Executive Committee Meeting of
the IEA Technology Collaborative Programme on Superconductivity
Open session, Area activity in Japan

July, 4th in 2017

Safety and Reliability verification tests for Superconducting Cable

Sumitomo Electric Industries, Ltd.
TAKATO MASUDA

Outline of NEDO's Project

Project : Safety and reliability verification tests of HTS cable

Purpose:

- To verify the **safety and reliability of HTS cables at accidents** by conducting model tests with actual dimension cable for 22 kV, 66kV and 275 kV class.
- To develop **5 kW class Brayton refrigerator system** with higher performance and to confirm its stable operation in the grid at Asahi SS.

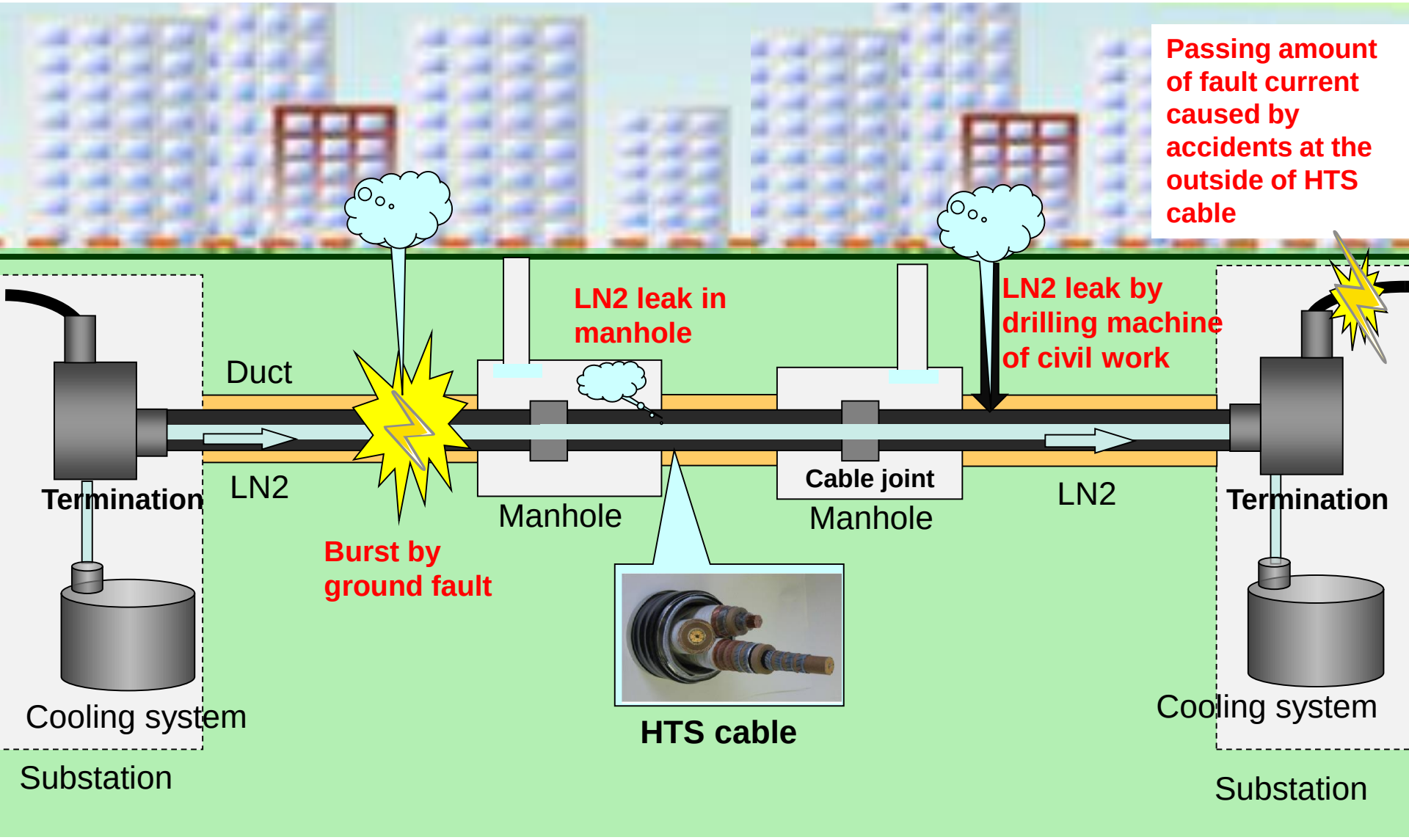
Period : **From July 2016 to March 2019**

Members :

NEDO (Project management), TEPCO (Utility , Project leader)
Sumitomo Electric, Furukawa Electric (Cable manufacturer)
Mayekawa Co. (Refrigerator manufacturer)

NEDO SUMITOMO ELECTRIC TEPCO FURUKAWA ELECTRIC GROUP MAYEKAWA

Image of the HTS cable system and its accident



Project schedule

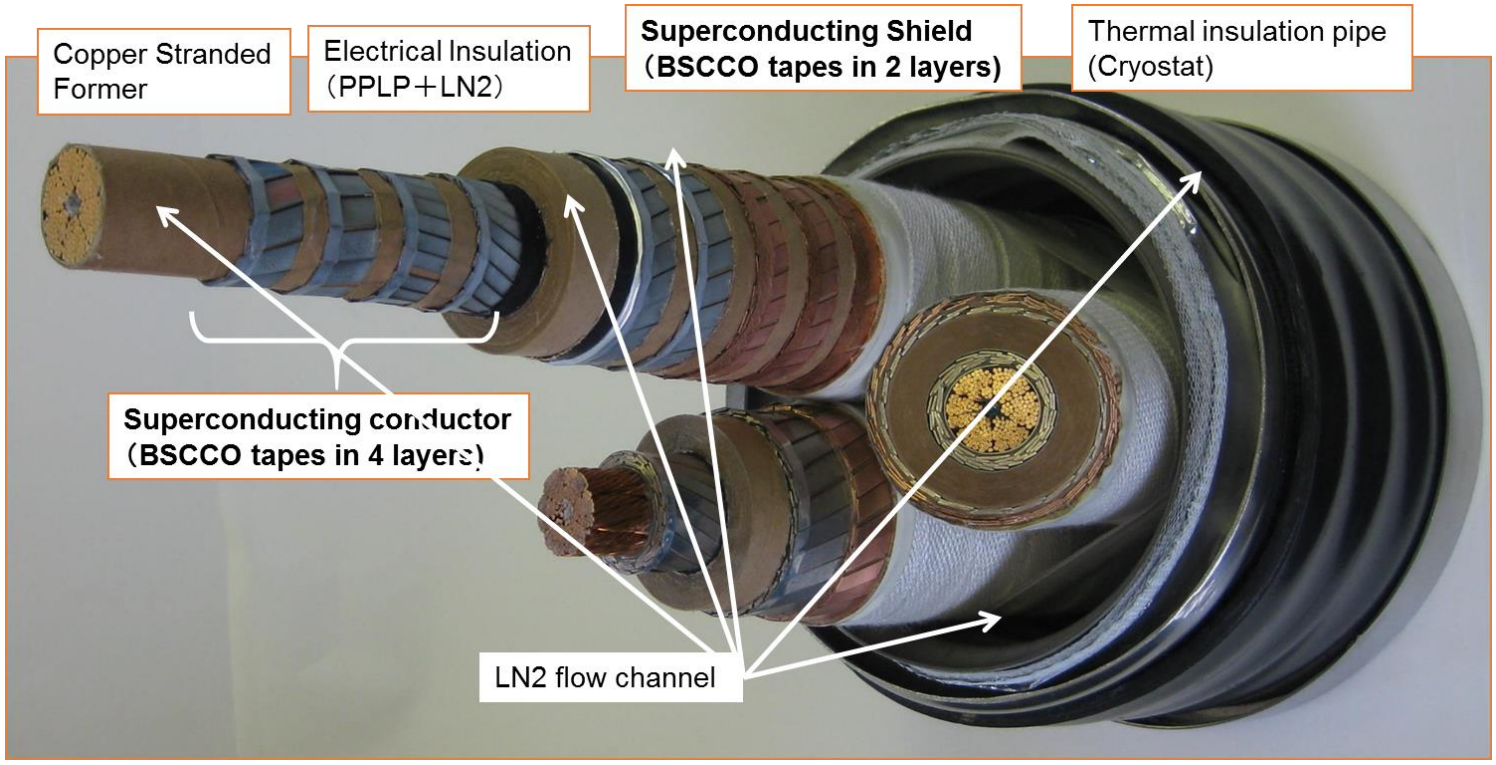
Items		FY 2016	FY 2017	FY 2018
Safety verification tests	Short circuit tests	66kV testing 275kV testing	Analysis and simulation 22kV testing	**Guideline**
	Ground fault tests	66kV testing with sheets and sample cables 275kV testing with sample cables	Analysis and simulation	
	LN2 blow-out tests		Testing in Manhole	
Improvement of cooling system and cryostat	Development of Bryton cycle refrigerator	Self Testing	In-grid operation	Residual performance test
	Improvement of Cable Cryostat	Improvement with short sample cable		Verification test with longer cable

66kV HTS cable ground fault

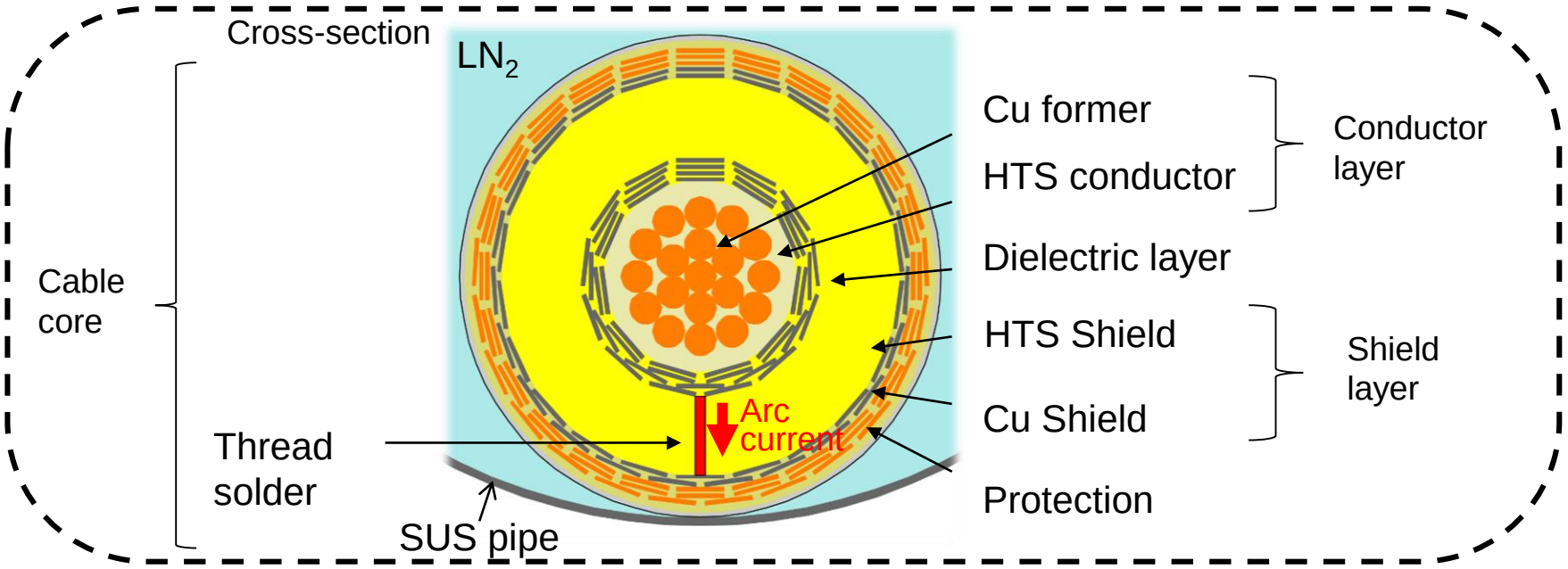
Purpose

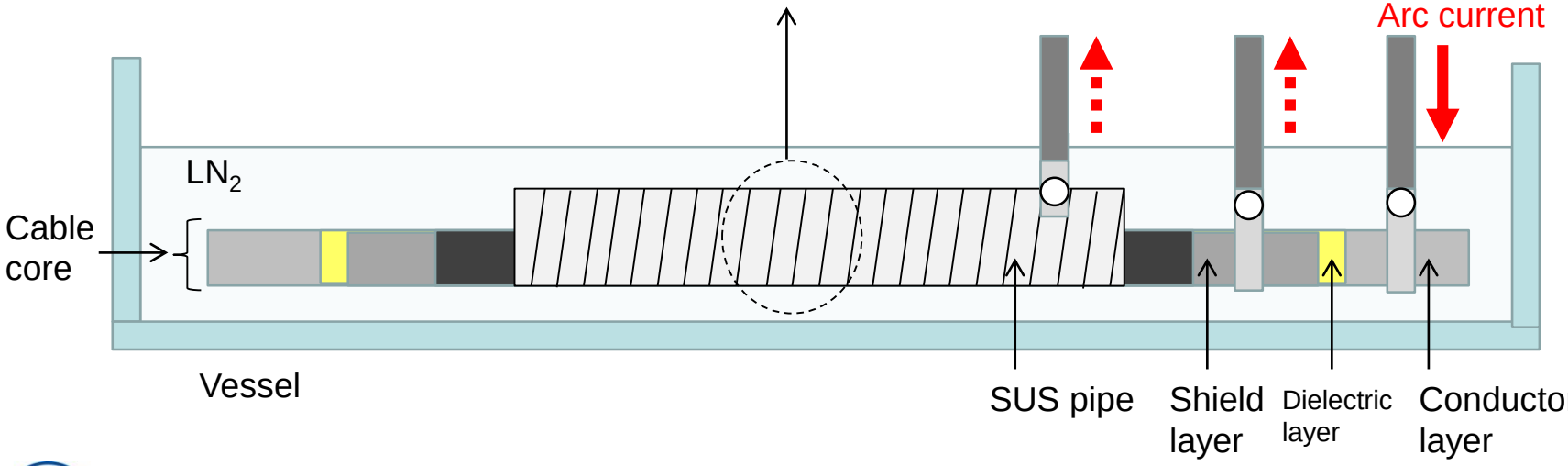
Conducting some model test using 66kV 3 cores cable

- to obtain the arc voltage level
- to confirm the LN2 behavior and check the damage of SC cable



Schematic view of the test apparatus





Result of the test

■ **Test condition : 1.5kA for 2sec (Worst condition of 66kV grid)**

■ **Test result**

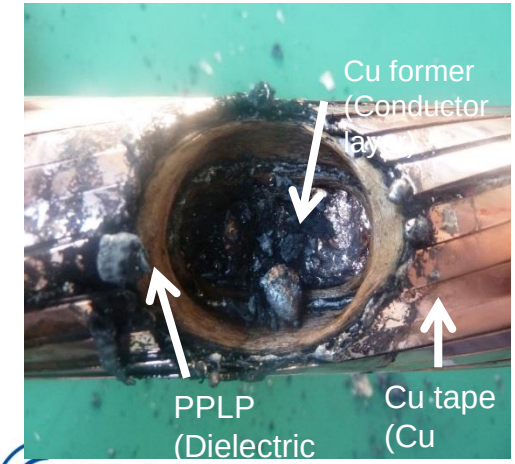
- Measured arc voltage and E field are 200 V and 300 V/m, respectively, which are almost the same as conventional cable.

- PPLP and shield layer were molten and penetrated. Cryostat was also molten.

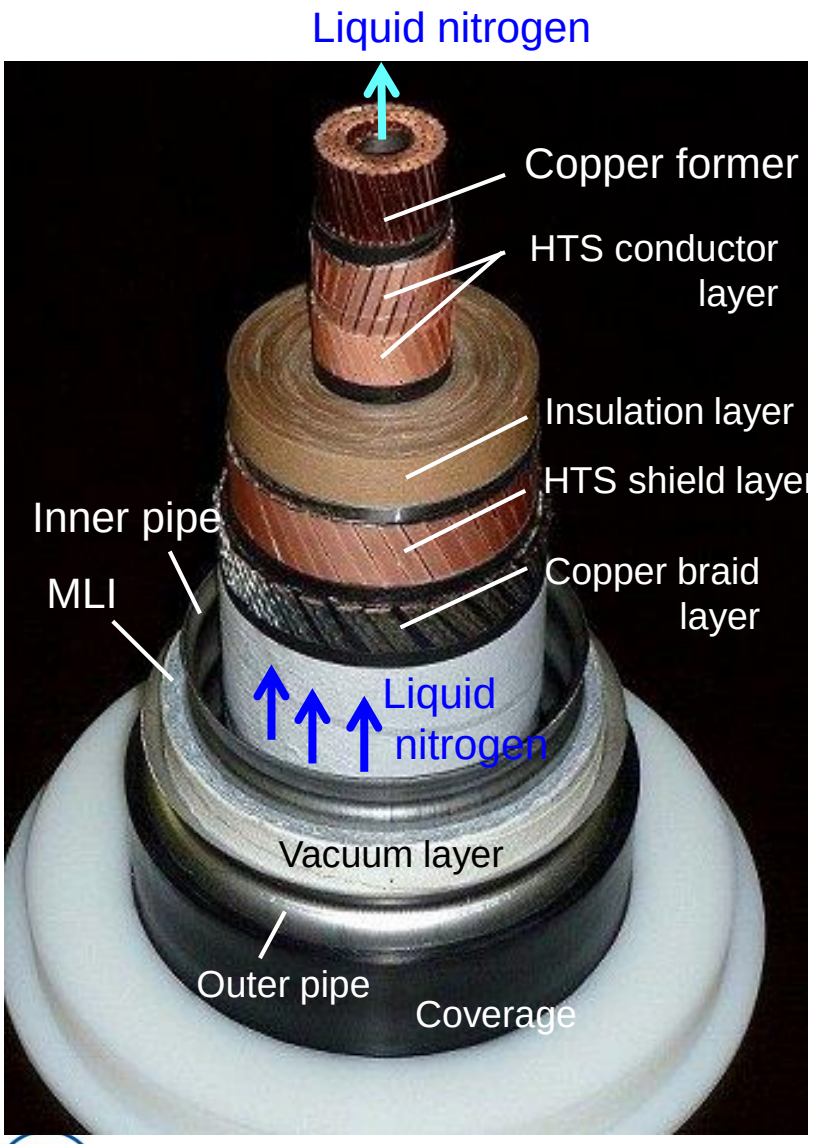
■ **Next step**

New Protection layer are now under research.

LN2 blow-out test is now being planned.



275kV HTS cable ground fault



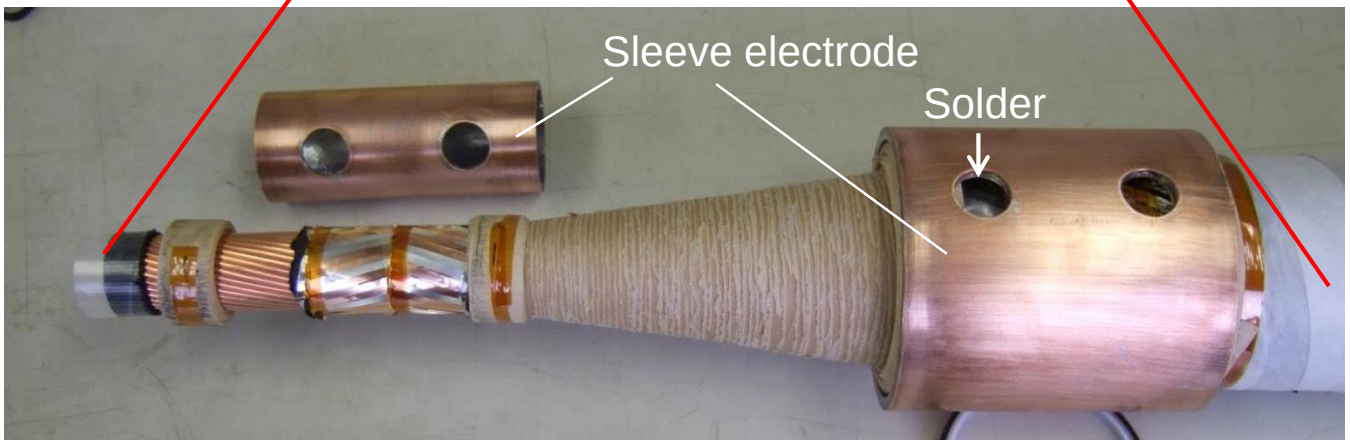
Structure	Specification	Diameter (mm)
Former	400 mm^2 hollow stranded copper	35.4
HTS conductor	2-layer YBCO	
Insulation	PP laminated paper	81.0
HTS Shield	1-layer YBCO	
Cu Protective	210 mm^2 copper tape	88.0
Protection	Insulation paper	
Cryostat pipe	SUS and PVC sheath	150

Cable-core for the sample

Cut cable-core for the standing sample (in process)

~ 1m-length

w/ an iron pin in a drilled hole



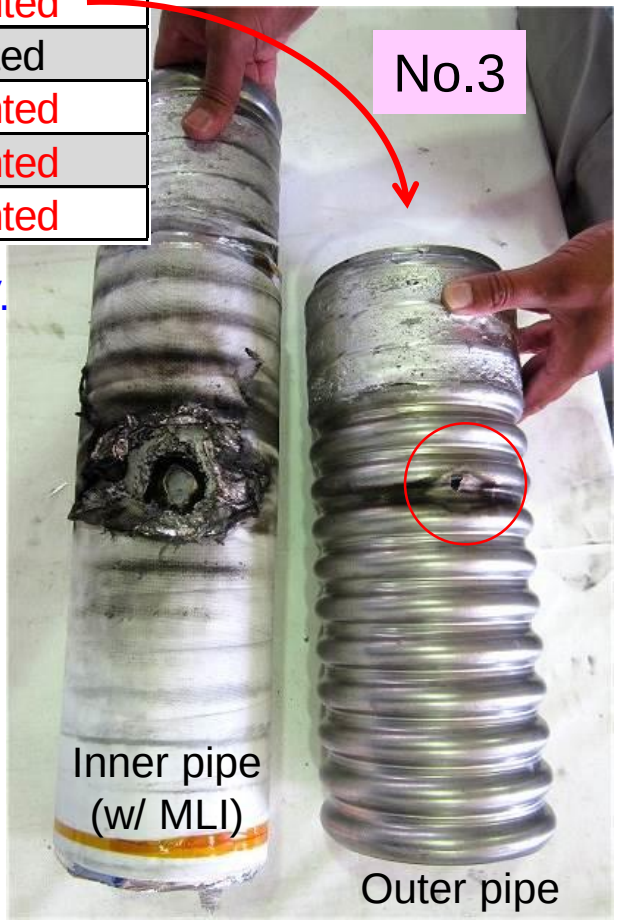
Upward to stand

→ Into the cryostat pipe

Damage of the cryostat pipe

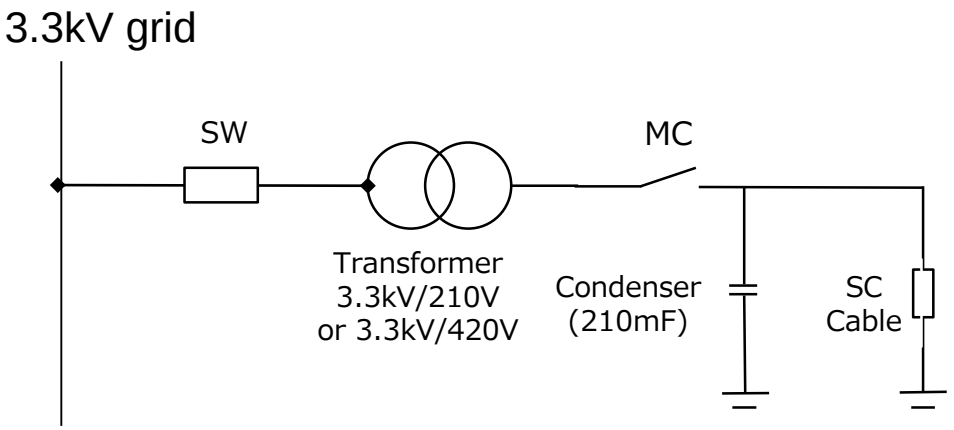
Sample	Current [kA]	Arc reach [cycle]	Arc reach Outer p.	Energy [MJ]	Damage of cryostat pipe
No.1	1.5	0.5		0.006	No damage
No.2	3	0.5		0.017	Inner pipe vented
No.3	5	0.5	*v*	0.033	Outer pipe vented
No.4	5	0.5		0.030	Inner pipe vented
No.5	7.5	3	*v*	0.214	Outer pipe vented
No.6	10	3	*v*	0.245	Outer pipe vented
No.7	10	3	*v*	0.325	Outer pipe vented

The arc did not revived with the voltage of 12 kV.

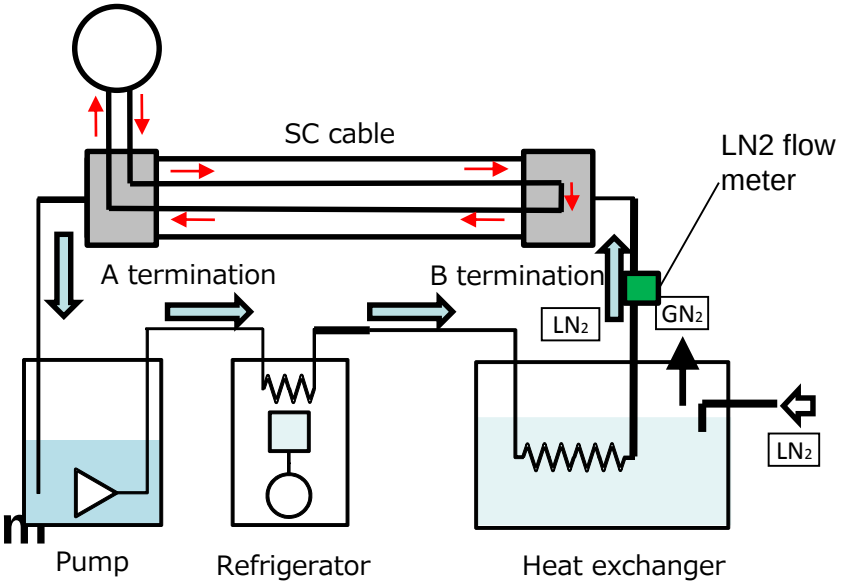


66kV Short circuit current tests

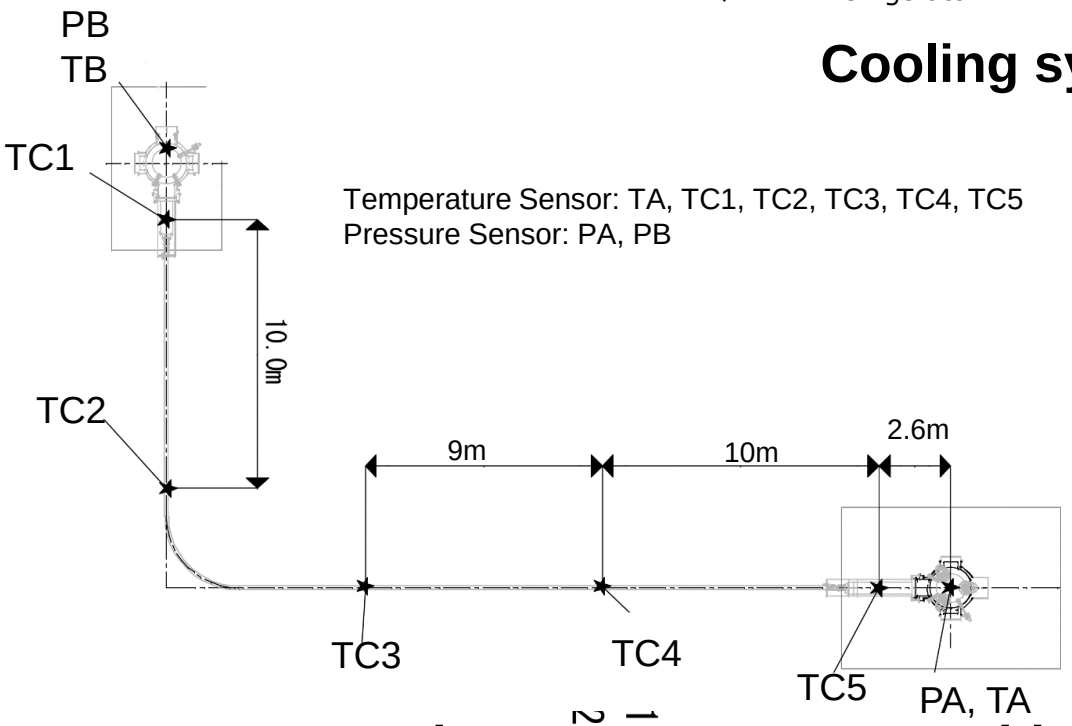
- In the 66 kV network in Japan, a fault current is assumed as maximum 31.5 kA for 2 sec, which is 15 times larger than nominal current 2 kA of the Yokohama HTS cable.
- The behavior of LN2 is not clarified at the short circuit accidents, especially in circulated LN2 cooling system through long length cable.
- Installing a 66 kV – 40 m HTS cable with LN2 circulated cooling system at Sumitomo Factory and conducting some short circuit tests.



Electrical Circuit of the testing system



Cooling system

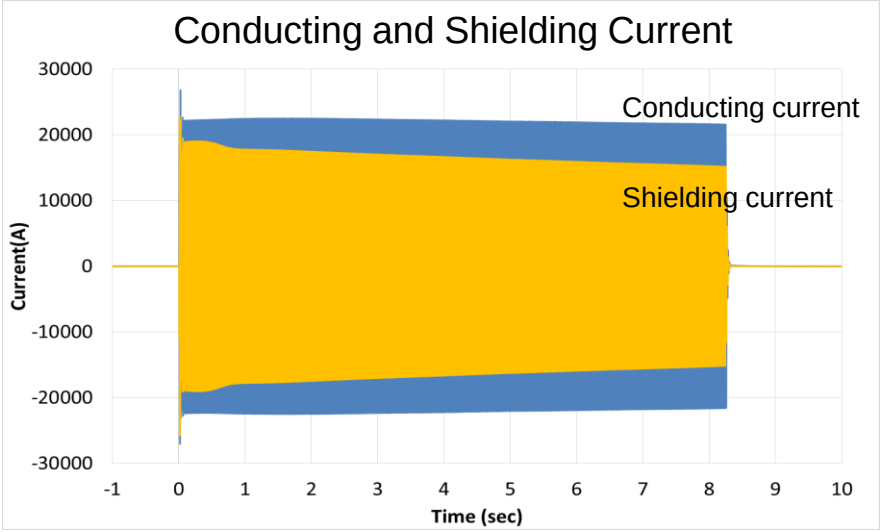


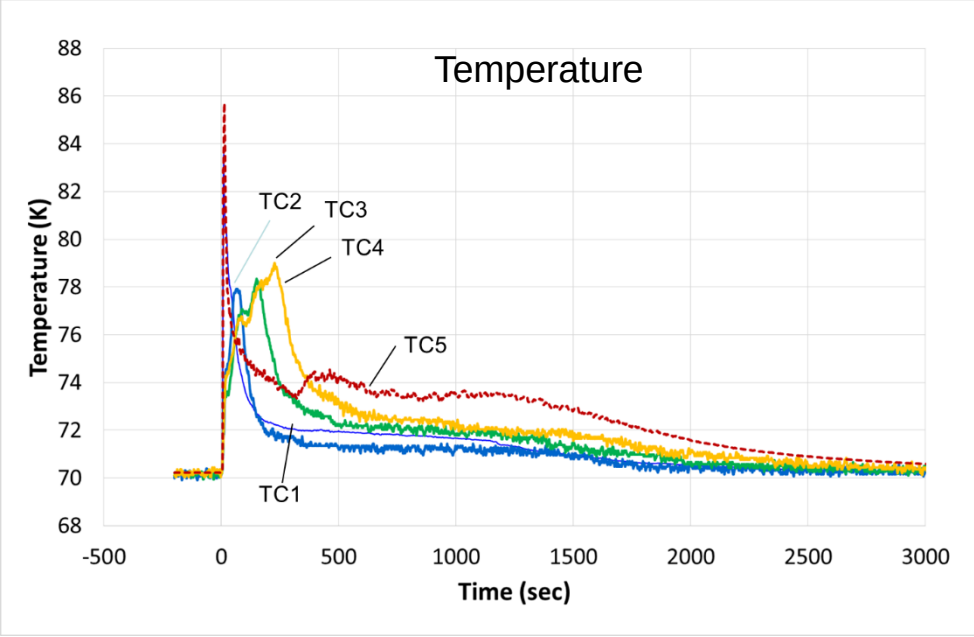
Temperature Sensor: TA, TC1, TC2, TC3, TC4, TC5
Pressure Sensor: PA, PB

Temperature and Pressure Sensor Position

Energy equivalent test @ 16 kA, 8.4 sec

- Due to the limitation of the grid capacity, 16 kA for 8.4 sec were applied to the system, whose energy is equivalent with that at 31.5kA for 2 sec.
- Max △T and △P are 16 K and 225kPa.
- The system can withstand against such large heat generation because of no difference of IC between before and after.
- Waseda University is now researching computer simulation and comparing between measured value and calculated values.
- In parallel, they are trying to make computer simulation with 3 km SC cable.





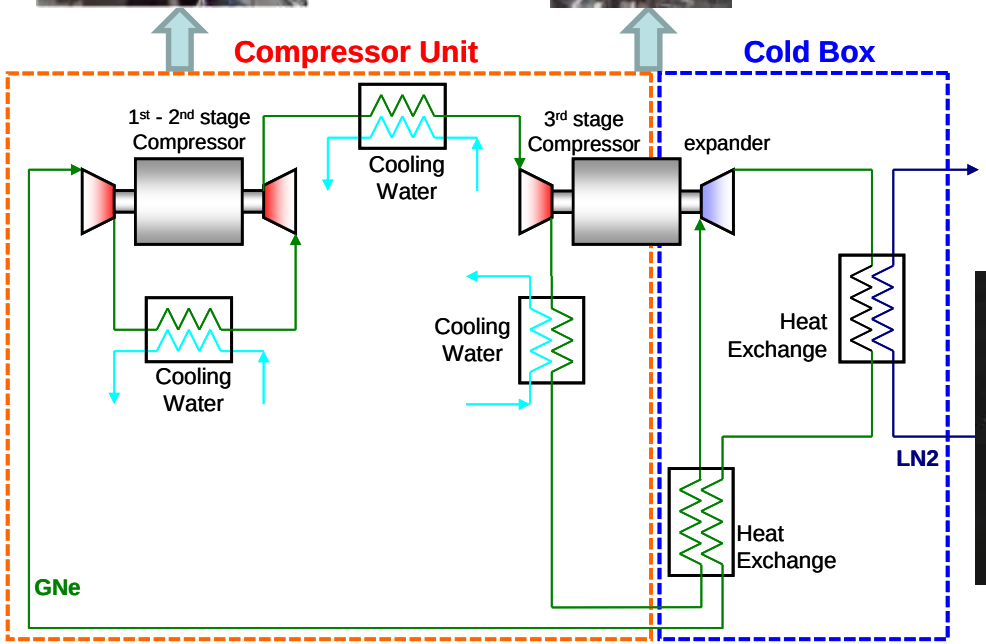
Brayton cooling system

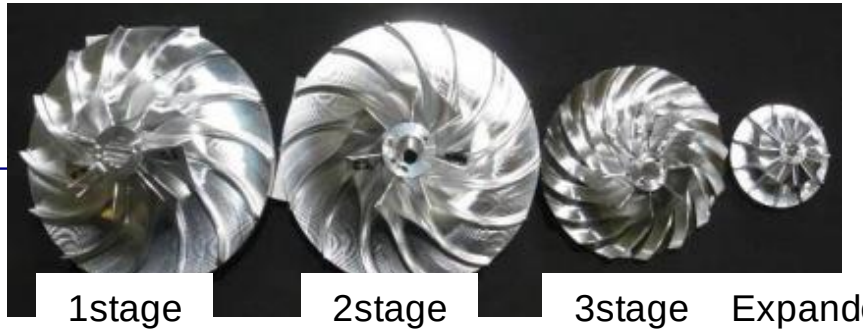
Specifications

Large capacity ・・・ **Cooling Capacity: 5 kW**

high efficiency ・・・ **COP: 0.1**

Long maintenance interval ・・・ **30,000 hours**

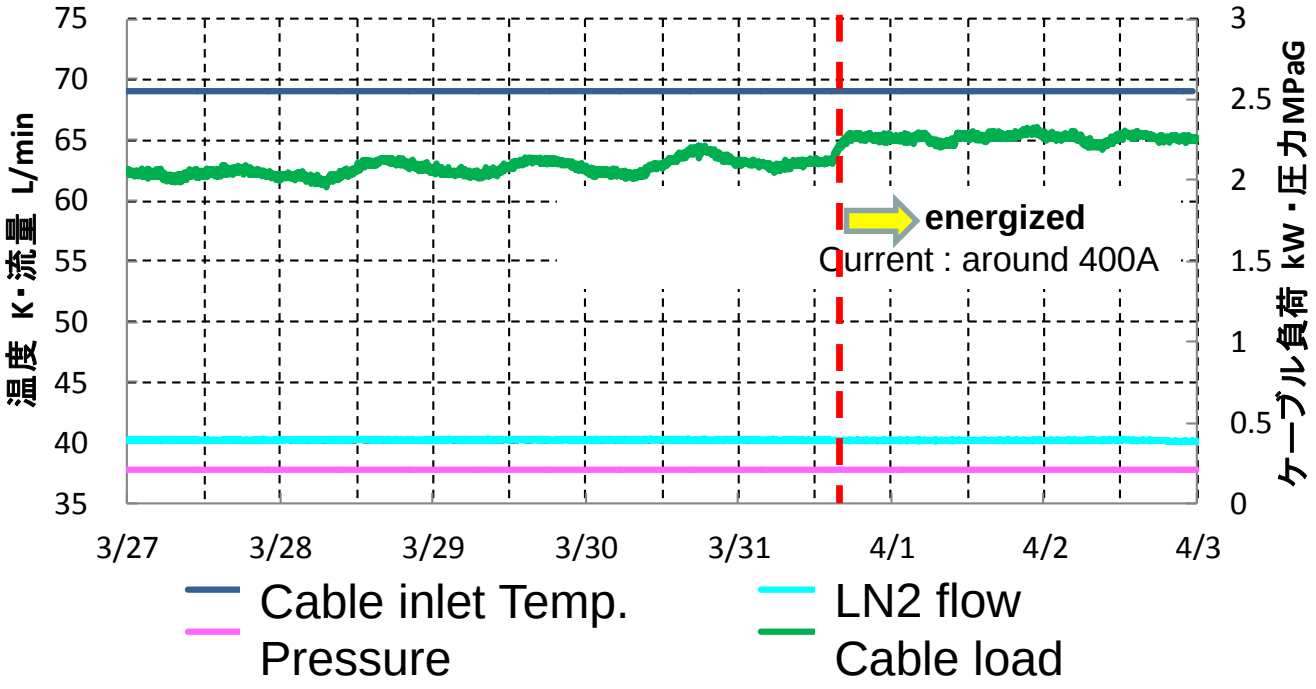




Re-energizing in real grid was started

HTS cable was energized on March 31, 2017. We intend to continue the HTS cable operation for one year.

Now, the status can be shown in SEI Web site.



http://www.sei.co.jp/super/cable/jissho.html