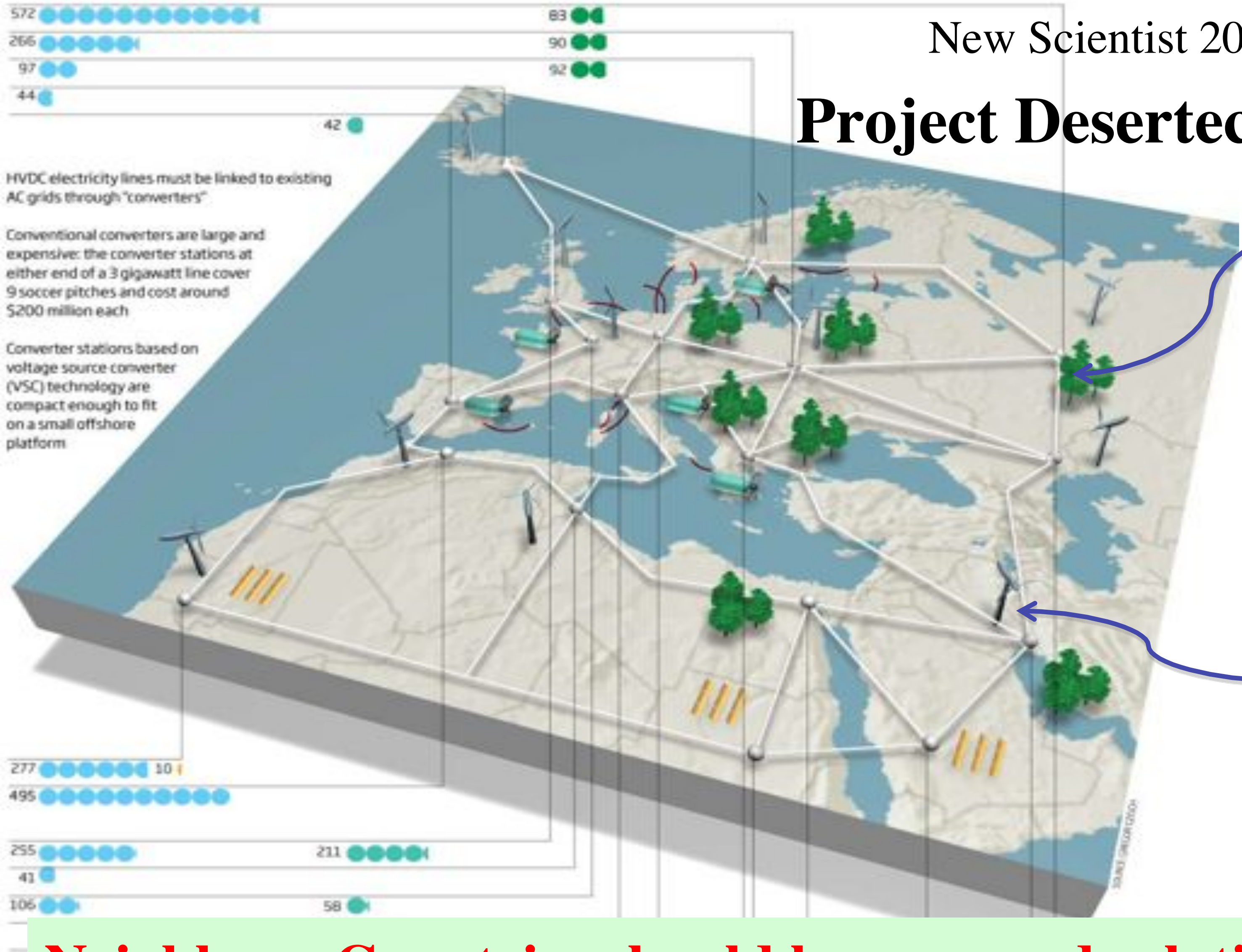
Propulsion

First Stage	2,200,000 KN thrust Thiokol solid fuel motor; Weight 49,000 kg
Second Stage	Aero-jet General solid fuel motor; Weight 27,000 kg
Third Stage	Hercules solid fuel motor; Weight 7,700 kg
Post-Boost Stage	Rocket-dyne re-startable liquid fuel motor; storable hypergolic fuel

A New Peace Keeper, DC_SC Transmission

IASS Workshop
@2011/05/13, Potsdam

New Scientist 2009/March



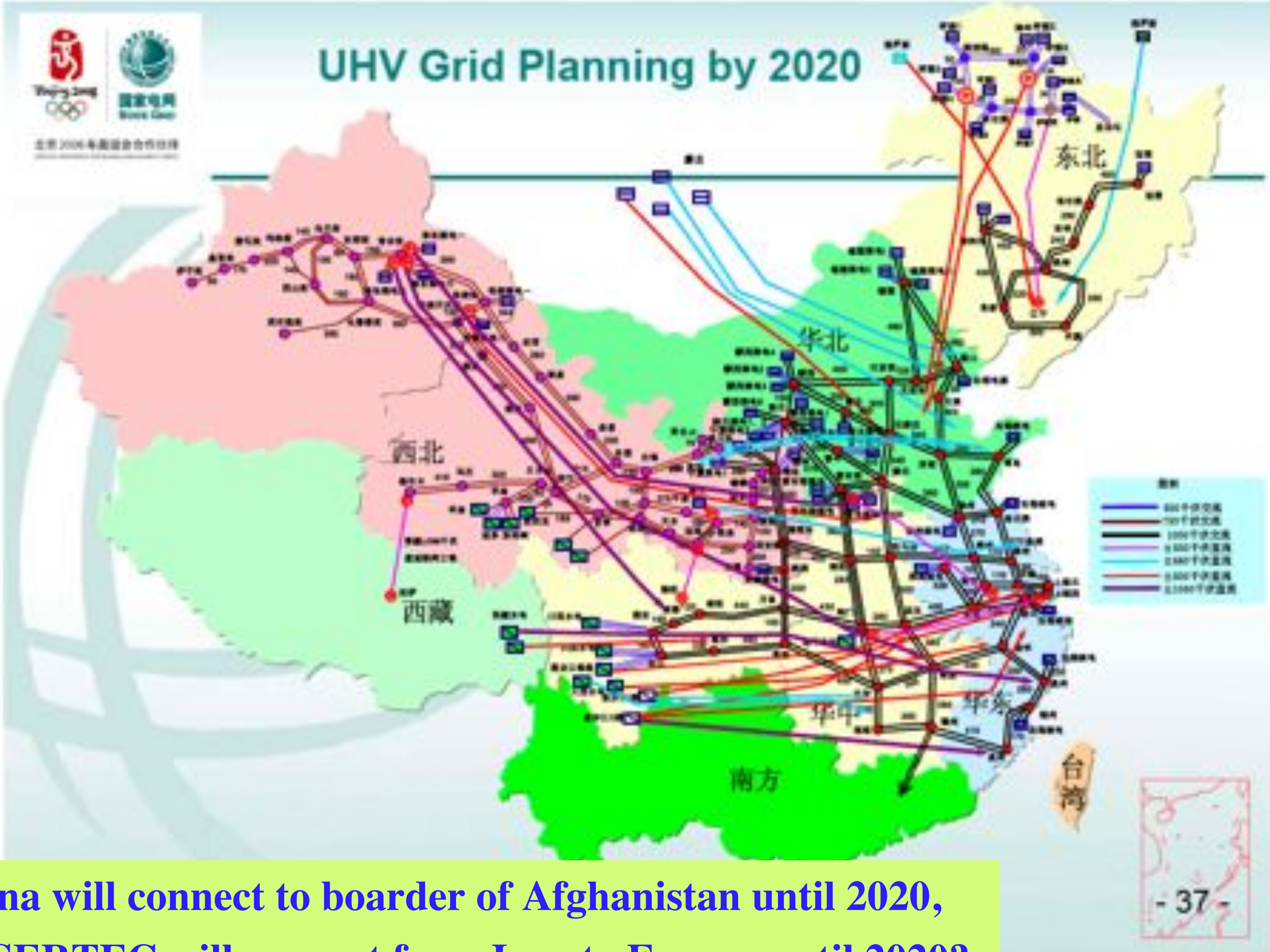
Project Desertec

Alaska
Canada
US

China,
Korea
Japan

Neighbour Countries should keep a good relation to get Energy inspite of they do not like each other.

UHVDC in China



China will connect to boarder of Afghanistan until 2020,
DESERTEC will connect from Iran to Europe until 2020?

A New Peace Keeper, DC_SC Transmission

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Now we have ~500 Nuclear Stations in the World,
we will make ~2000 Nuclear Stations in 21st Century

Europe (mid night) ⟶ Japan (day time)
Europe (day time) ⟵ Japan (mid night)

We can save Nuclear Reactors
& Lifetime > 10 centuries?

And connect Energy from Desert.
Can we get the budget from defense because of keeping peace?