FURUKAWA ELECTRIC

TEPCO FURUKAWA ELECTRIC GROUP

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Protection against the ground fault for 275 kV HTS cable and experiment

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Content of this presentation

1. About experiment

- Ground fault accidents for HTS cables
- Samples of the standing style
- Results of the samples without protection

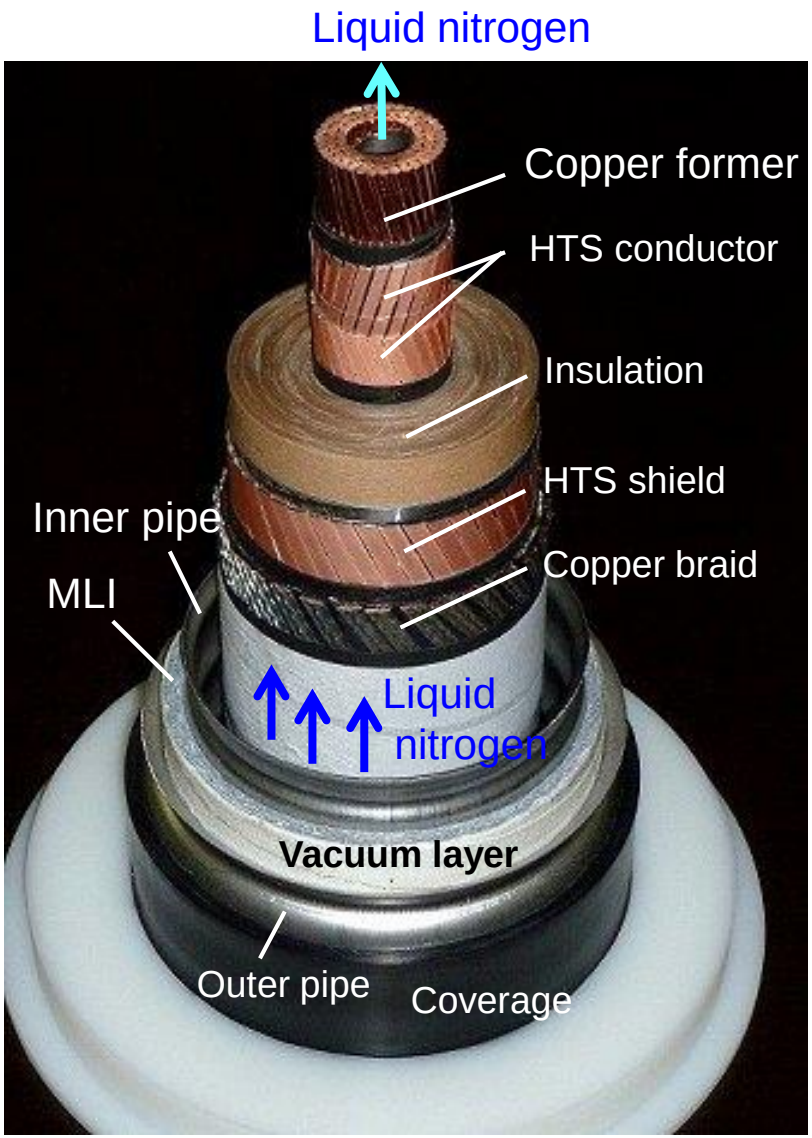
2. Protections against the ground fault

- Behavior of the current and voltage
- Protection for the cable core and cryostat pipe

3. Effects of protections

- Results of the samples with protection

Structure of the cable



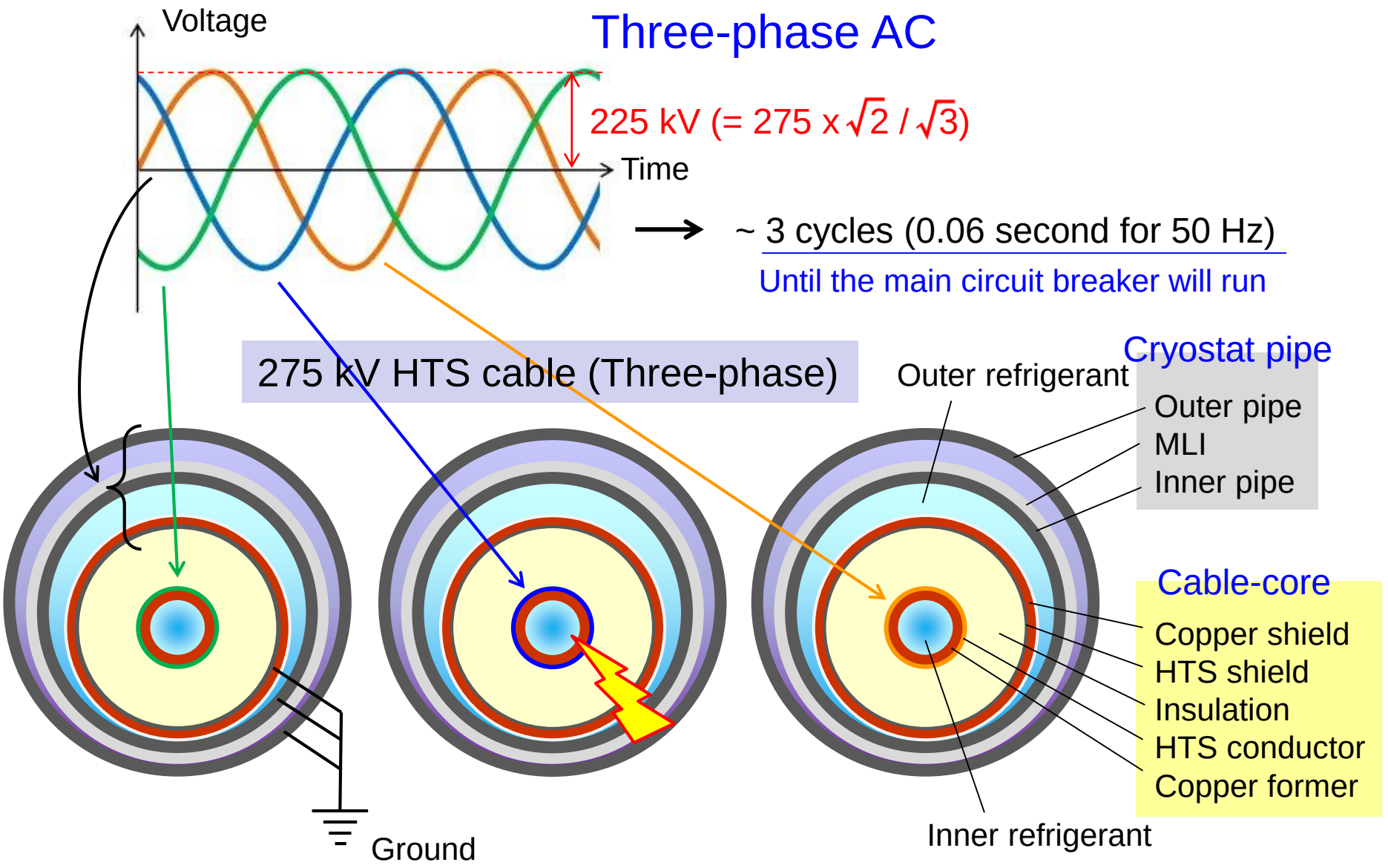
Material & Design

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 Shield	210 mm^2 copper tape	88.0
Protection	Insulation paper	
Cryostat pipe	SUS and PVC sheath	150

To cancel the magnetic field due to the alternating current

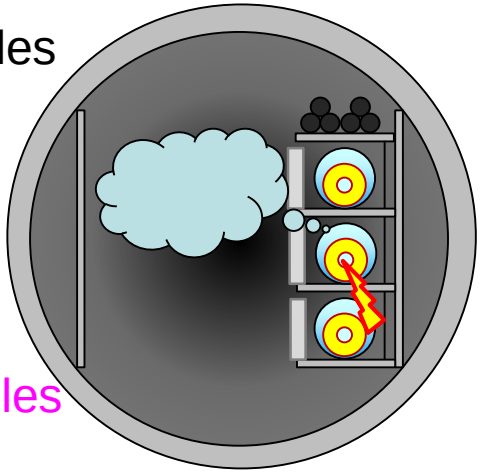
Single core is stored into a cryostat pipe.
=> 3 set are needed for three-phase AC system.

Ground fault accident



Purpose of our research

275 kV HTS cables
in a tunnel



Current (or Energy)
at the ground fault accident

High

Low

~ 63 kA (actual result ~ 50 kA) for 275 kV cables

Outer pipe is vented.

Outer pipe is not vented.

LN_2 leaked

- Damages to the neighbors
- Lack of oxygen

- High pressure of the refrigerant

LN_2 not leaked

Where is this border?

=> Can this be possibly lifted up?

This presentation's theme

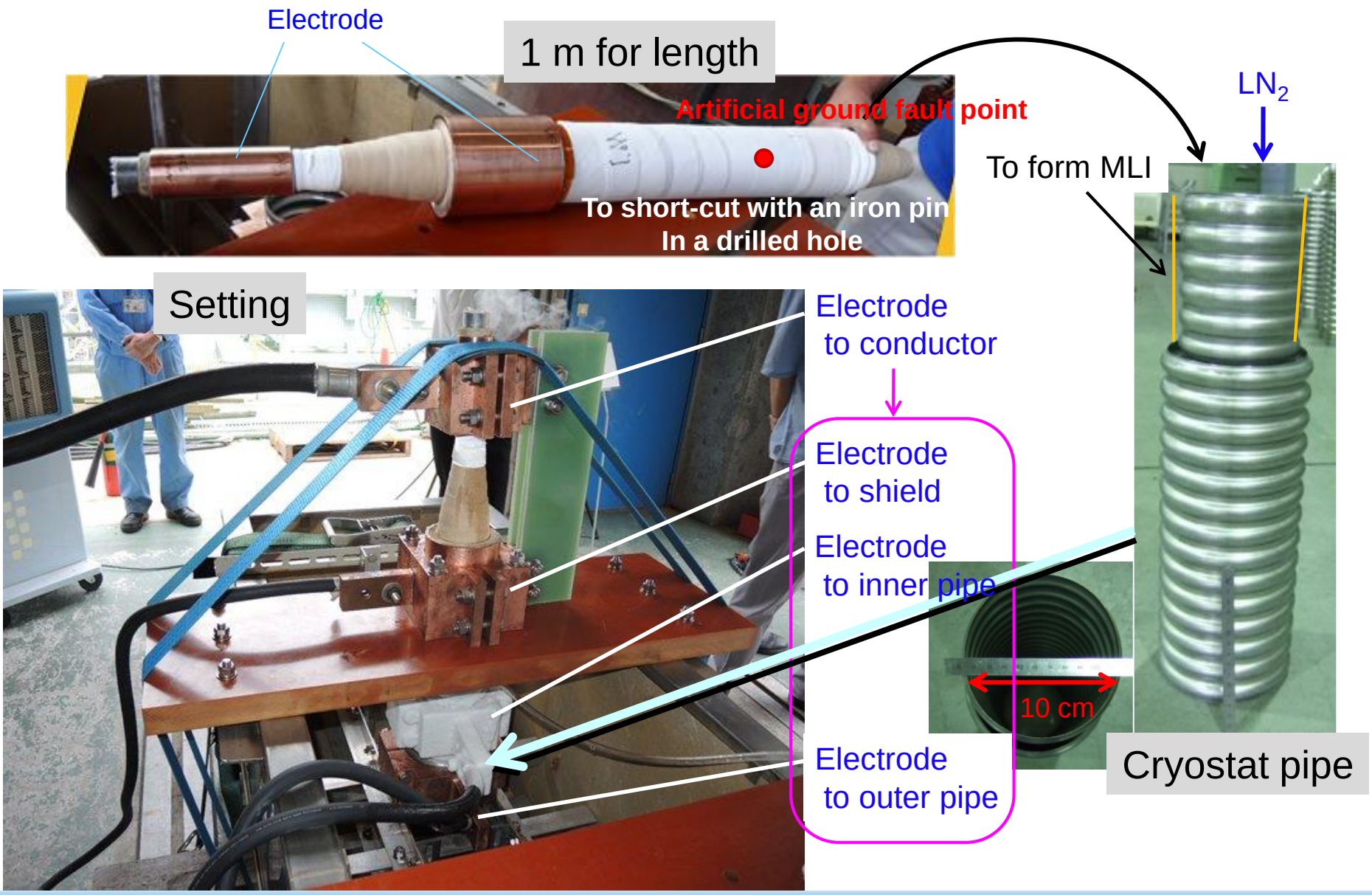
Sample style to examine

We have an HTS cable system to examine.

But it is too expensive to burn out….

=> We adopted the standing style.

Sample of standing style



Circuit & Measure

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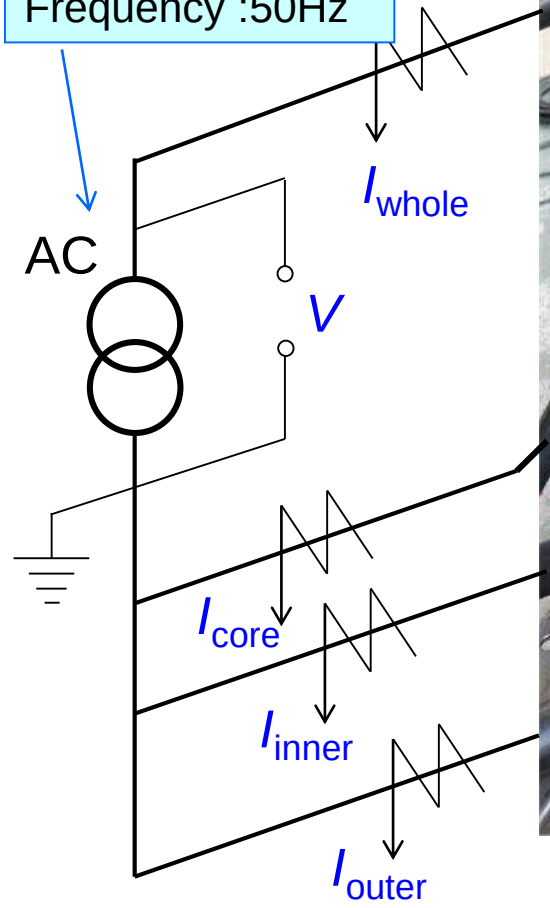
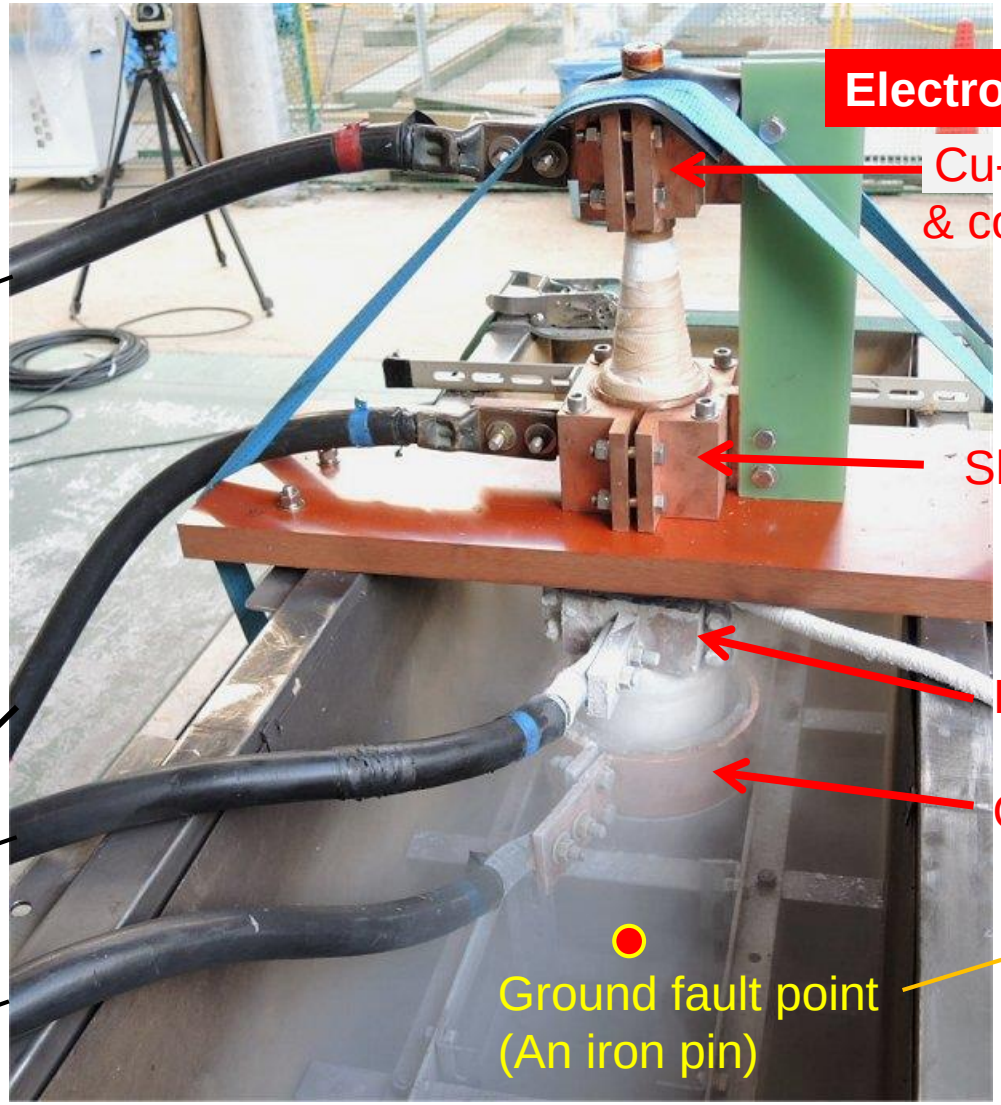
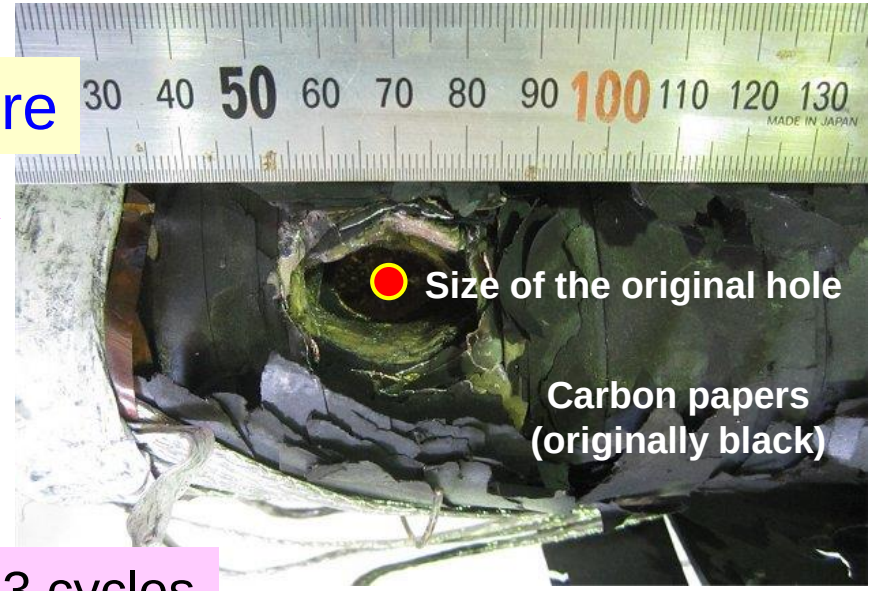
Current :<AC20kA
Voltage :<12kV
Frequency :50Hz





Results (w/o protection)

Core



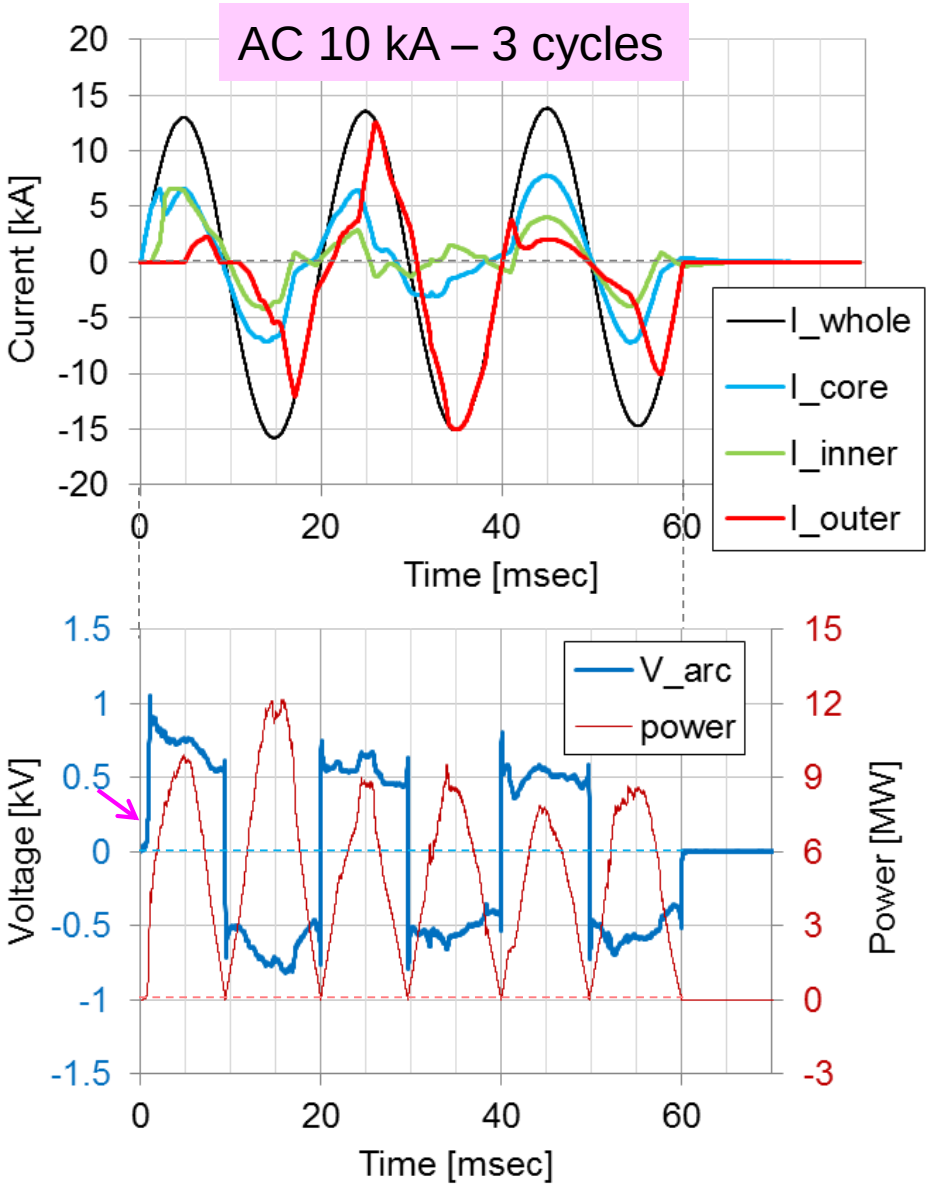
AC 10 kA – 3 cycles

Pipes

Inner pipe
;w/o MLI

Outer pipe

Current & Voltage



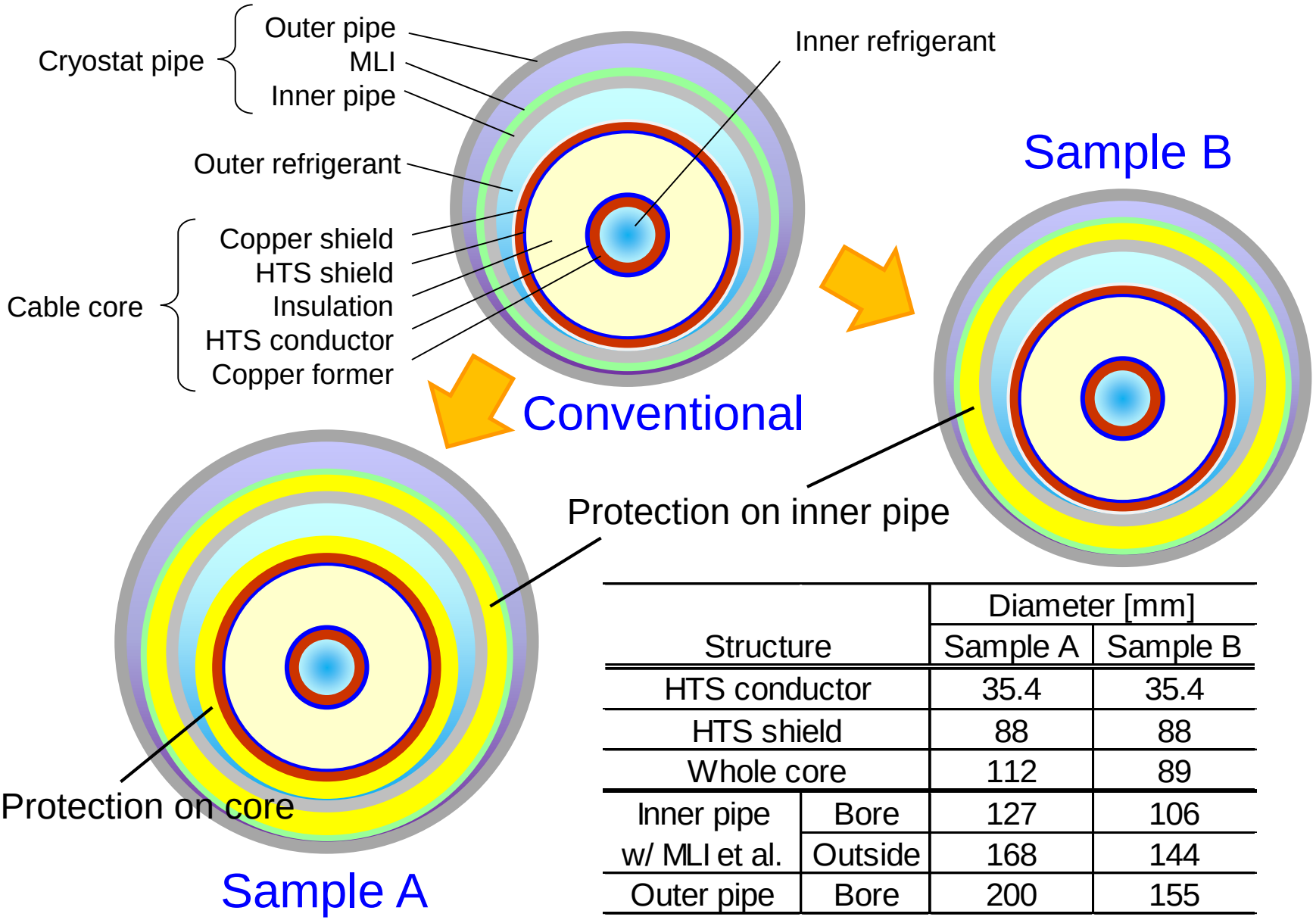
Current

- Current flowed in all 3 paths,
  the shield and both of the cryostat pipe.
  Their amount equals to the source current.
- Current flowed in the shield at first,
  and in the outer pipe at last.

Voltage

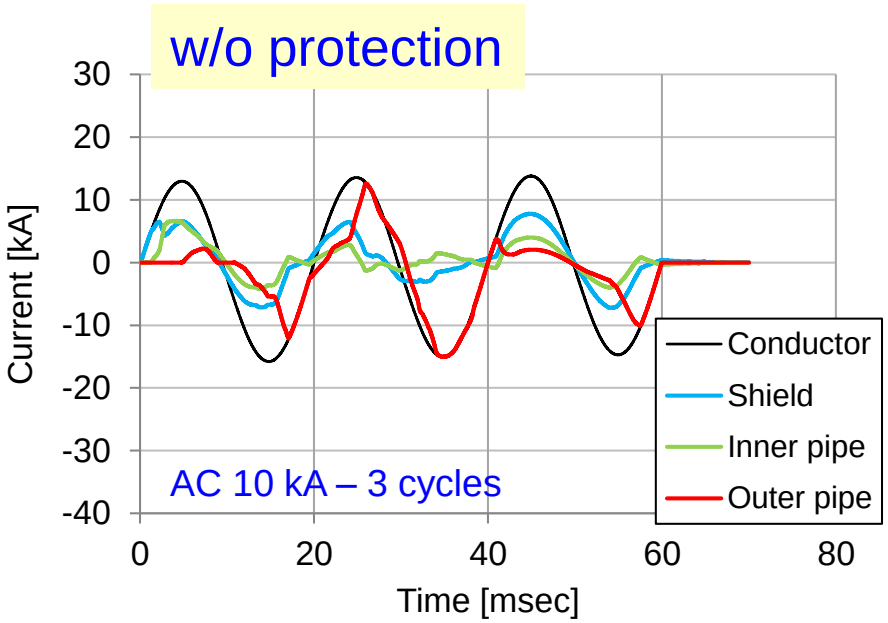
- Voltage rose abruptly in around 1ms,
  and was relatively stable.
- Amount of the energy was
  approximately 0.3 MJ for 3 cycles.

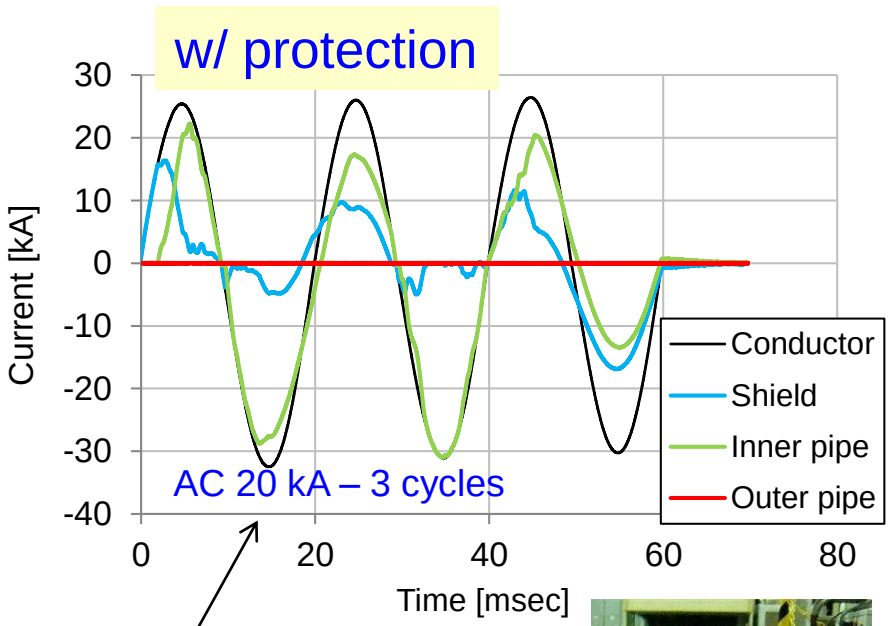
Protection for core and inner pipe



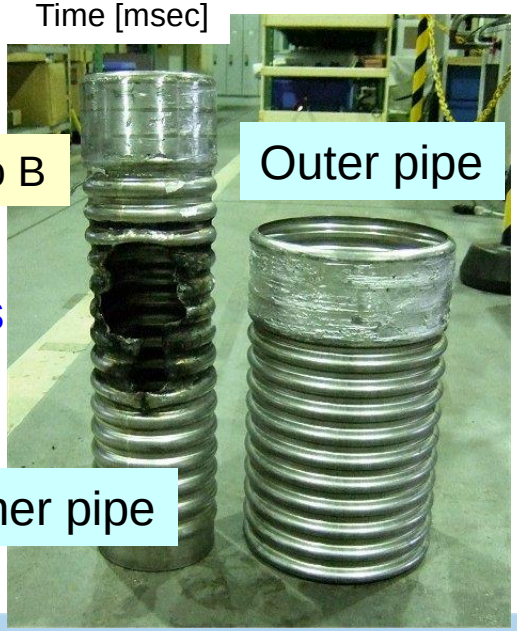
Structure		Diameter [mm]	
		Sample A	Sample B
HTS conductor		35.4	35.4
HTS shield		88	88
Whole core		112	89
Inner pipe w/ MLI et al.	Bore	127	106
	Outside	168	144
Outer pipe	Bore	200	155

Results (w/ protection)





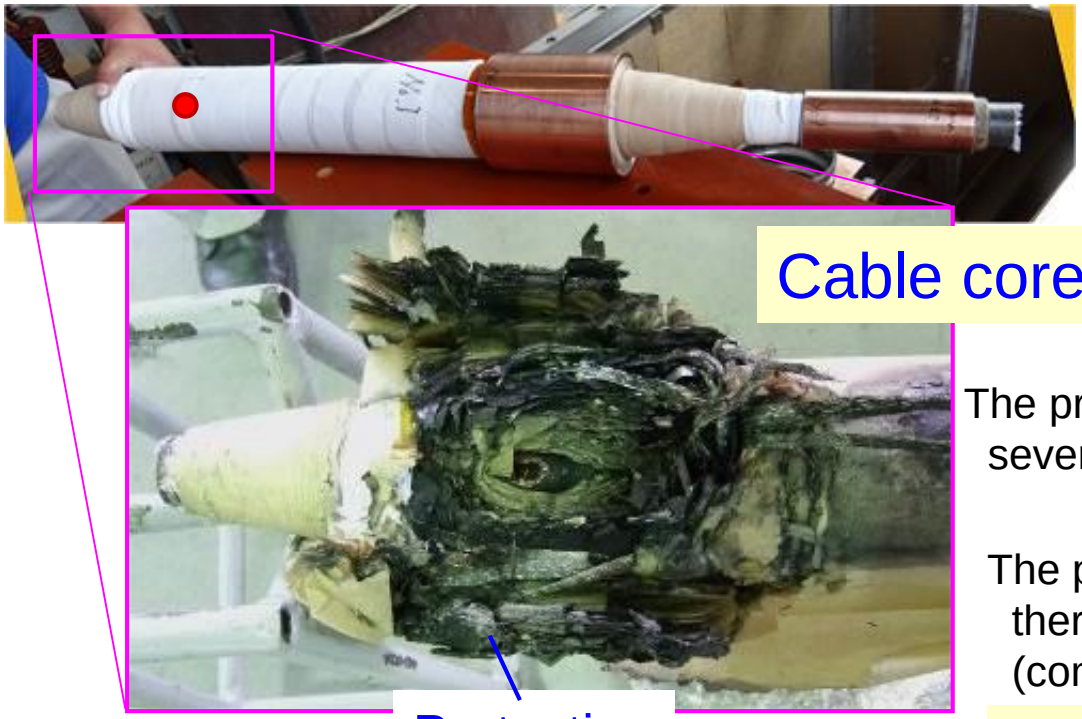
Sample A, similar to B



Outer pipe kept its soundness

NOT reached by arc discharge

Effect of protections



The protection on the core was severely damaged, as well as the core itself.

The protection on the inner pipe was damaged thermally, in spite of its outer soundness. (common to sample A and B)

Summary

- Ground fault examinations for 275 kV HTS cable were conducted.

  AC 10 ~ 20 kA, 3 cycles for samples of the standing style.

- Protection for the core and inner pipe was provided.
  => Successfully kept the soundness of the outer pipe.

  The arc discharge to outer pipe was interrupted,
  regardless of the protection on the core.

- Protection on the inner pipe remained,
  despite that on the core damaged severely.

  Protection on the core may worthless for 275 kV cable.

ACKNOWLEDGMENT
This work has been supported by the NEDO

Sample list and details

w/o protections

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.