

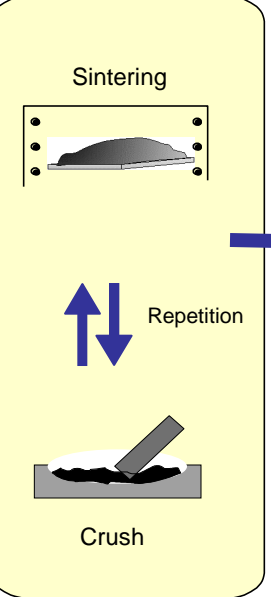
Recent progress of coil applications using DI-BSCCO wires at Sumitomo Electric

Kazuhiko Hayashi

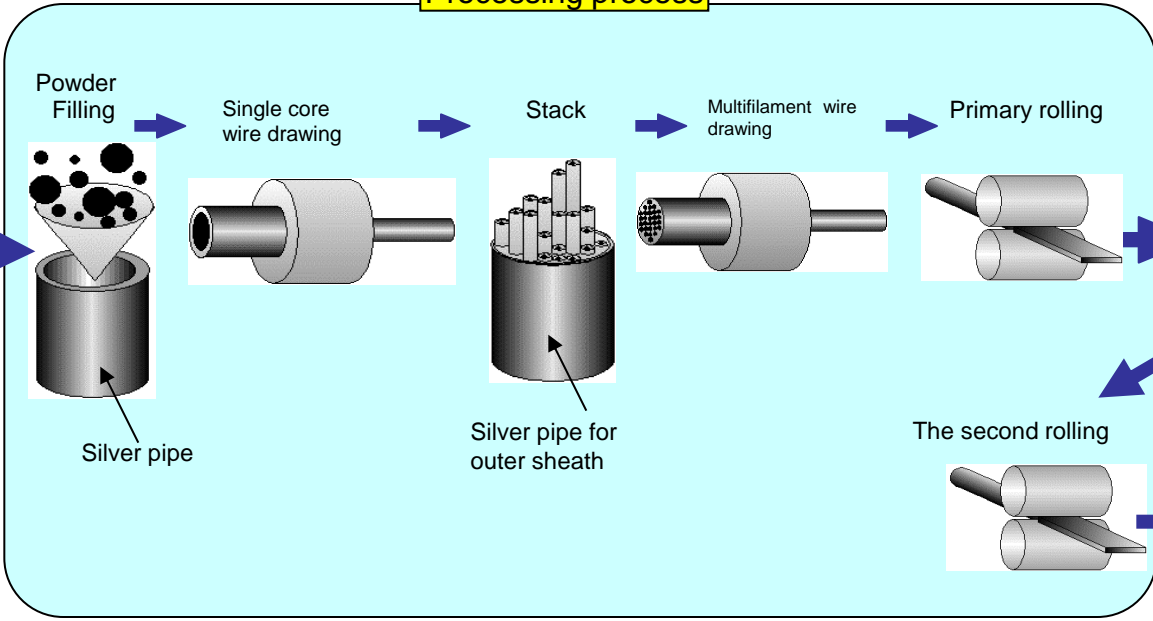
Superconductivity Technology Division
Sumitomo Electric Industries, Ltd.

Bismuth-based high temperature superconducting wire production process (BSCCO; $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$)

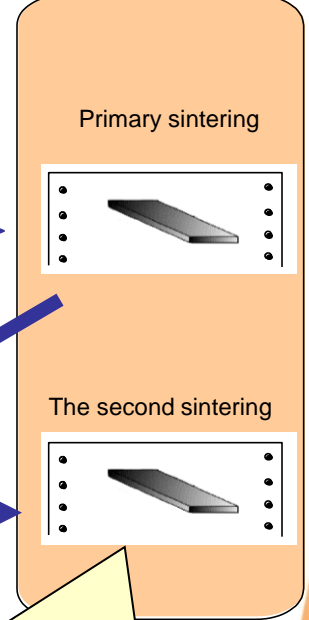
Powdery process



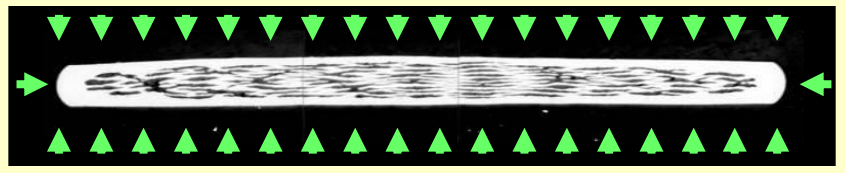
Processing process



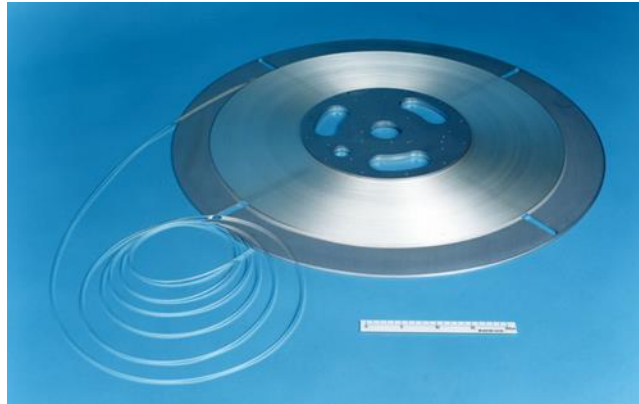
Sintering process



Pressurization sintering:
Total control of temperature,
pressure, the atmosphere



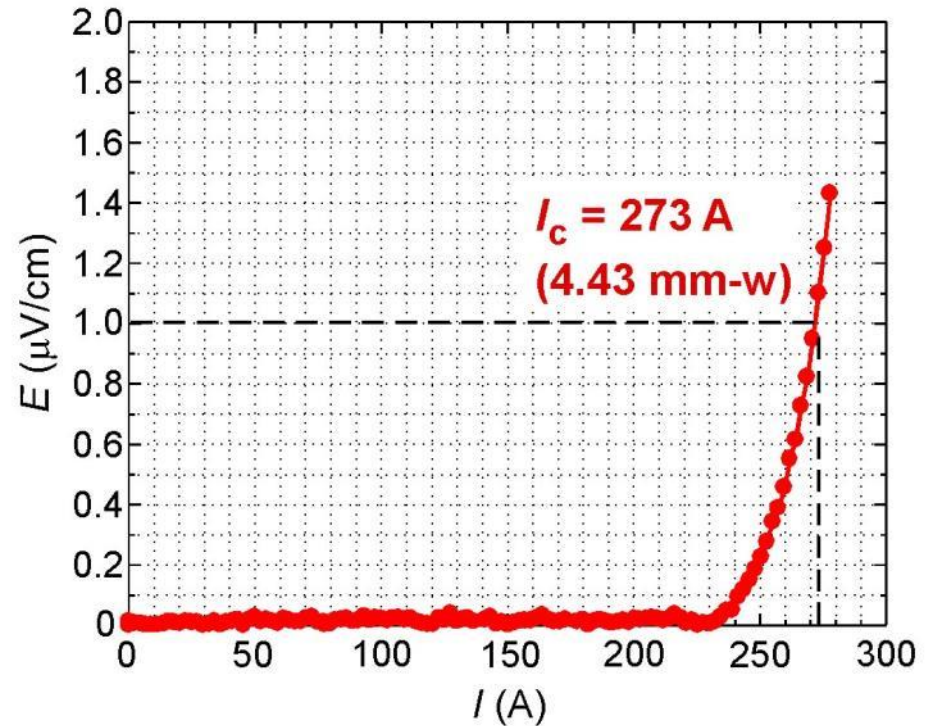
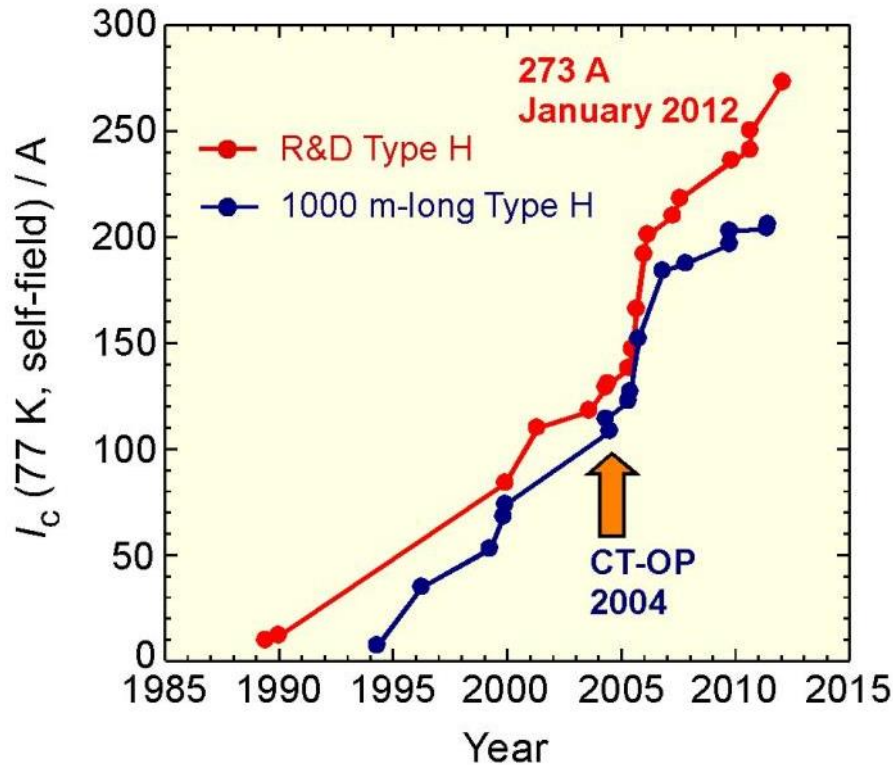
ConTrolled OverPressure Sintering



I_c : 273A (@ 77K, s.f)

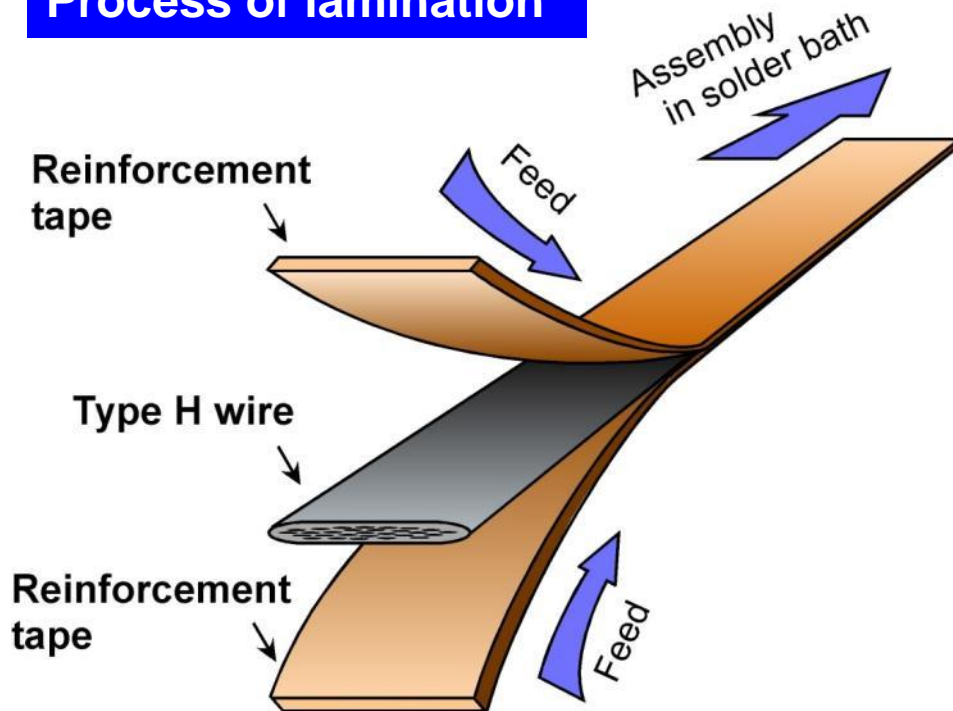
J_c : 77kA/cm²

→ 613 A/cm-width



Type HT (mechanically-reinforced Type H)

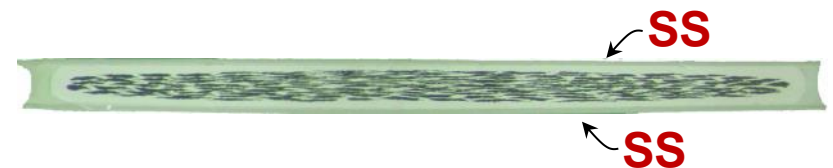
Process of lamination



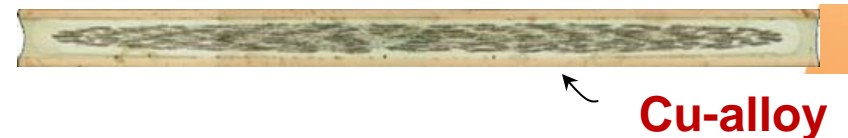
Bare wire (Type H)



Type HT-SS (Reinforced with Stainless Steel)



Type HT-CA (Reinforced with Cu-alloy)

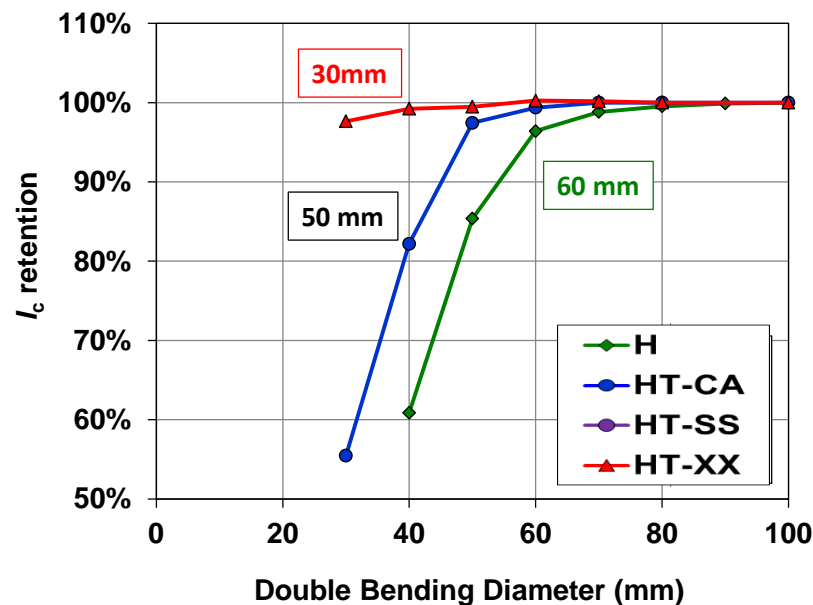
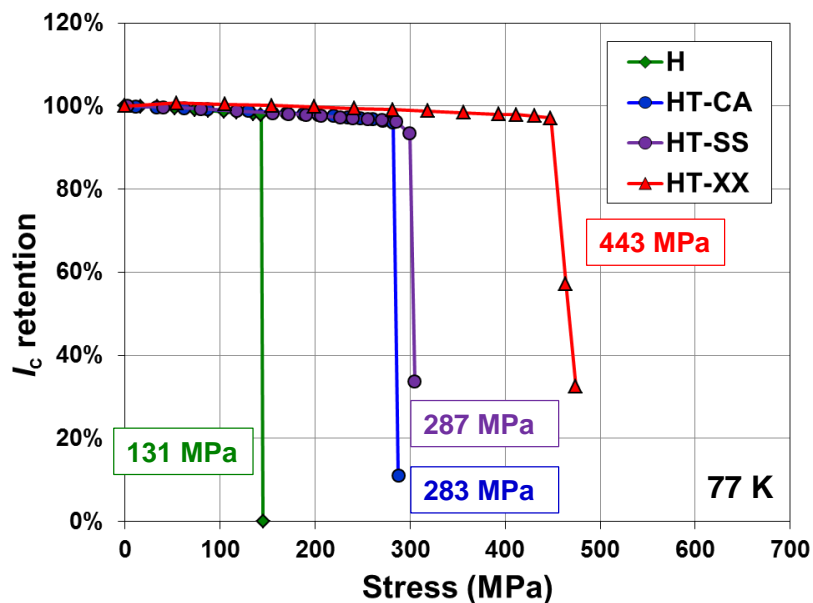


Type HT (Type H with Toughness) is laminated with reinforcement tapes. They are firmly bonded with Type H, and de-lamination never occurs, as long as the wire temperature is kept below 200°C.

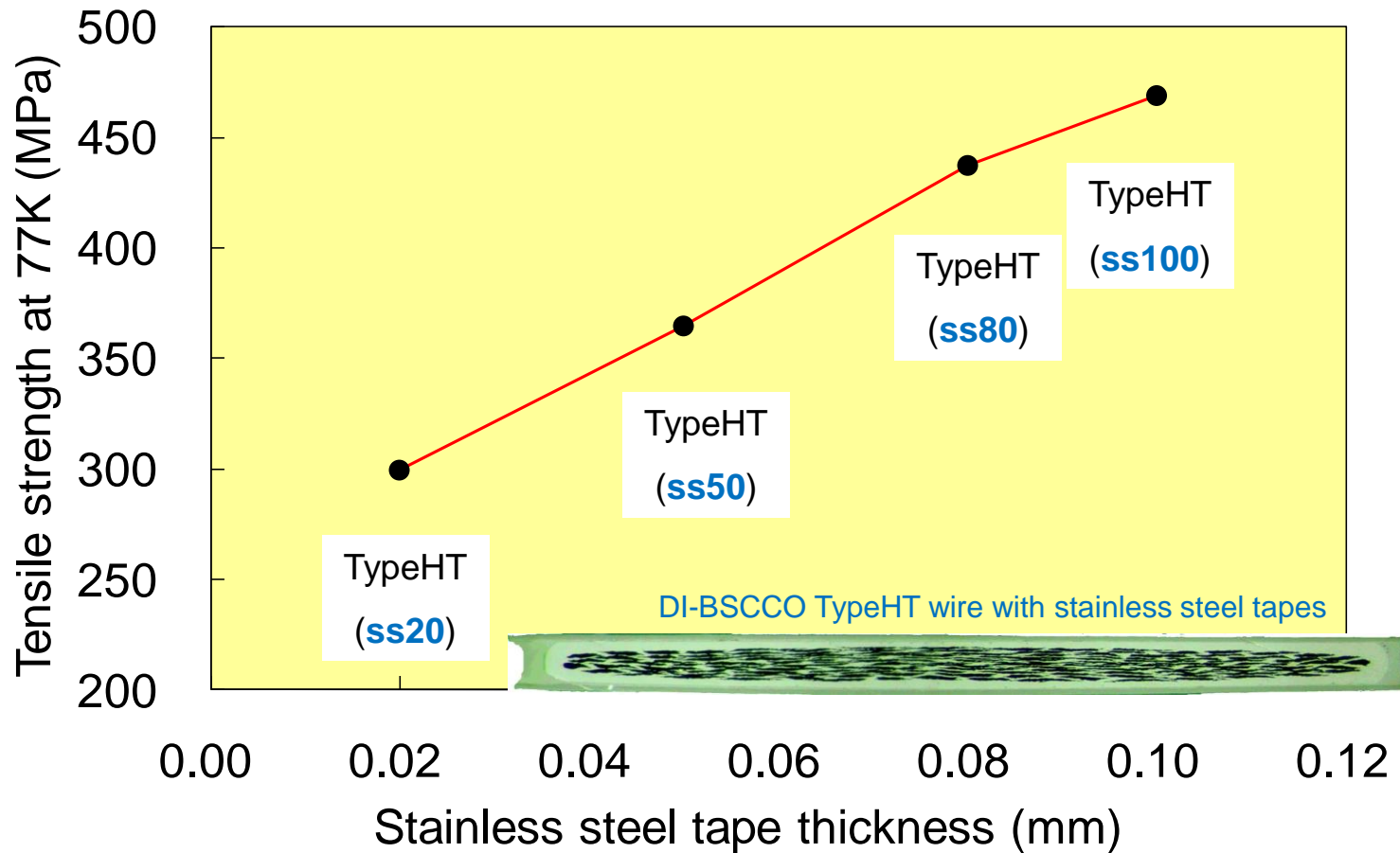
Specifications of DI-BSCCO wire

	Type H	Type HT-SS	Type HT-CA	Type HT-XX
Width	4.3+/-0.3mm	4.5+/-0.3mm	4.5+/-0.3mm	4.5+/-0.3mm
Thickness	0.23+/-0.03mm	0.30+/-0.04mm	0.36+/-0.04mm	0.29+/-0.04mm
Reinforcement	—	SS	CA	XX
Allowable tension * (RT)	80N **	230N **	280N **	410N **
Allowable stress * (77K)	130 MPa **	270 MPa **	250 MPa **	430 MPa **
Allowable strain * (77K)	0.2% **	0.4% **	0.3% **	0.5% **
Allowable bending diameter * (RT)	70mm **	60mm **	60mm **	40mm **

* Correspond to 95% of critical currents ** Reference



R&D for Higher Strength Wire

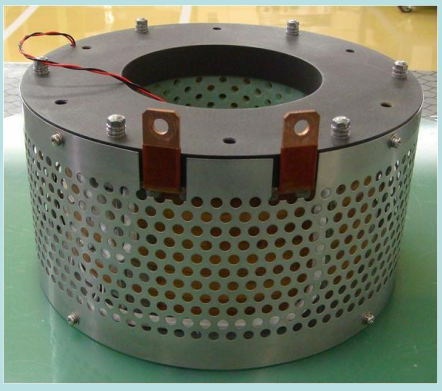


Stainless steel tape thickness	Critical Tensile Stress (77K)	Critical Double Bend Diameter (RT)	J_e (ex. $I_c=200A$)
20 μ m	285MPa	40mm	157A/mm ²
50 μ m	360MPa	38mm	131A/mm ²
100 μ m	460MPa	34mm	102A/mm ²

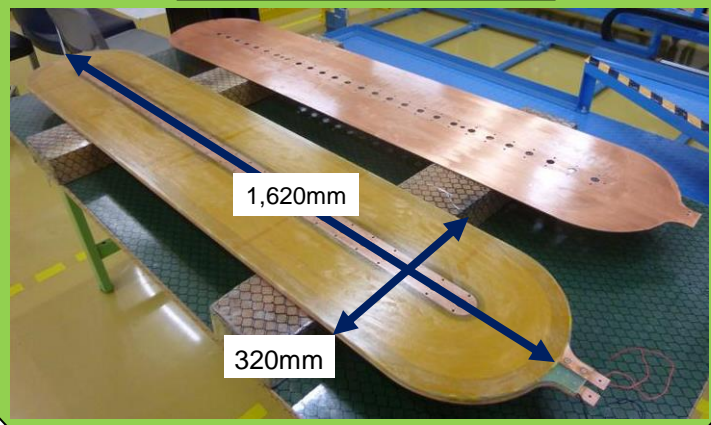
Refrigerator cooling type
Magnet system



Liquid nitrogen cooling
Magnet



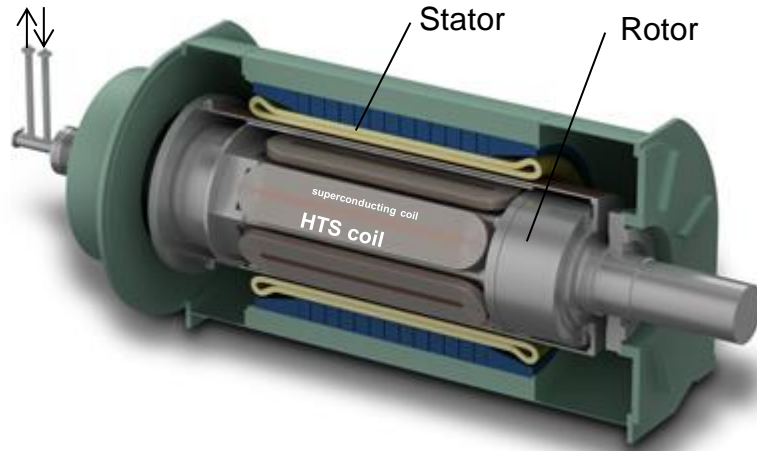
Coil for the rotating
machine



3 MW HTS ship motor

DI-BSCCO

He Gas



Manufactured by Kawasaki Heavy Industries

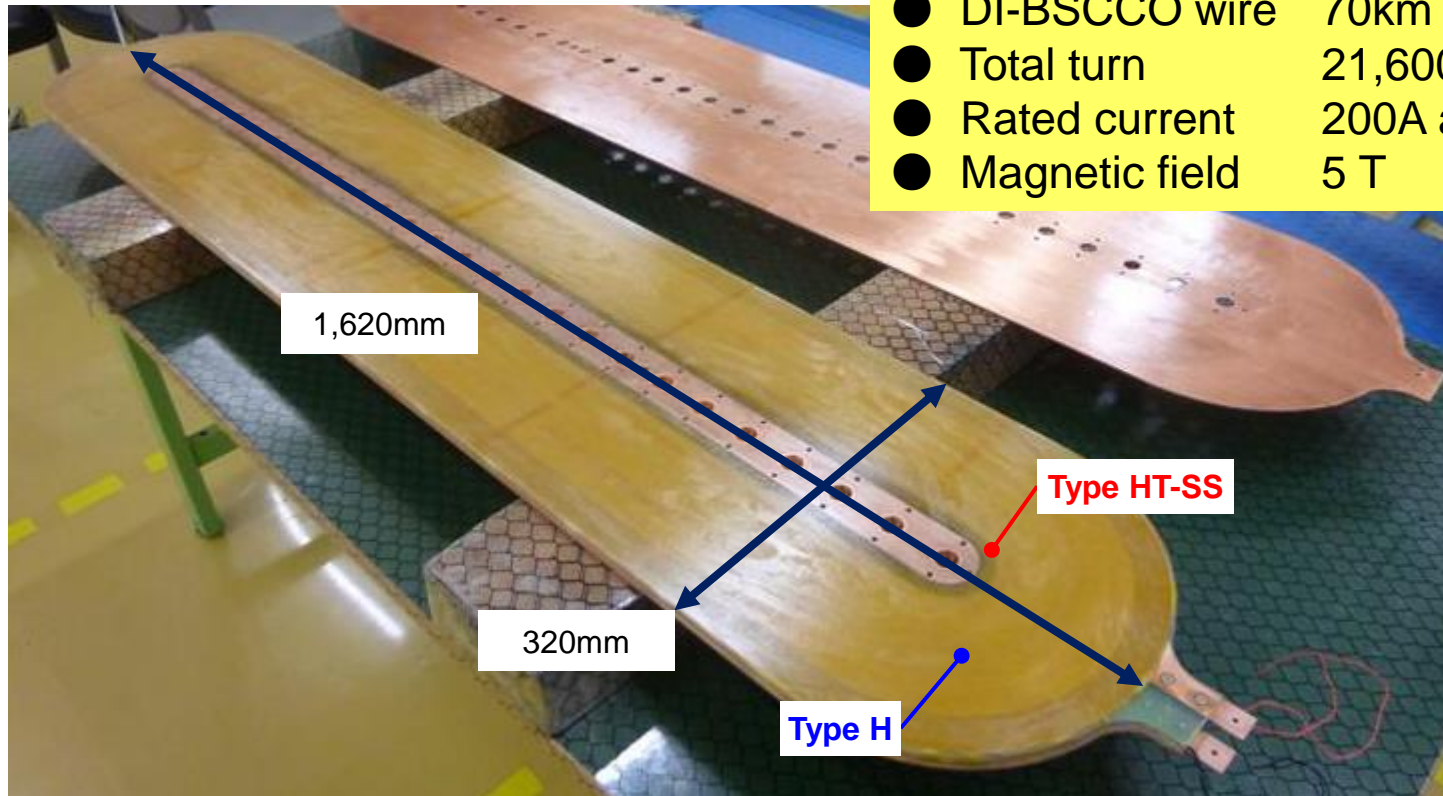


- Rated output 3 MW
- Rotating speed 160 rpm
- Efficiency 98%
- Fuel saving 18%
- Torque density 40 kNm/m³

The 3 MW HTS motor with DI-BSCCO field coils succeeded in load test, and achieved the high efficiency of 98% with half the size of a conventional motor.

This study was supported by New Energy and Industrial Technology Development Organization (NEDO) of Japan.

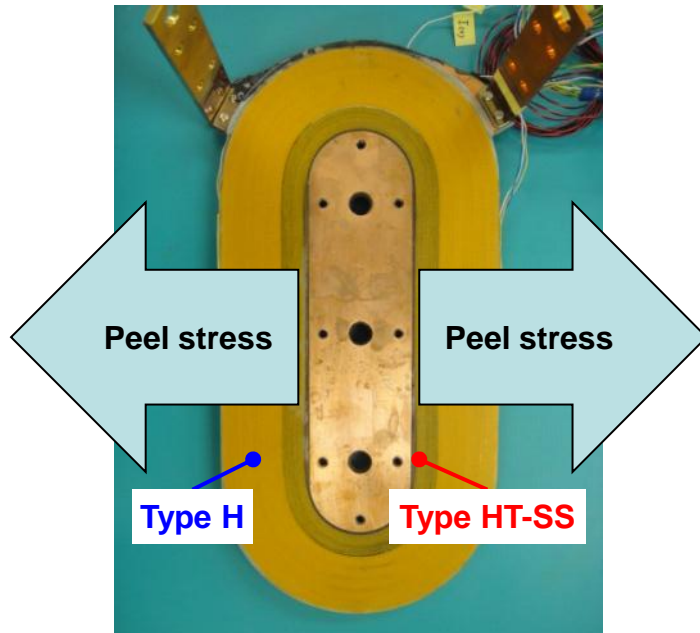
- Coil number 24 coils / 6 poles
- DI-BSCCO wire 70km / 24 coils
- Total turn 21,600 turns
- Rated current 200A at 30 K
- Magnetic field 5 T



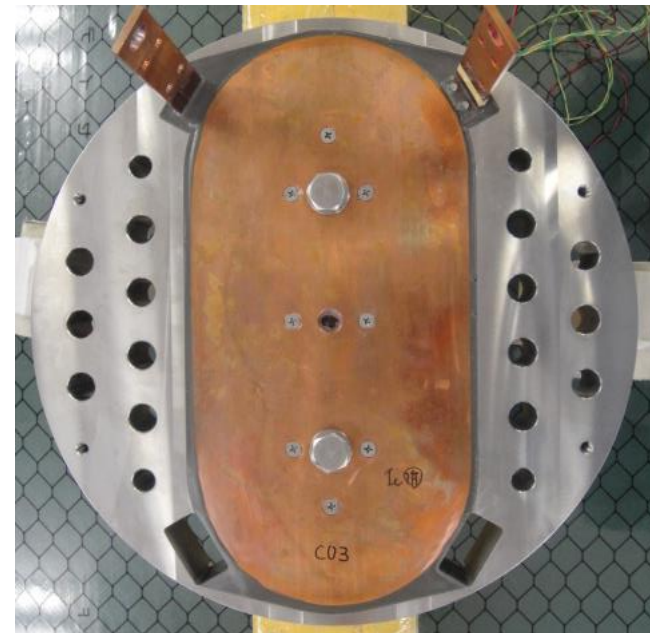
**To endure small-diameter bending, the inner winding is Type HT-SS.
To increase current density, the outer winding is Type H.**

This study was supported by New Energy and Industrial Technology Development Organization (NEDO) of Japan.

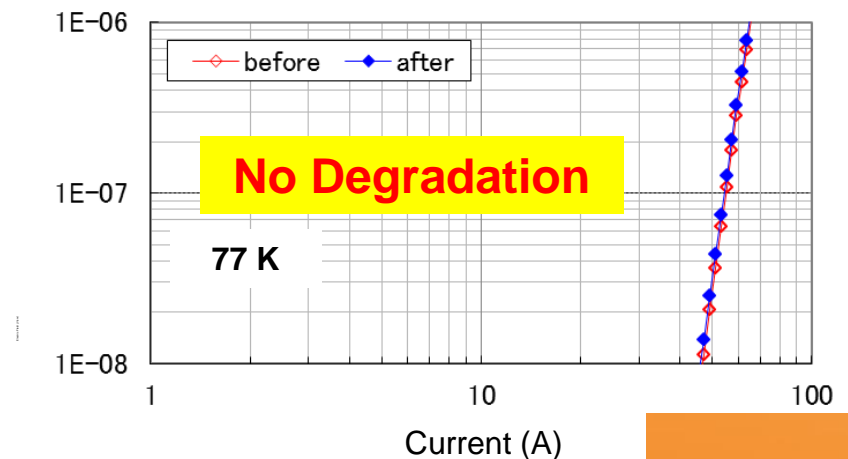
Test Coil



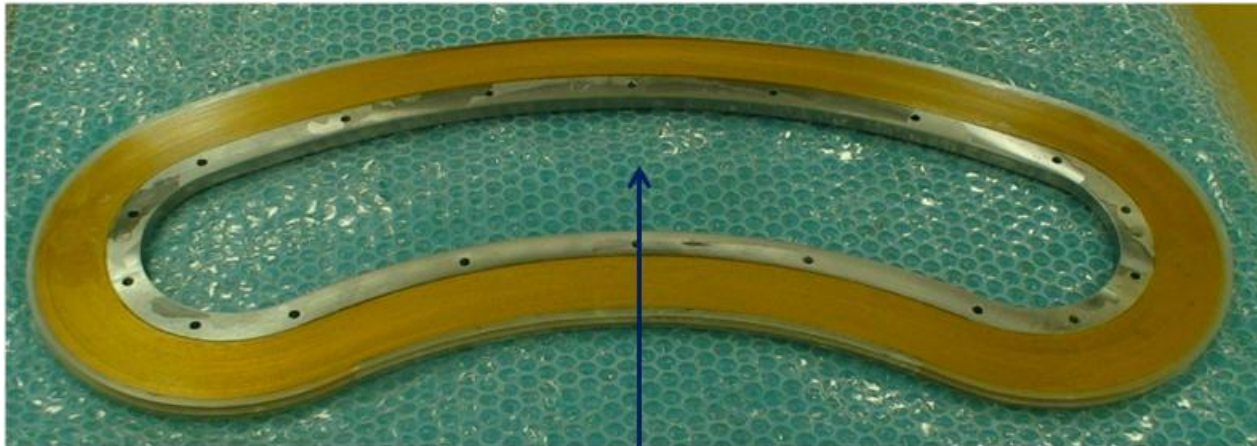
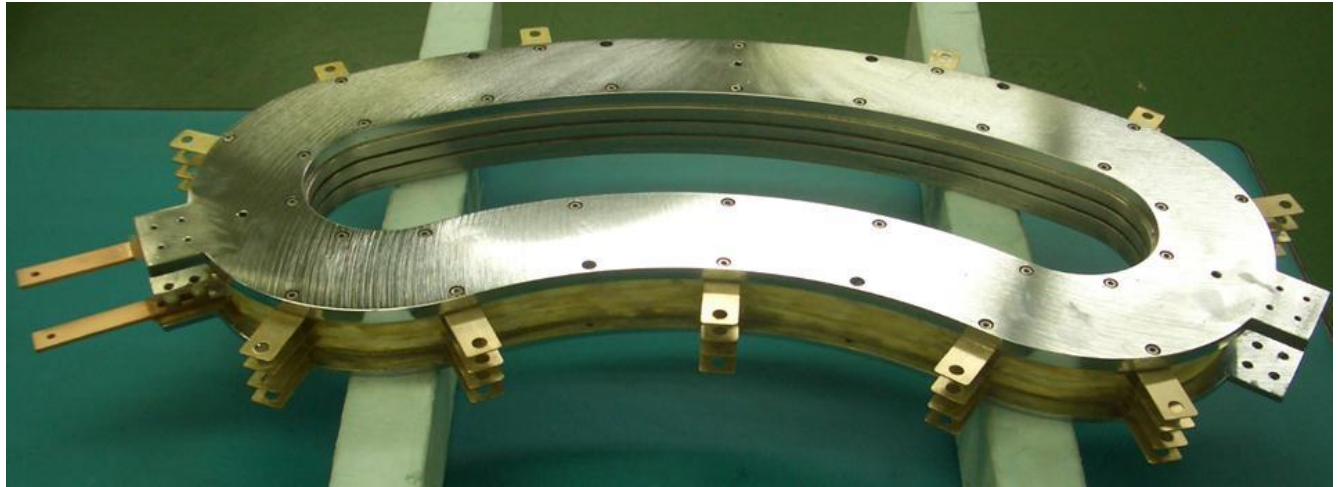
Reinforced with stainless steel case



Coil temperature	4.2 K
Backup field	4.2 T
Coil current	0 \Leftrightarrow 330A
Applied stress	43 MPa = rated stress (29 MPa) x 1.5
Number of cycle	2,400 Equivalent to 20 years operation



Deflection magnet



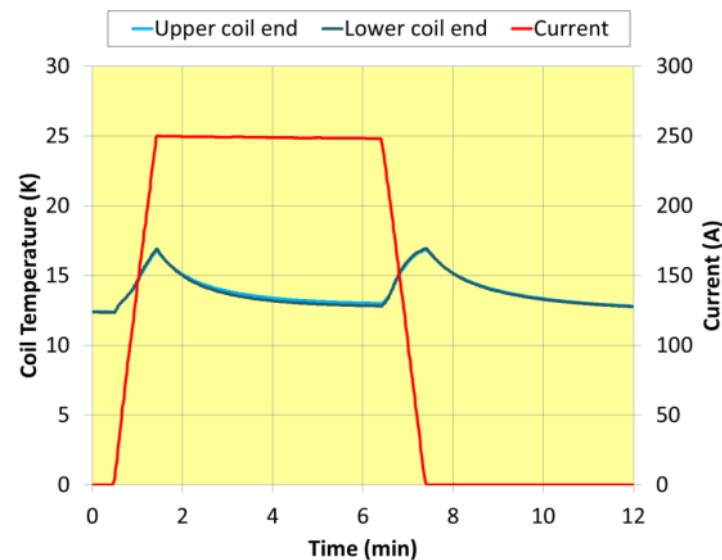
R=400mm

Coil for Osaka university

Refrigerator cooled magnet

+/-5 Tesla /φ100 mm

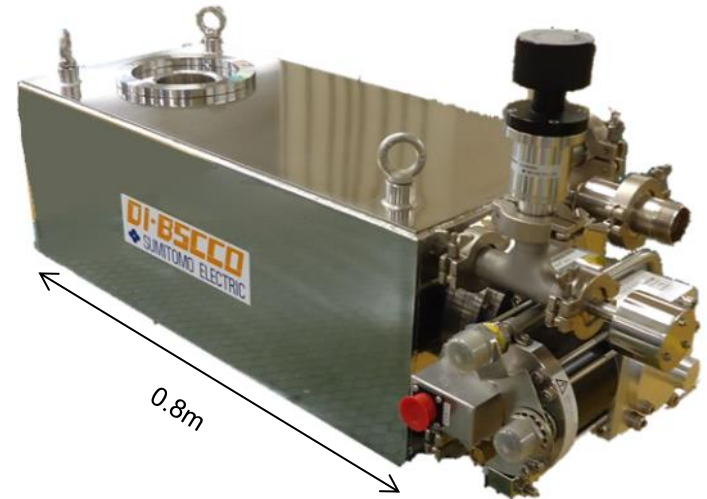
+/-5.7 Tesla /φ150 mm



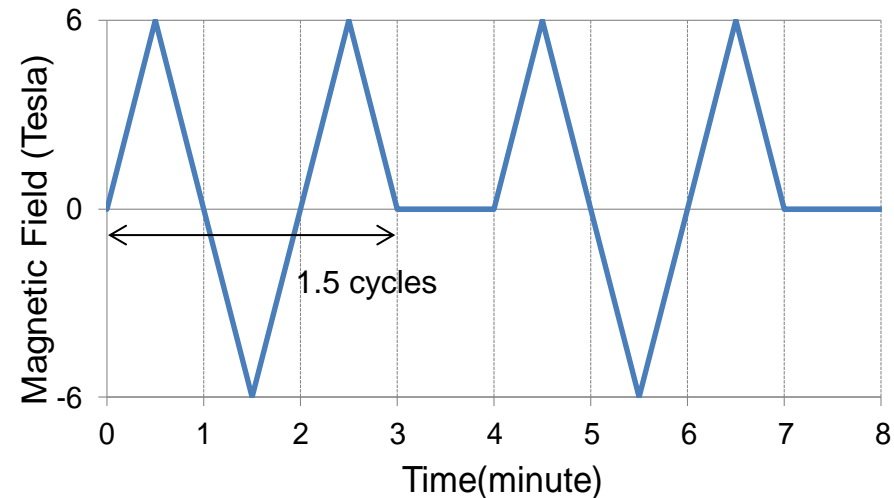
	A	B	C	D
Center field	+/-5 T	+/-10 T	+/-5.7 T	+/-5 T
R.T. bore	100 mm	100 mm	150 mm	300 mm
Iop	175A	250A	250A	250A
Inductance	4 H	11 H	5H	20 H
Storage Energy	61 kJ	344 kJ	156 kJ	625 kJ
Sweep rate	5 T / 30s	10 T / 10 min.	5 T / 50s	5 T / 180s
Wire type	Type H	Type HT-SS, Type H	Type HT-SS, Type H	Type HT-SS, Type H

DI-BSCCO[®] Compact magnet system

- ✓ Fast sweep rate (1T / 5 sec.)
 - ✓ A wide variety of operating methods and patterns
 - ✓ No refrigerant
 - ✓ Compact, light, and low residual field
- < Use application >
 BH curve tracer, VSM, Field annealing, Test, Experiment

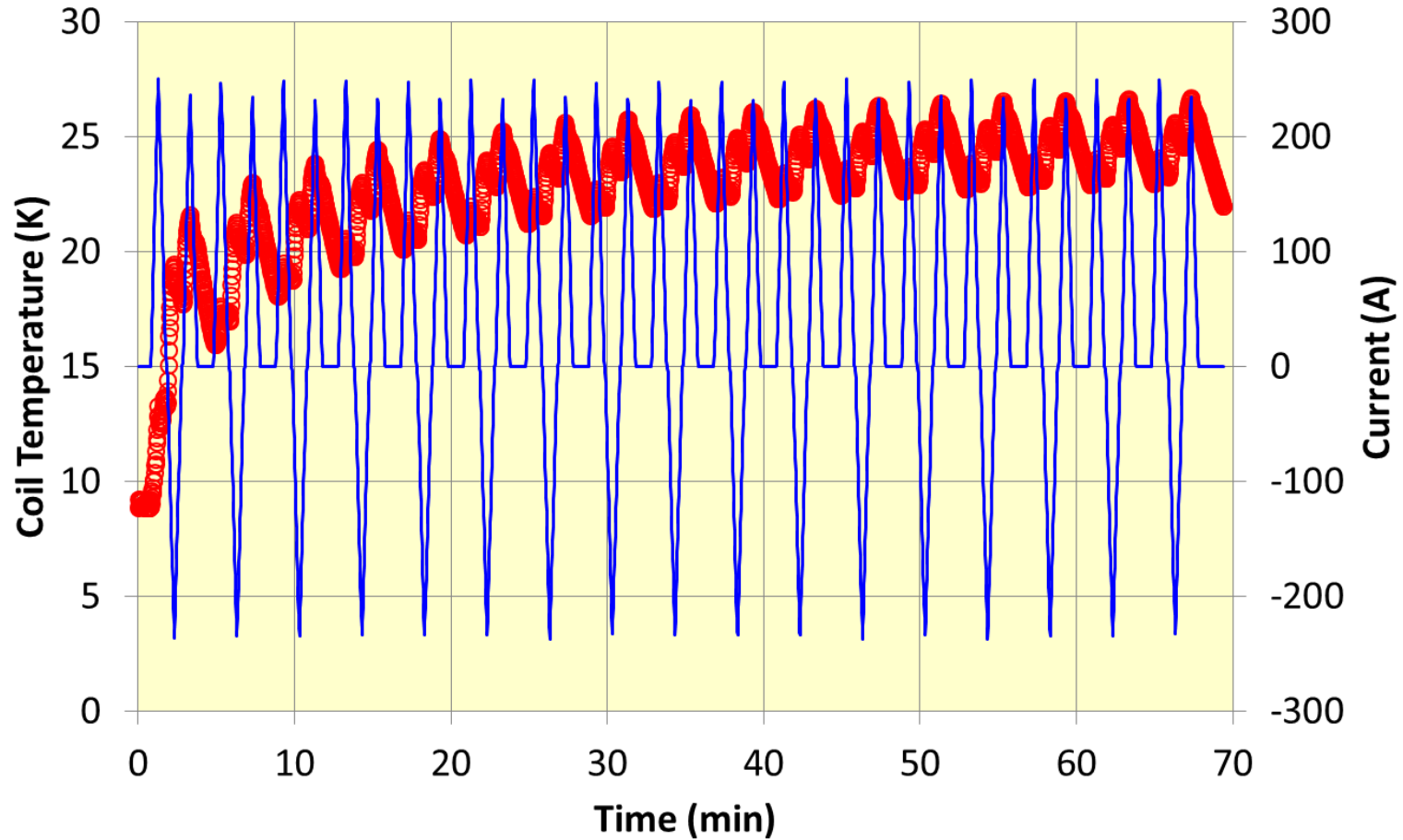


Model name	DI-BSCCO-MS 6T-70
Field strength	±6T
R.T. bore	Φ70mm
Sweep rate	6T/30sec.
Operating current	250A
Inductance	about 1H
Field homogeneity	0.3%/10mmDSV
Size	0.8mX0.3mX0.3m
Weight	About 100kg



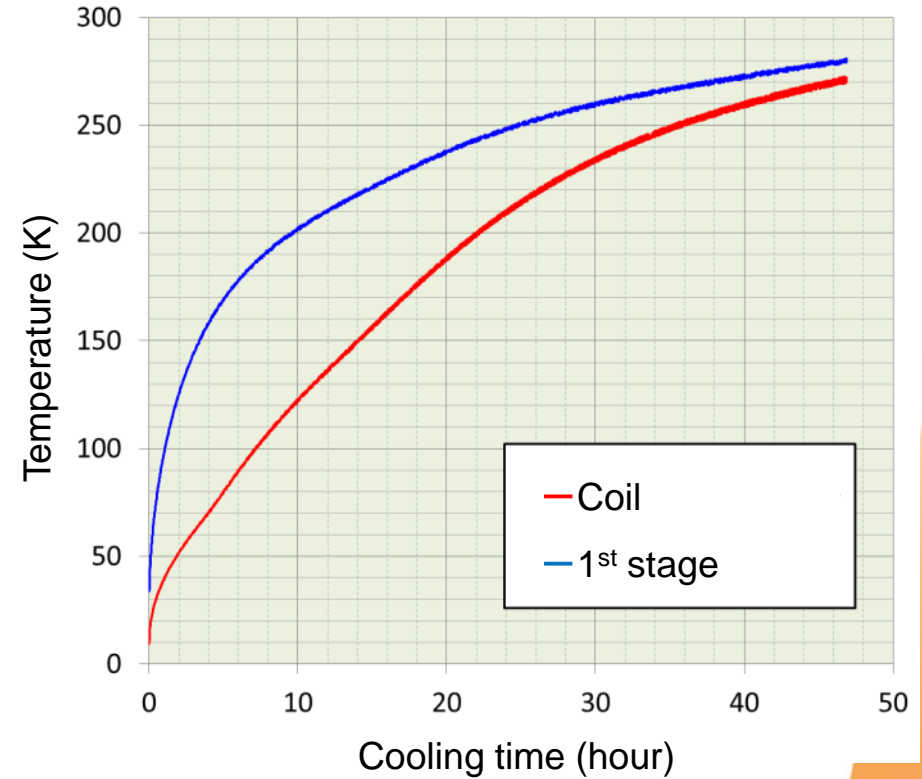
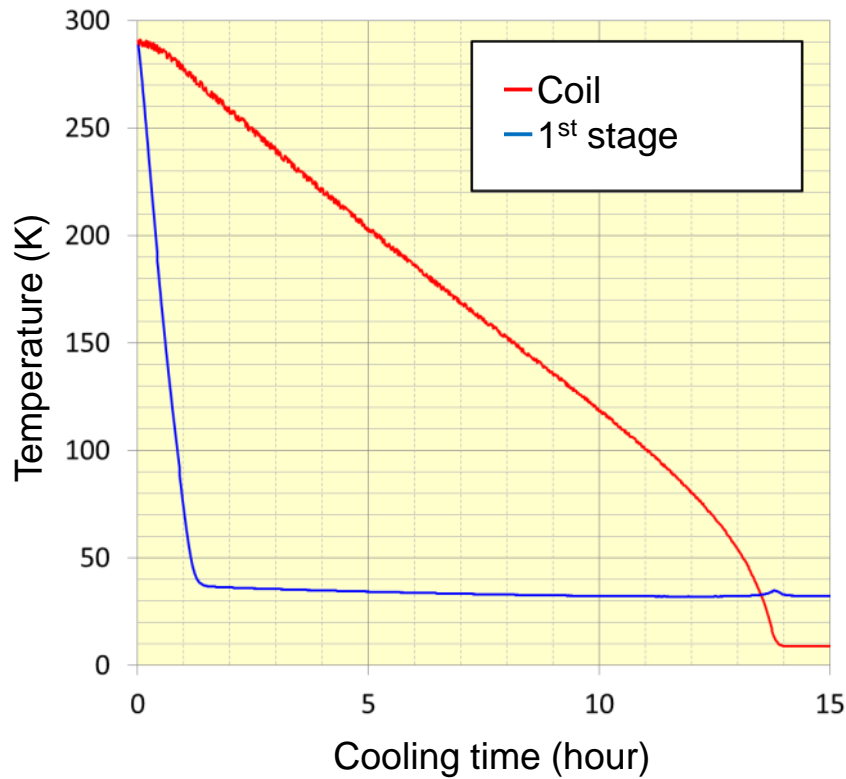
6 Tesla - 70 mm magnet

Temperature change
3 minutes / 1.5 cycles + 1 minute interval



- Coil temperature
- Operating current

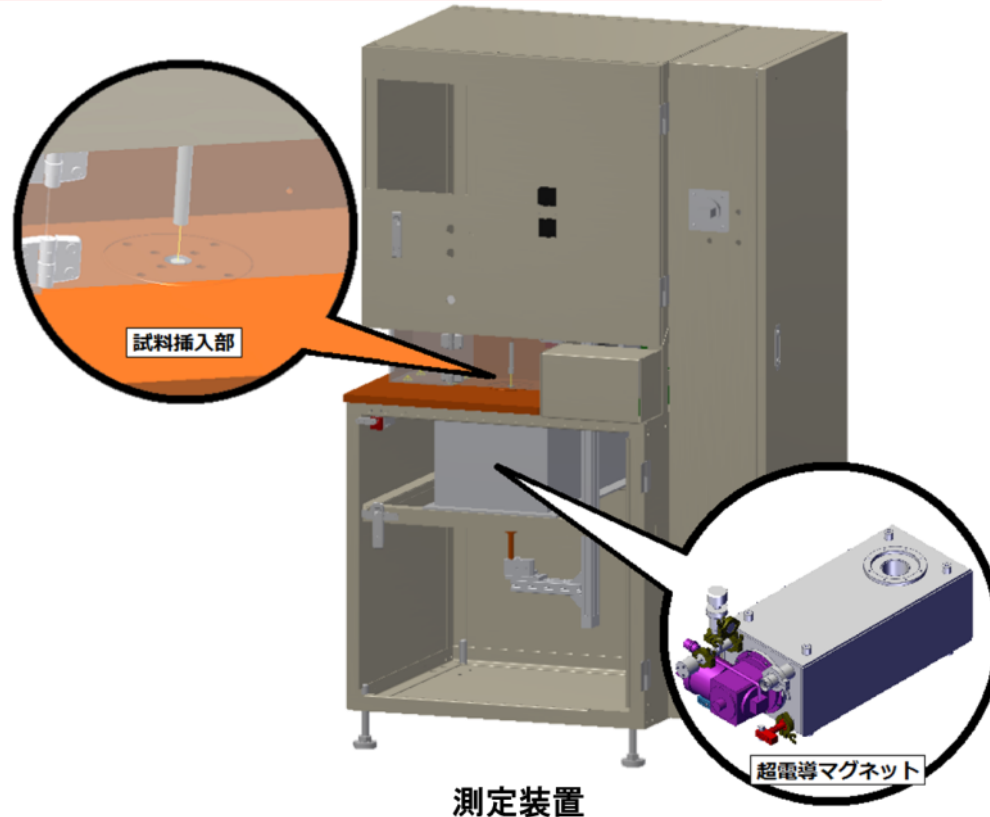
6Tesla - 70mm magnet



Coil can be cooled down in a night.

高温超電導BHカーブトレーサ SBH-1000 **新製品**

高温超電導マグネットを利用し高保磁力磁石の磁化特性を高速・高精度に自動測定。



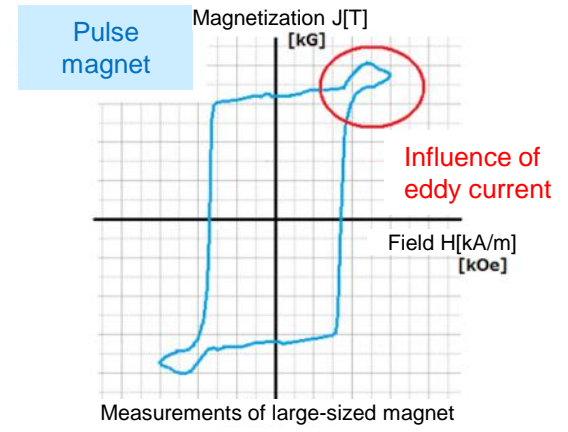
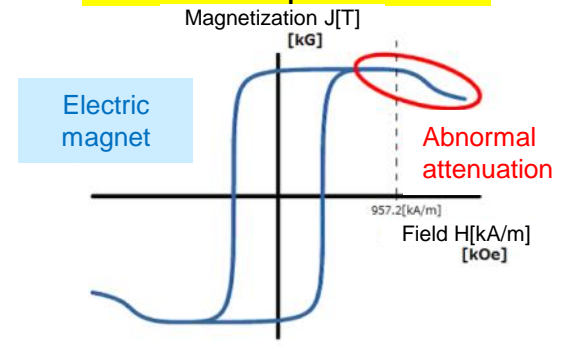
W1063mm × D1000mm × H1771mm



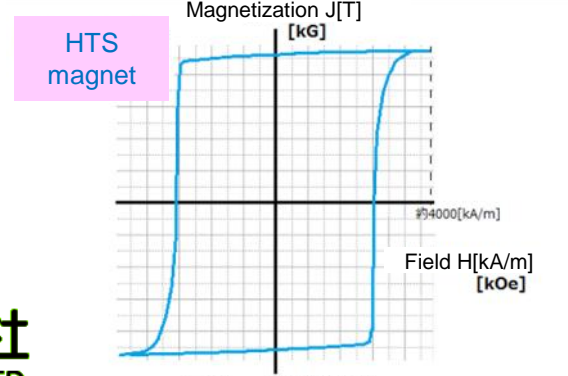
Features

- Static magnetic fields can be applied by HTS magnet
- Air core HTS magnet allows magnets with a high coercive force to be measured owing to no saturation of magnetic poles.
- Magnetic properties at a high temperature can be measured.
- Static magnetic fields allow large-sized magnets to be measured because of little influence of eddy currents.
- Measurement of a small-sized specimen (under development)
 - Precise measurements such as degradations after processes are possible because of no influence of magnetic aftereffect by a pulse field.

Previous problems



Wave form with HTS BH curve tracer



[VSM-5HSC] High Temperature Superconducting Type of Vibrating Sample Magnetometer

The world's first* of one-twentieth of measurement speed is realized compared to this company's existing product by adopting high temperature superconductivity magnet to VSM.

Br, HcJ high accuracy measurement of 0.5 mm cube magnet becomes possible.

*Investigated as of July, 2014 by Toei Industry Co., Ltd.

Features

Realization of High Speed Measurement

High speed measurement is realized by adopting high temperature superconductivity magnet.

Hmax = 5Tesla, Full Loop measurement becomes possible in 21 minutes.

(This company's existing machine: Full Loop measurement needs 40 minutes.)

High Accuracy Measurement of Small Sample

High accuracy measurement of Br, HcJ of 0.5 mm cube magnet, etc. of Br, HcJ and comparative measurement of micro surface area become possible.

Also, comparative measurement of finishing degradation becomes possible.

Sample Temperature Variable Measurement

-50°C - +200°C temperature variable UNIT(Optional)

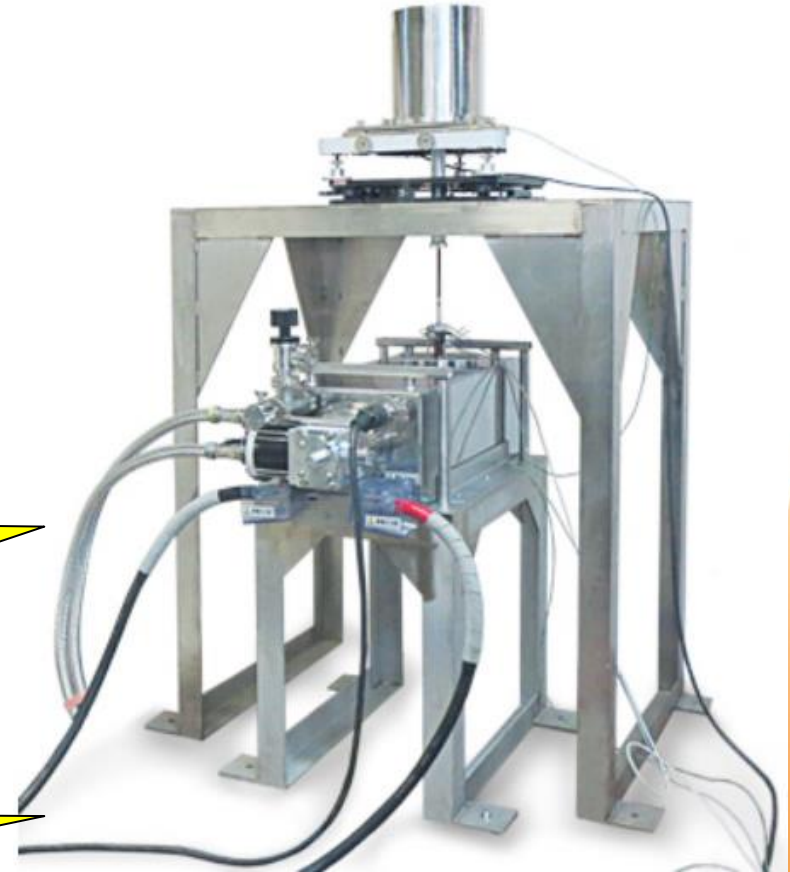
Miniaturization of Magnetic Field Generation

Size of magnet system part: 0.8 x 0.3 x 0.3 m

High speed

High accuracy

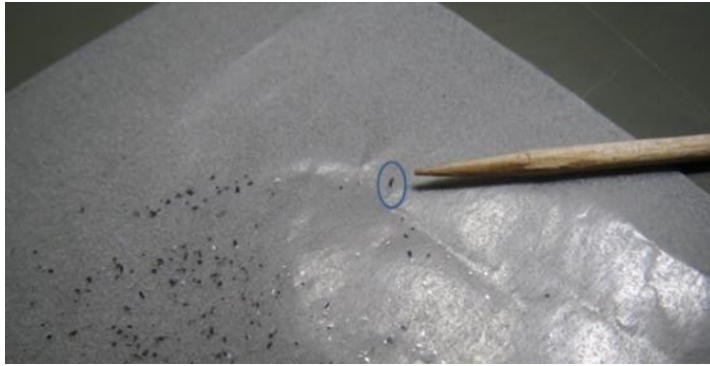
Compact



Refer to

<http://www.toeikogyo.co.jp/english/products/sei-01/vsm-5hsc.html>

VSM is a device measuring the magnetization characteristic of the sample by vibrating the sample in the uniform magnetic field at a constant frequency and an amplitude, and by detecting electromotive force evoked by the detection coil which is located in the neighborhood of the sample using PSD (Phase Sensitive Detector phase sensitive detection).



SmCo

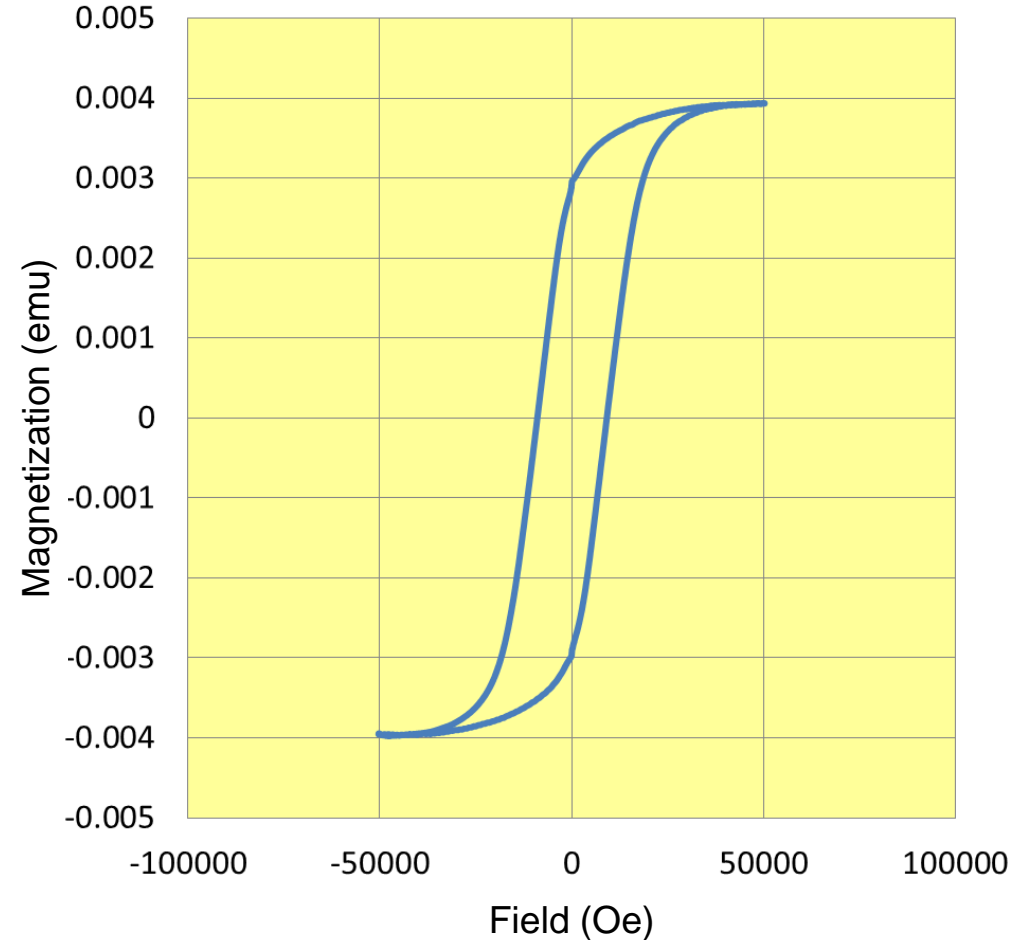
$M_s = 0.00383$ emu

$M_r = 0.00293$ emu

$H_c = 9153$ Oe

Measurement time 6 minutes

Use of DI-BSCCO magnet



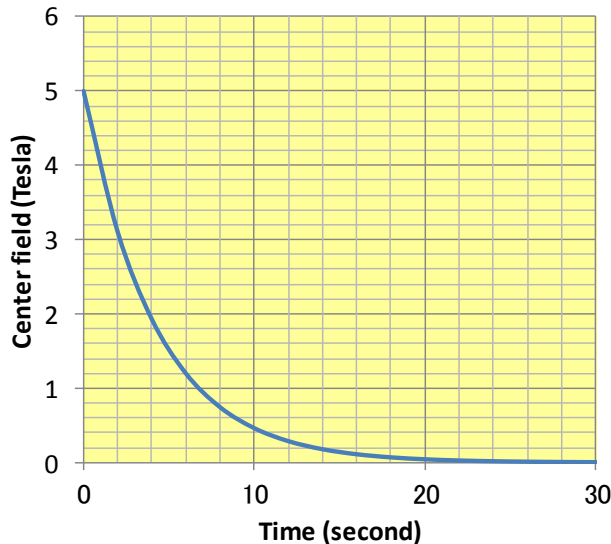
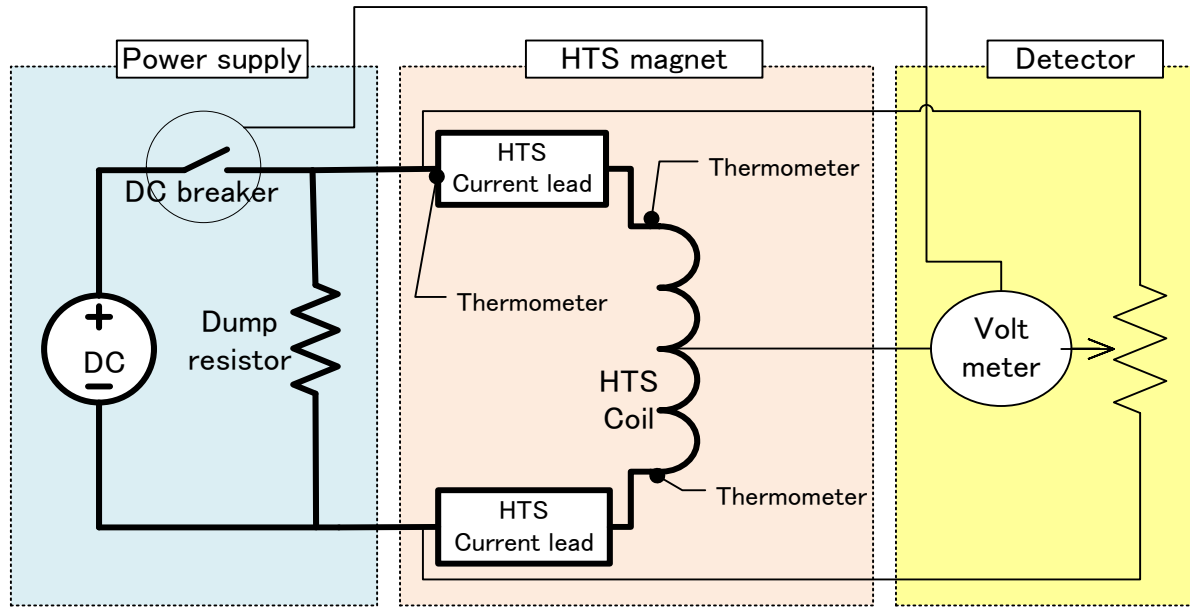
TOEI 東英工業株式会社

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TEL (042)791-1211 (代表) FAX (042)792-0490
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TEL: +81-42-791-1211 FAX: +81-42-792-0490

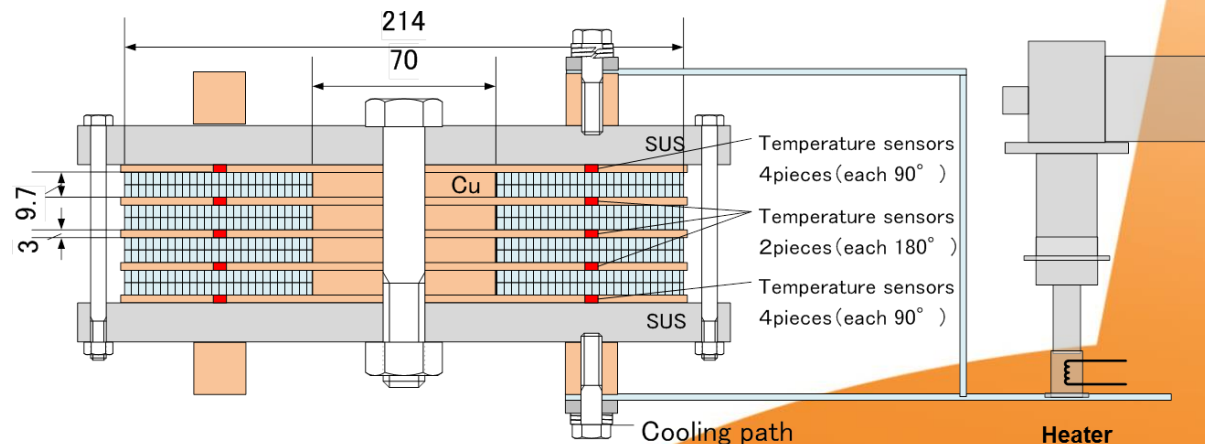
Example of protection circuit



With protective circuit reducing a magnetic field in a short time in case of the abnormality such as a blackout or a breakdown.

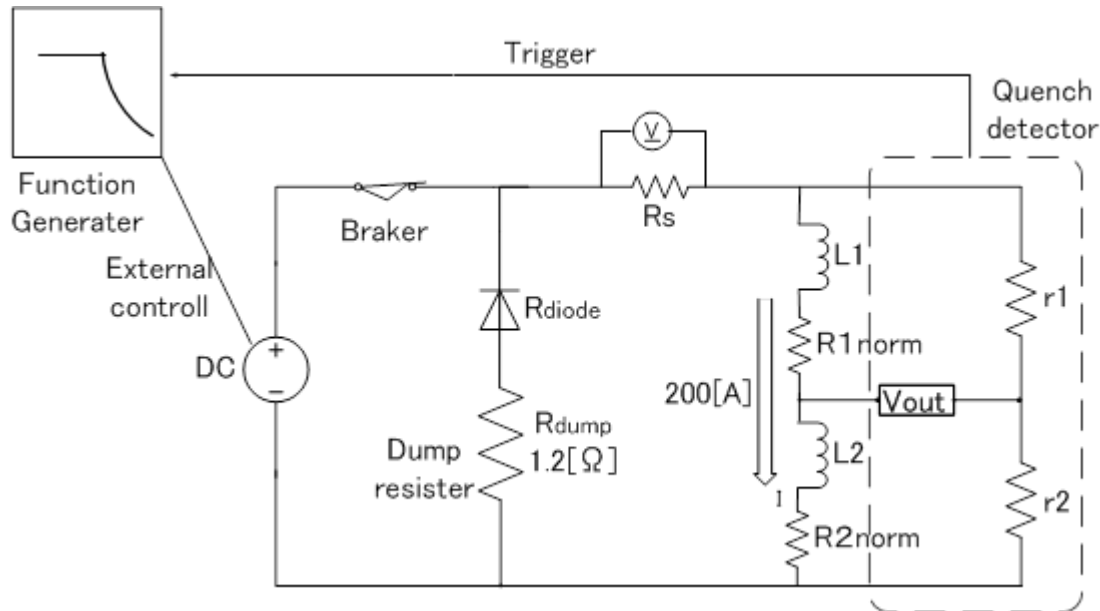
DI-BSCCO coil for quench protection tests

Type of DI-BSCCO wire	Type Hi
I _c of DI-BSCCO wire (77K, s.f.)	about 180 A
ID/OD of winding	70 mm/214 mm
Number of stack	4
Total length	880 m
Total number of turns	2000(=500 turns × 4)
Maximum parallel magnetic field	4.2 T
Maximum perpendicular magnetic field	2.0 T
Inductance	0.4 H
Stored energy	8.2 kJ at 200A



This study was supported by Japan Science and Technology Agency (JST) of Japan.

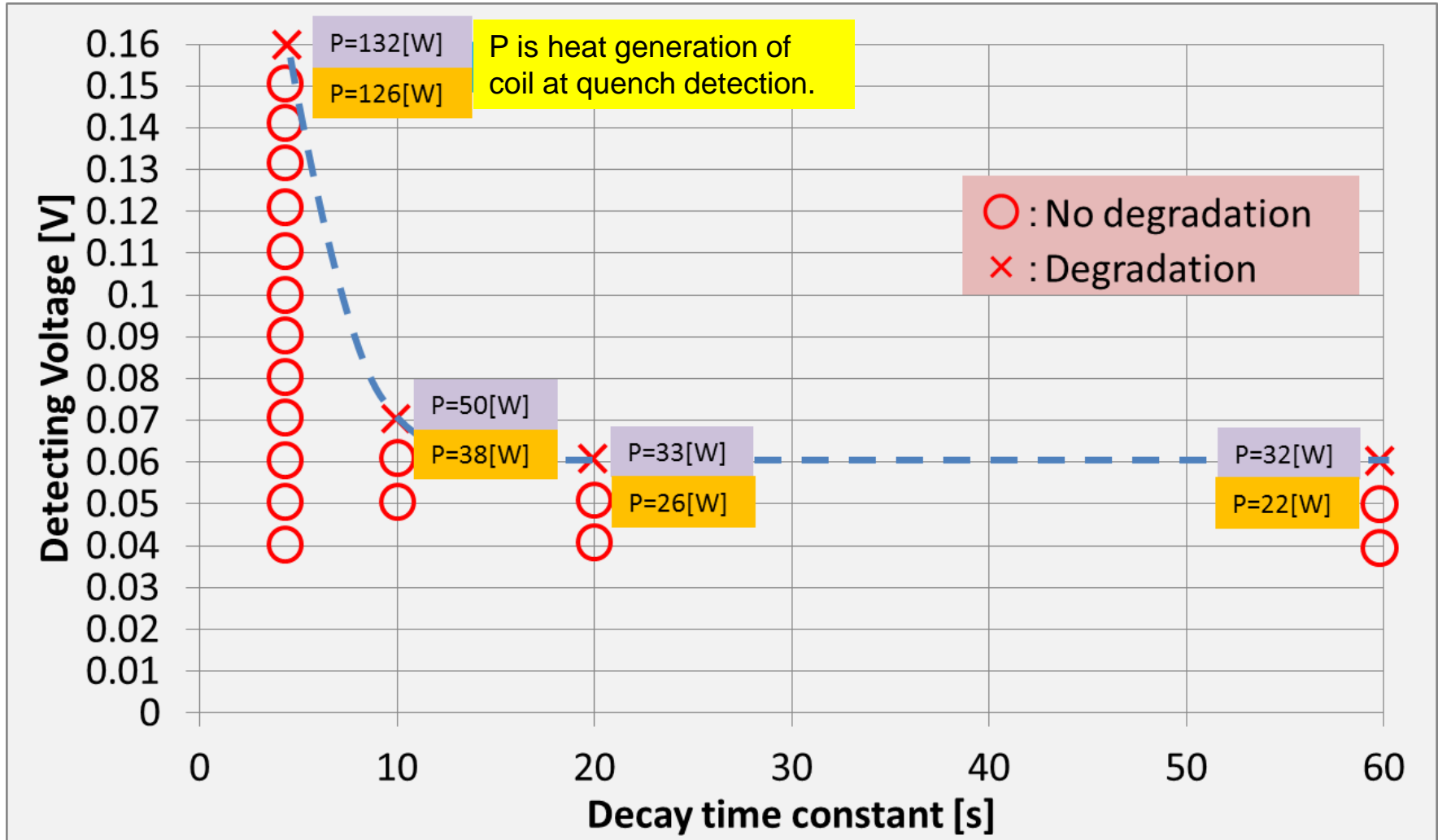
Experimental methodology



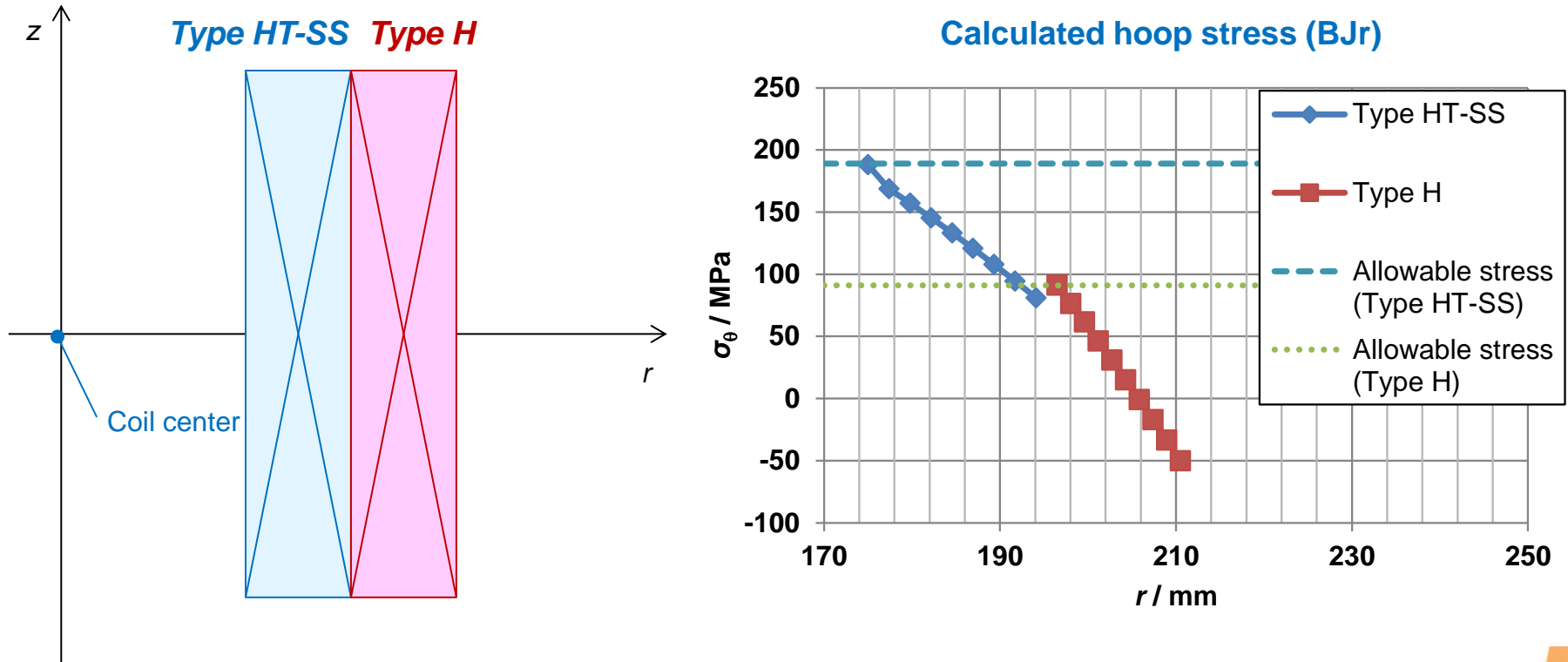
$$\begin{aligned}
 V_{out} &= \frac{1}{2} I (R1_{norm} - R2_{norm}) \\
 &= \frac{1}{2} (V_1 - V_2)
 \end{aligned}$$

Operation current	200 A
Quench detection	Detection voltage is parameter. Detection time is 0.1 sec.
Quench generation	Raise the coil temperature from 35K
Current decay	External control with wave form generation $I(t) = 200A \times \exp(-t/\tau)$ $\tau = 4, 10, 20, 60 \text{ sec.}$

Results of quench protection tests

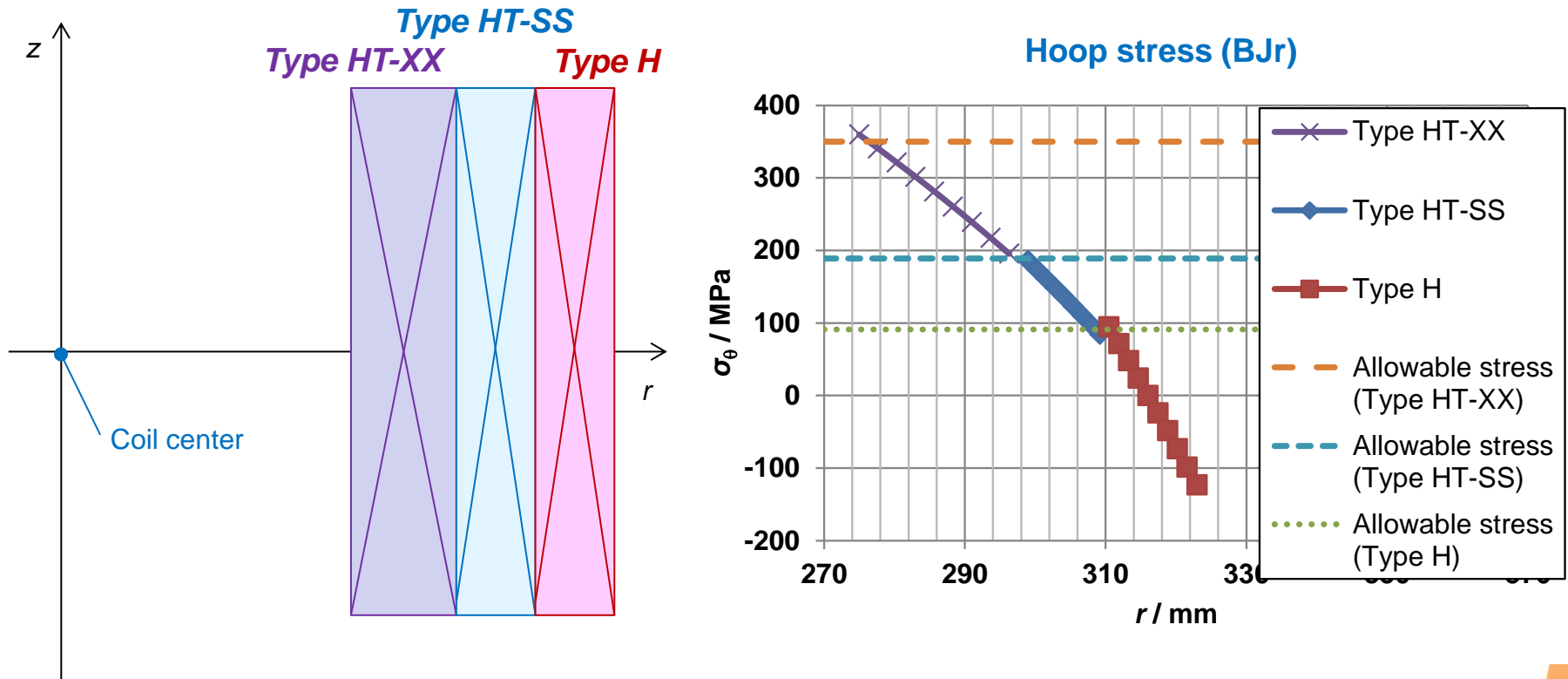


A design of 5 T – ϕ 300 magnet



The inner 55% of the total wire length is Type HT-SS and the outer 45% is Type H, not to exceed each allowable stresses (designed values).

A design of 5 T – ϕ 500 magnet with Type HT-XX



The inner 44% of the total wire length is Type HT-XX, the medium 24% is Type HT-SS, and the outer 32% is Type H.

Type HT-XX will realize higher field and/or larger-size magnet.



Thank you for your attention.

Please utilize our WEB site.

www.sei.co.jp/super/

HTS Wire



DI-BSCCO(Bi2223) wire

HTS Wire

DI-BSCCO Type H

DI-BSCCO Type HT

HTS Magnet/Coil



Various HTS magnets HTS motor cooled by LN₂

HTS Magnet/Coil

HTS Coil designing



Topics



Press Release
Newsletter
"SEI WORLD"
Technical Paper

HTS Cable



3-in-One HTS cable

HTS Cable

Movie



What's New

- October 29, 2013 [High Tc Superconducting Cable Project celebrates its first anniversary.](#)
- October 29, 2012 [High Tc Superconducting Cable Project](#)
- October 22, 2012 [We supplies Type HT-CA wire to HTS Cable project in Germany & Russia](#)
- May 15, 2012 [200A DI-BSCCO \(Type H, Type HT and Type G\) released.](#)

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