TTC/ARIES topical workshop on flux trapping and magnetic shielding

Measurement of magnetic shielding performance and permeability of soft magnetic alloy for SRF

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OHTAMA

Outline

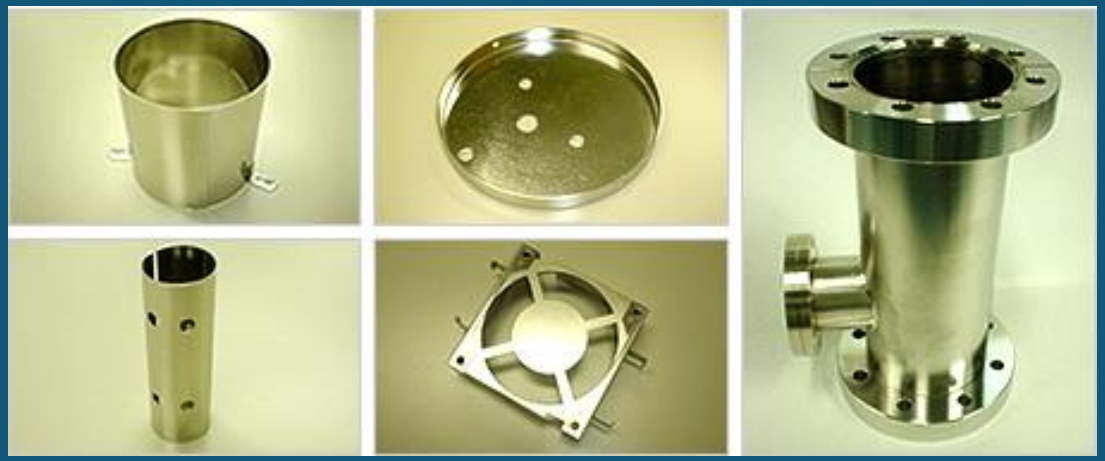
1. Introduction
2. Production process of magnetic shields
3. Performance tests of DC magnetic shield
4. Measurement of magnetic properties (at RT, at cryogenic temperature)
5. Summary

1. Introduction

Magnetic shielding parts are shaped by several processes such as pressing, cutting, welding, etc.

Press forming

Cutting

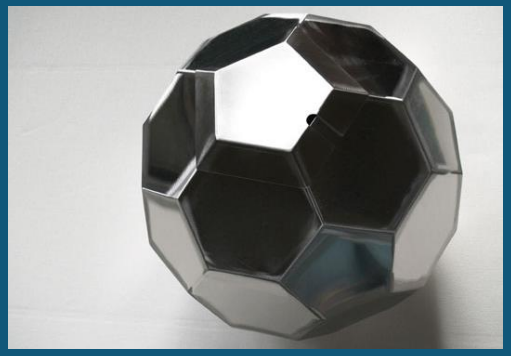


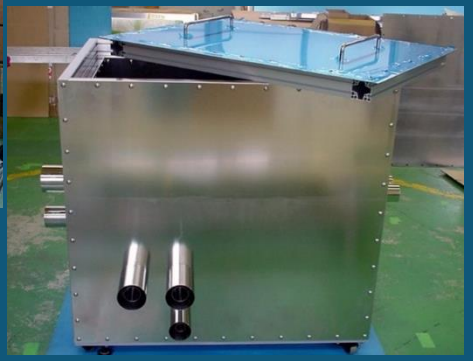
Combined process

Sheet metal processing, Welding, Cutting, Press Polish

1. Introduction

Various type of shapes can be formed by joining parts and frames. For certain customized and specific orders you can talk to a shield maker.

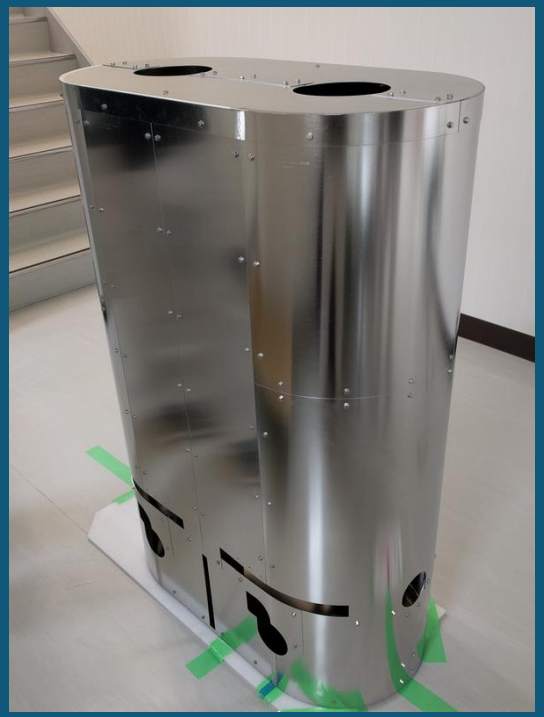


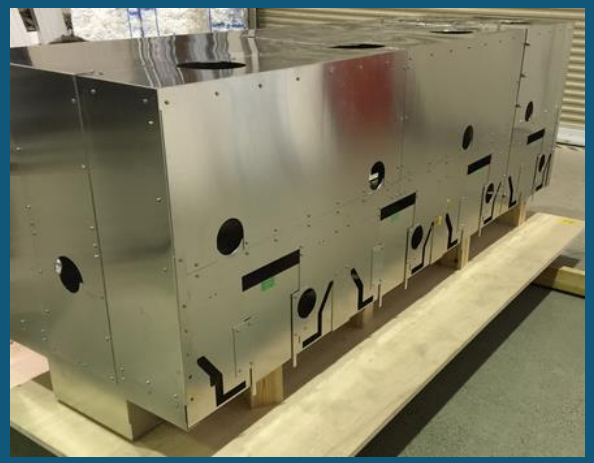


1. Introduction

All of the magnetic shields for the SRF of the FRIB were completed and passed performance tests.

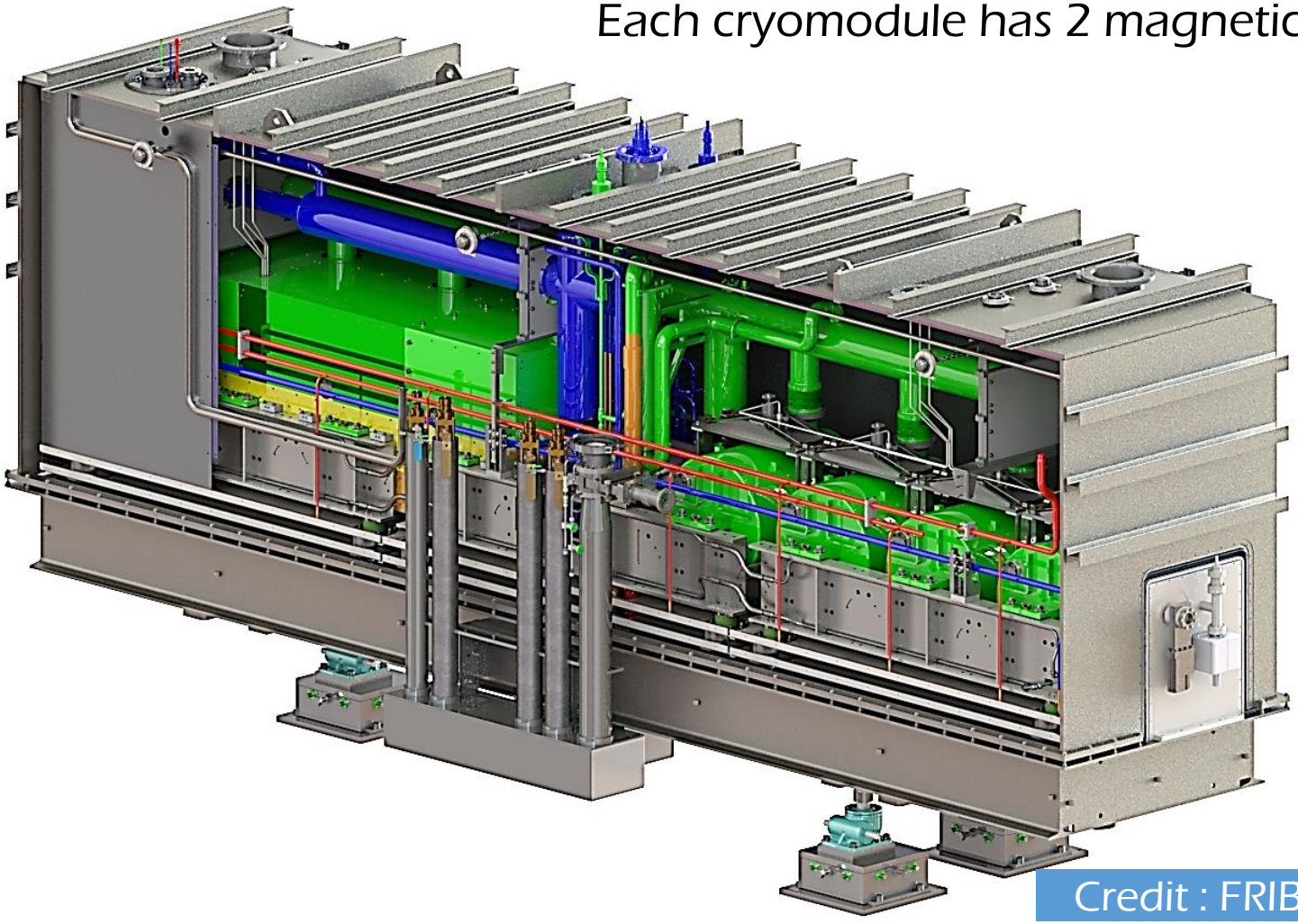
- β=0.53 ×18
- β=0.29 × 12
- β=0.041 × 4
- β=0.085 × 2 for beam calibration
- β=0.53 ×1 for beam calibration





2. Production process of magnetic shields

Magnetic shield for SRF cavity of FRIB
β= 0.53 Half Wave Cryomodule
Each cryomodule has 2 magnetic shields.



Credit : FRIB

2. Production process of magnetic shields

The steps and processes from planning to inspection

Design1	Basic design Performance, Shape, etc.	FRIB
Design2	Manufacture drawing (Parts design) Scheduling, review	FRIB+OHTAMA
Manufacturing1	QC design Material control (inspection)	OHTAMA
Manufacturing2	Sheet metal processing, Welding Heat treatment Assembly	OHTAMA
Test	Inspection (Dimension and Magnetic shield Performance)	OHTAMA

2. Production process of magnetic shields

Need to discuss and get ideas/specific details based on user's specifics and criteria.

Design1

Design2

Manufacturing1

Manufacturing2

Test

FRIB design

Inside remnant field ≦ 1.5μT (15mG)

Material : Mu-Metal μ≧9000@4.2-25K

Discussions

FRIB order (OHTAMA guarantee)

Reduce 80% geomagnetic field inside of the shields

To measure 18 points of magnetic field and report

Material : Mu-Metal (record BH data every annealing batch)

FRIB design

Basic design +Drawing

CAD data

OHTAMA

Manufacture drawing

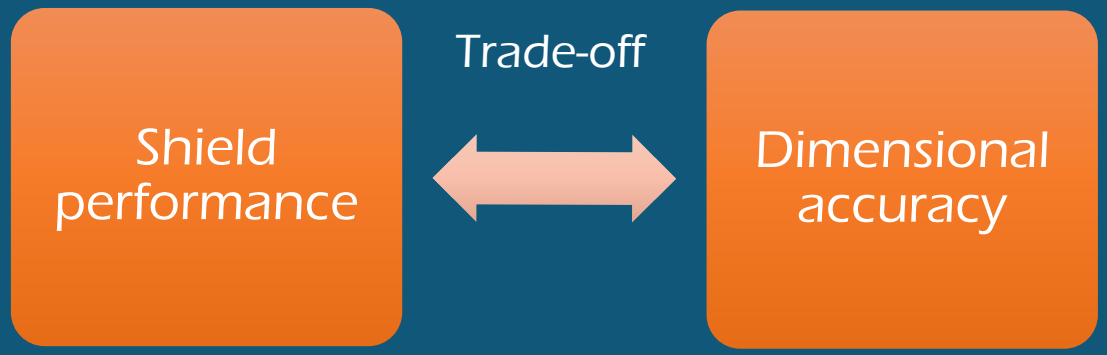
β=0.53 contains of total 200 parts/set

2. Production process of magnetic shields

Magnetic shield performance is generated by Heat treatment (Annealing)

The higher the temperature the better and the higher the magnetic properties will be.

Take note: The the higher the temperature the higher the risk of deforming the material.



Repairing deformation degrades performance.

2. Production process of magnetic shields

Depending on the size and quantity, the furnace type can be changed. Take note: Delivery times and cost will be variable.

Design1

Design2

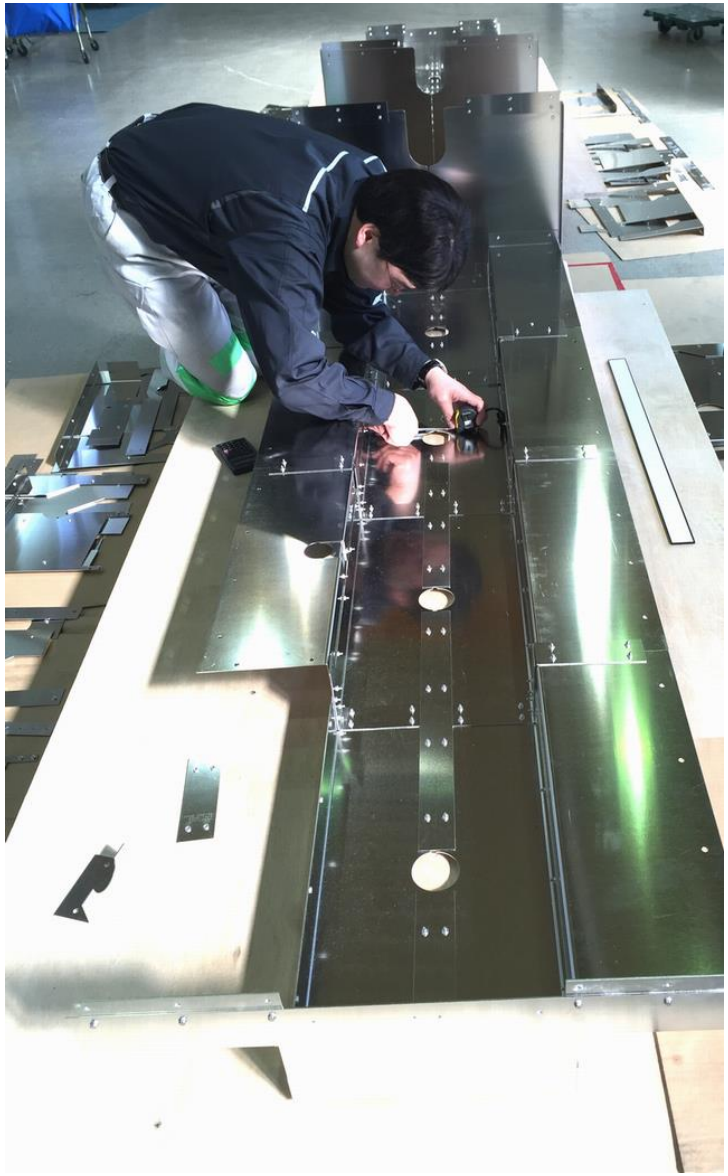
Manufacturing1

Manufacturing2

Test

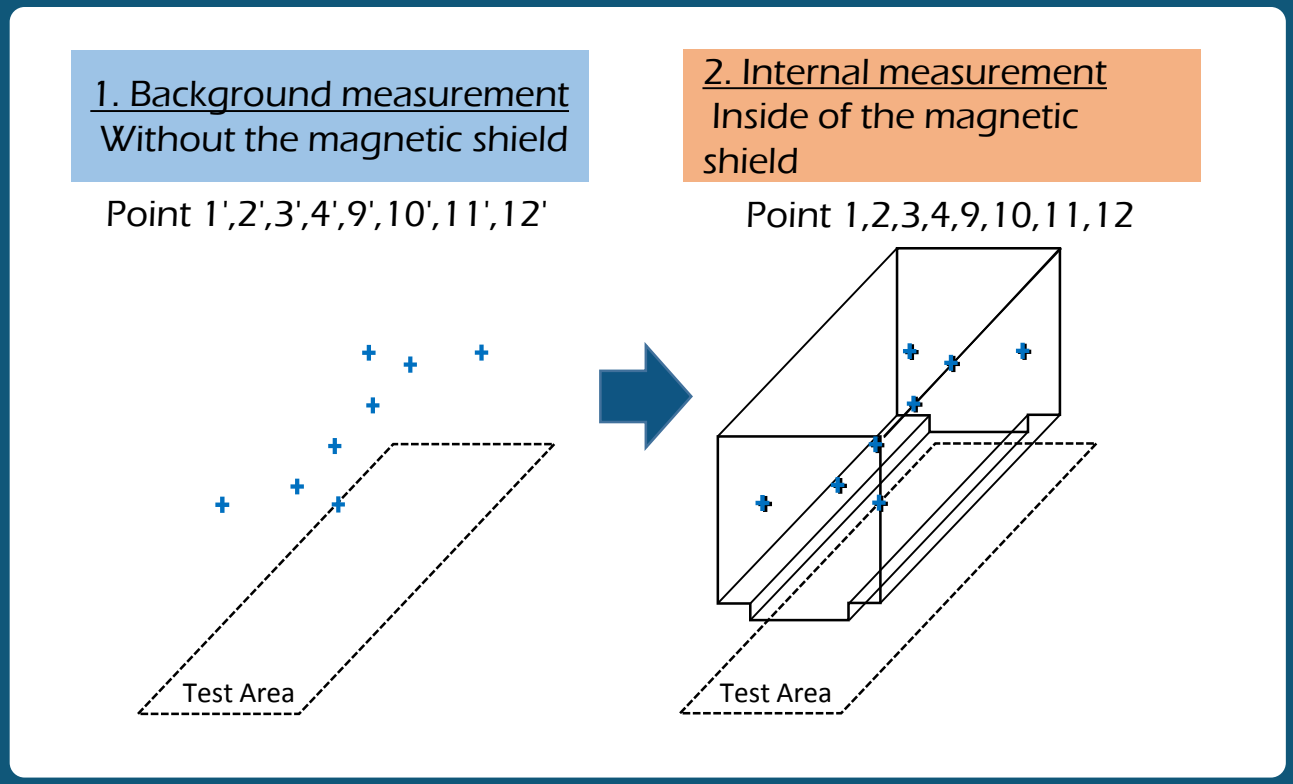
Furnace
Hydrogen gas atmosphere
1100 degrees Celsius
Keep 4 hours

3. Performance tests of DC magnetic shield



3. Performance tests of DC magnetic shield

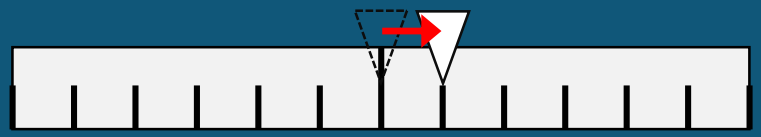
Magnetic shielding performance was evaluated by comparison of internal magnetic field and background (geomagnetic field).



3. Performance tests of DC magnetic shield

When Zero point is shifted, calibration is necessary.

Zero point may shift

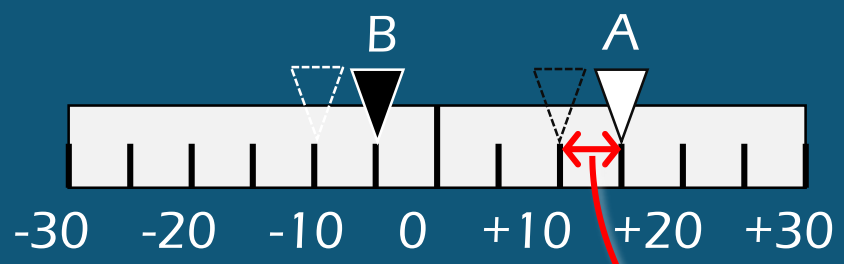


3 Axis sensor need to be adjusted each axis

Some magnetometers have Zero adjuster

3. Performance tests of DC magnetic shield

Calibration using Zero chamber

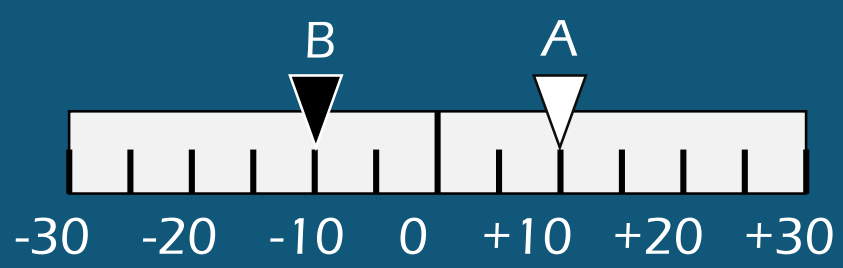


A+B≠0

A-B=2*C

Calibration

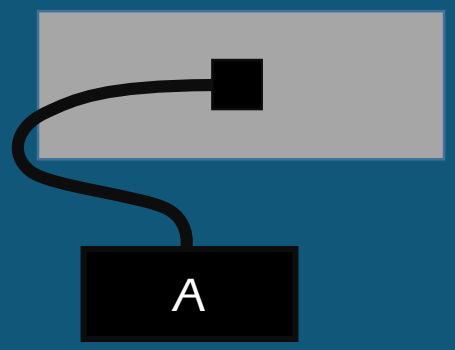
D=A-C

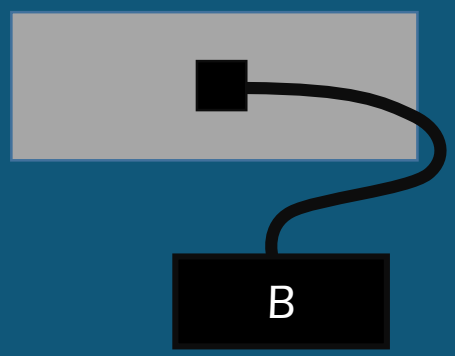


A+B=0

A-B=2*C

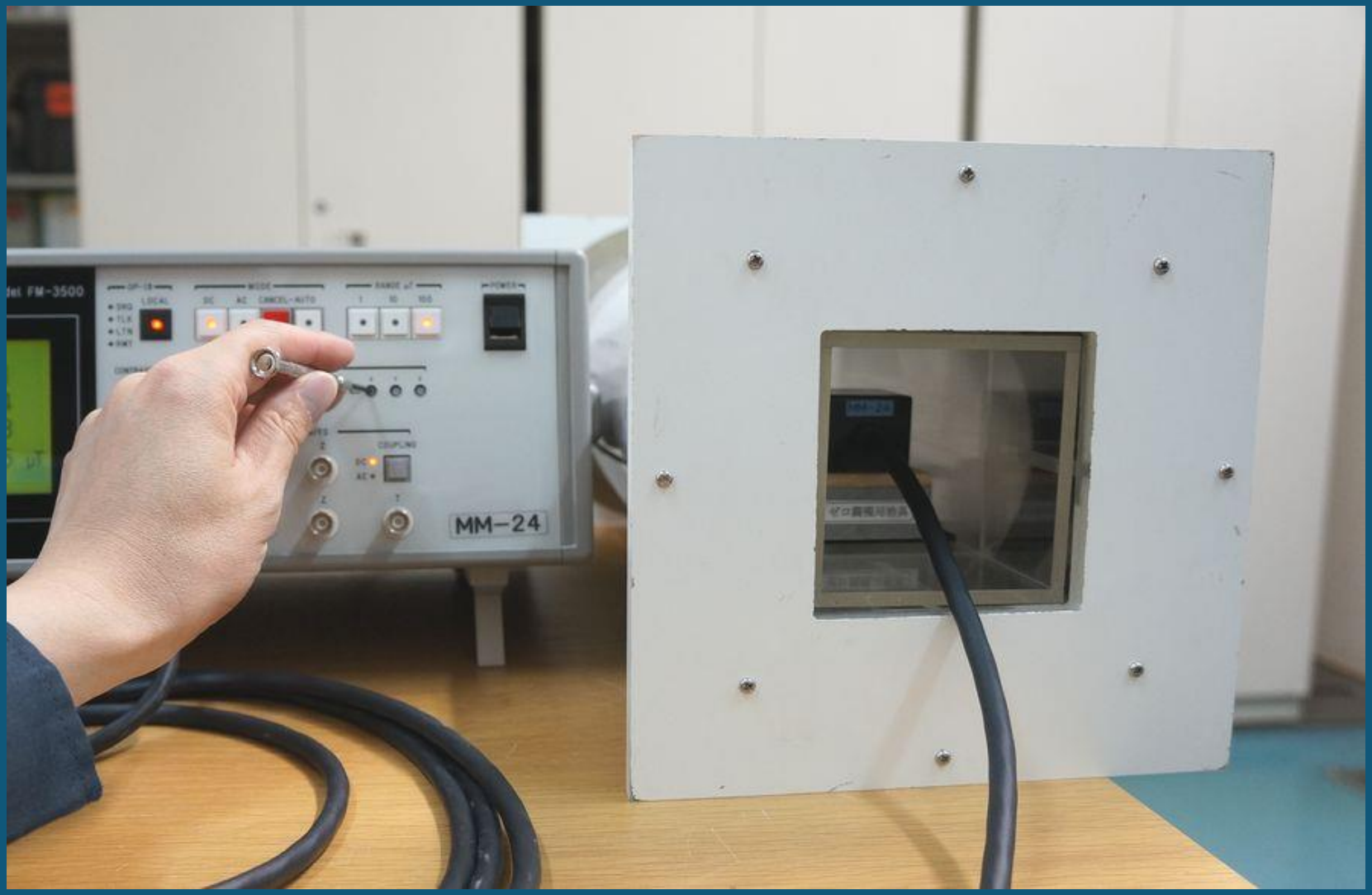
Center of Zero chamber is not zero (C remains)





3. Performance tests of DC magnetic shield

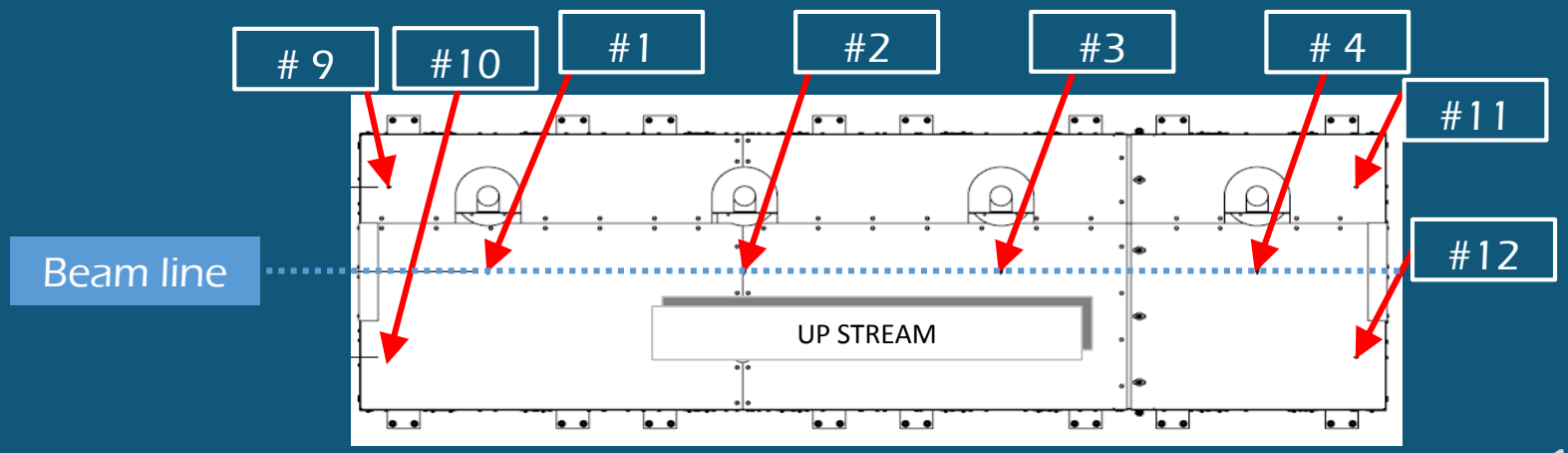
Calibration using Zero chamber



3. Performance tests of DC magnetic shield

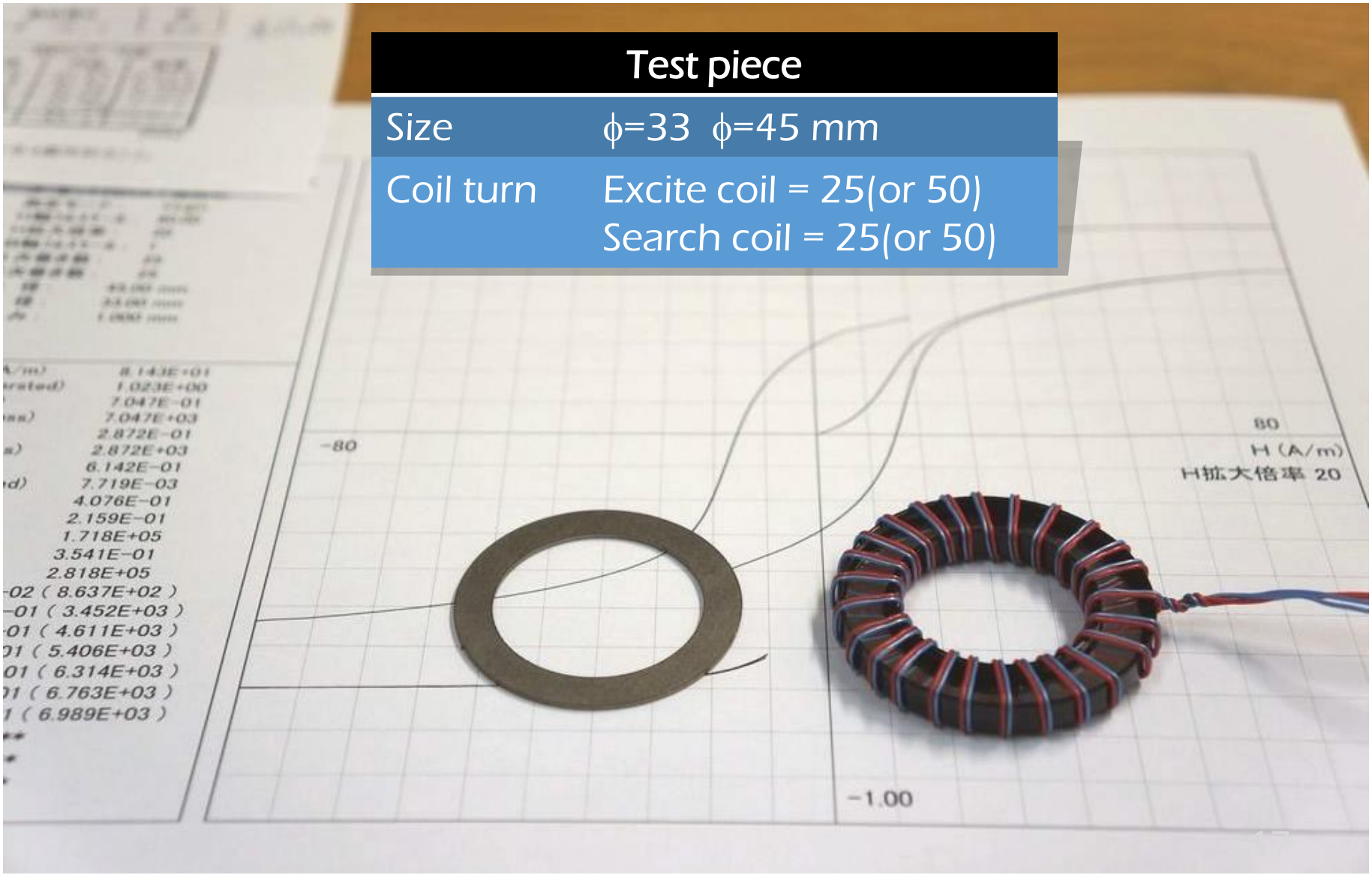
Result of magnetic shield performance test (@ room temperature)

MEASUREMENT POINT	BACKGROUND (without shield)(μT)	INTERNAL MEASUREMENT(μT)
POINT #1	42.88	0.33
POINT #2	43.40	0.37
POINT #3	41.37	0.40
POINT #4	39.83	0.42
POINT #9	41.46	0.15
POINT #10	42.91	0.32
POINT #11	39.42	0.26
POINT #12	39.18	0.23



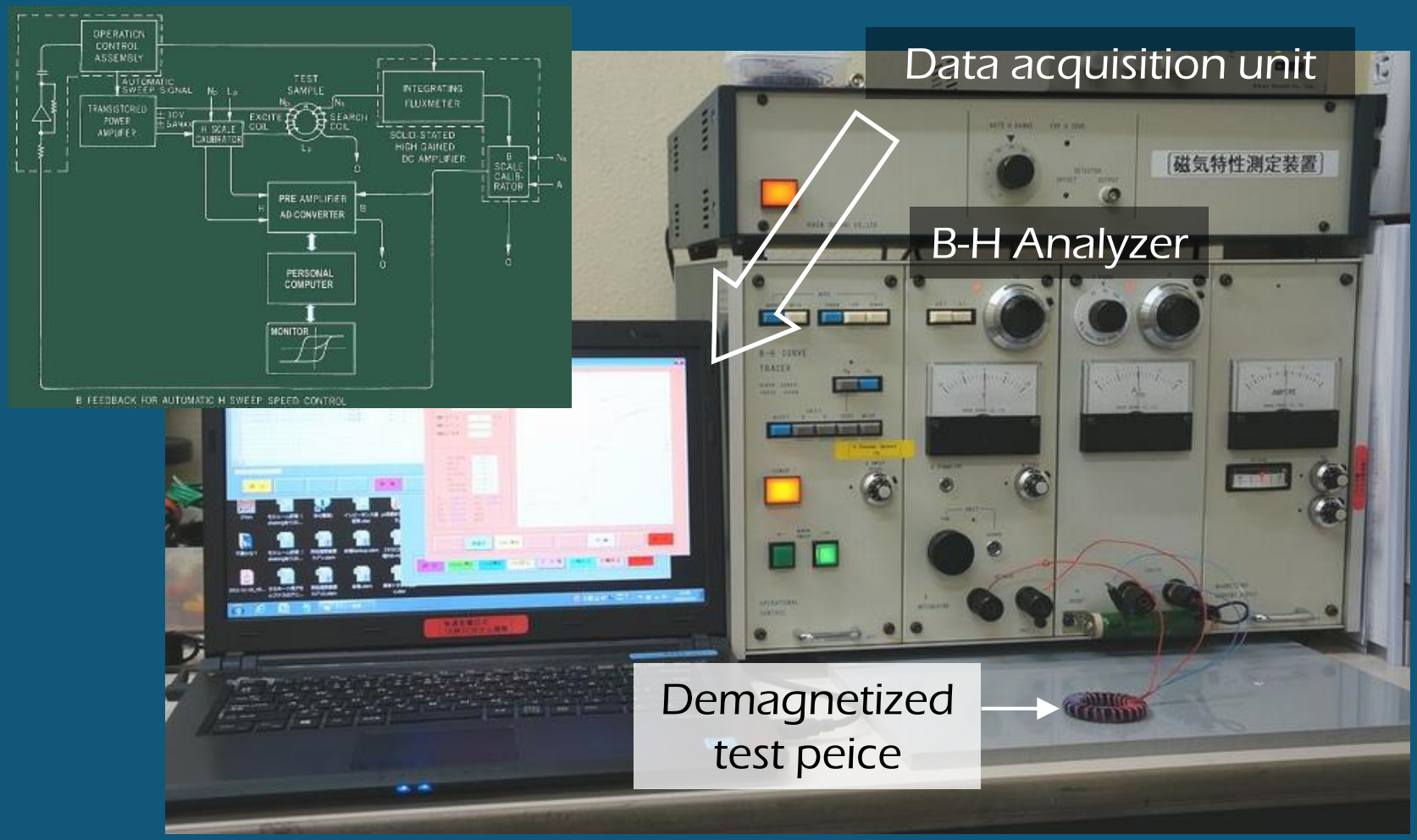
4. Measurement of magnetic properties

Test piece	
Size	ϕ=33 ϕ=45 mm
Coil turn	Excite coil = 25(or 50) Search coil = 25(or 50)



4. Measurement of magnetic properties

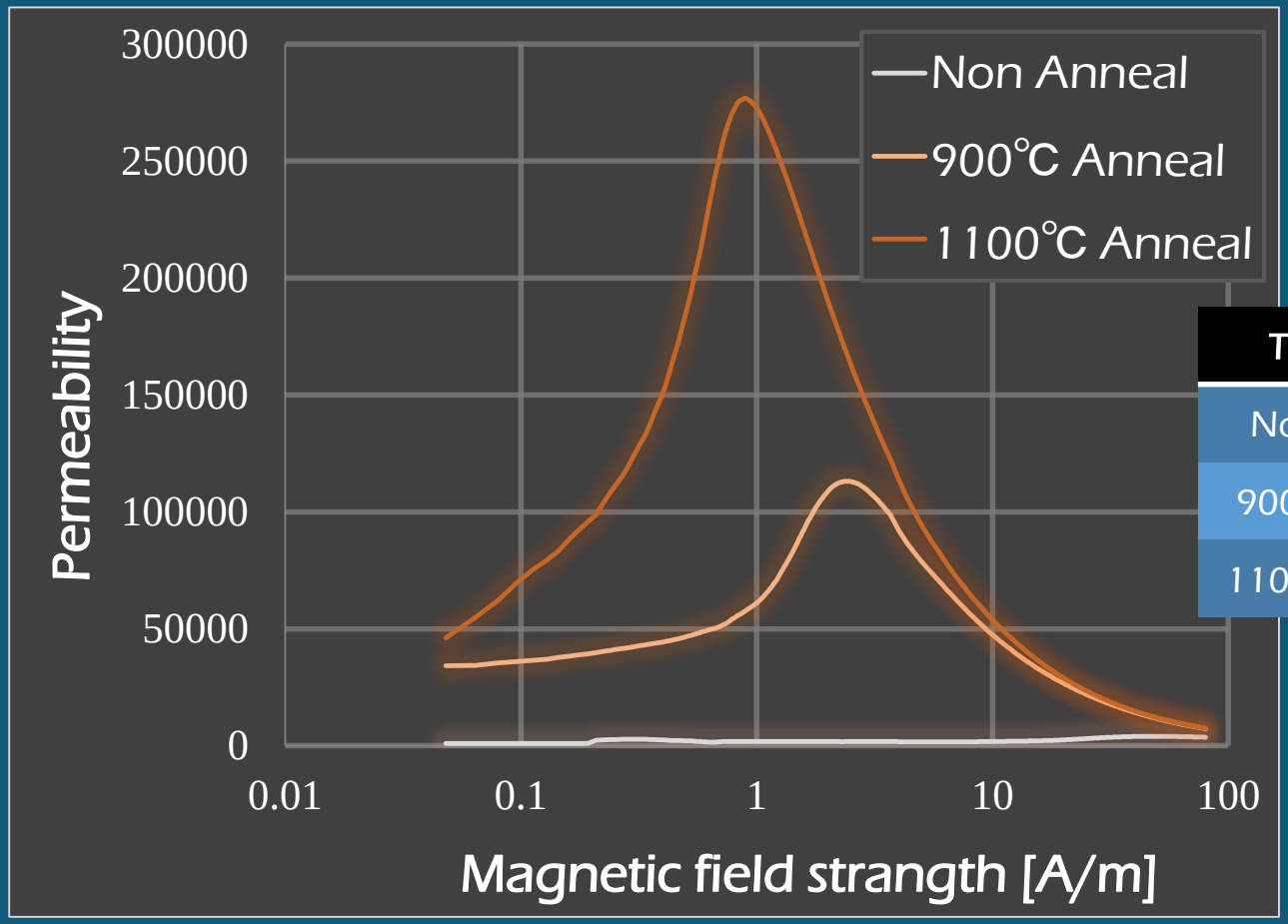
Using B-H analyzer, magnetic properties are recorded as B-H data, and permeability is calculated by computer analysis.



4. Measurement of magnetic properties

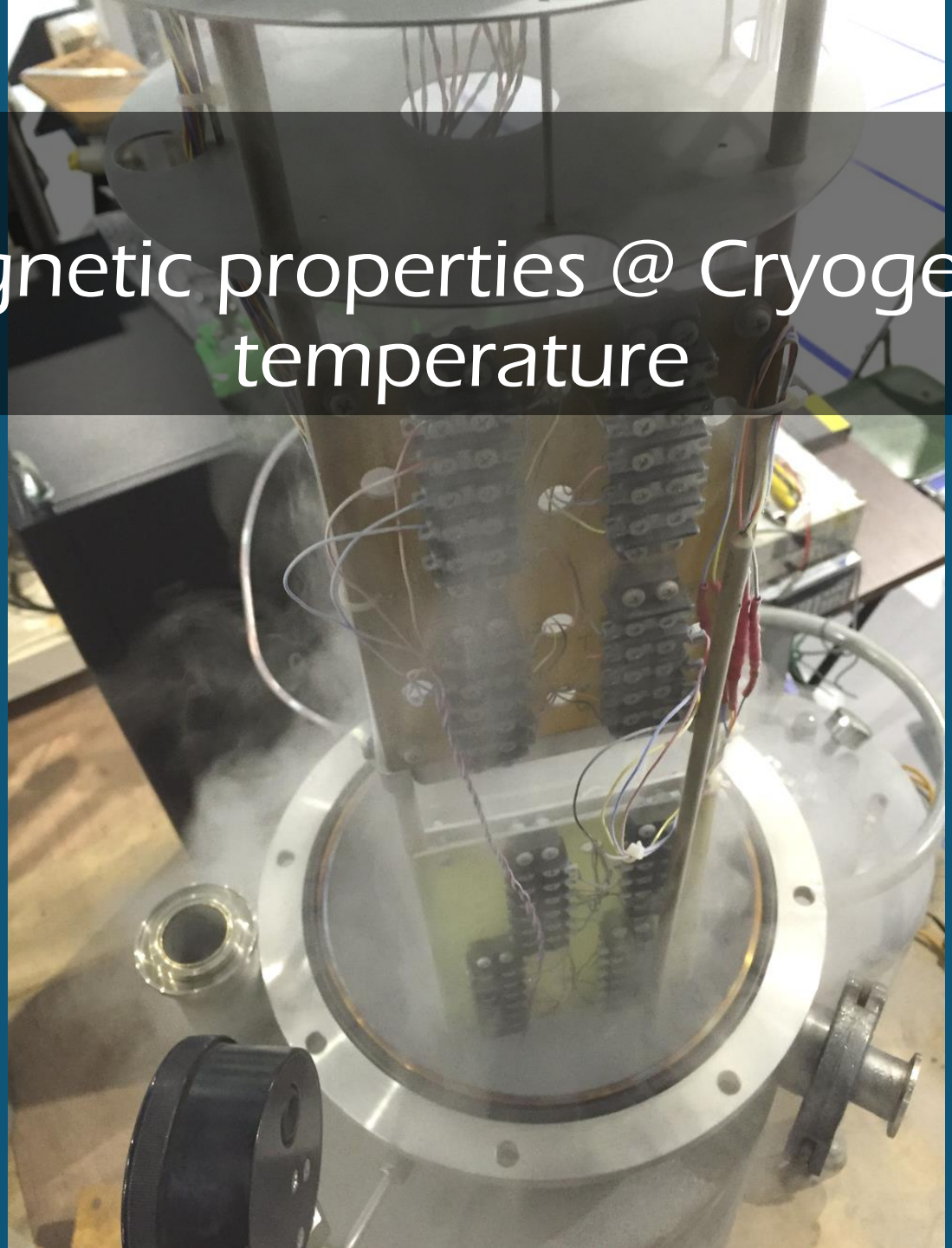
Magnetic properties are indicated by B-H hysteresis curves, μ-H curves or Hc and maximum value of B.

Example : Result of measurements (@R.T.)



Test piece	Hc [A/m]	B80 [T]
Non Anneal	28.2	0.368
900℃ Anneal	1.76	0.745
1100℃ Anneal	0.67	0.751

Magnetic properties @ Cryogenic temperature

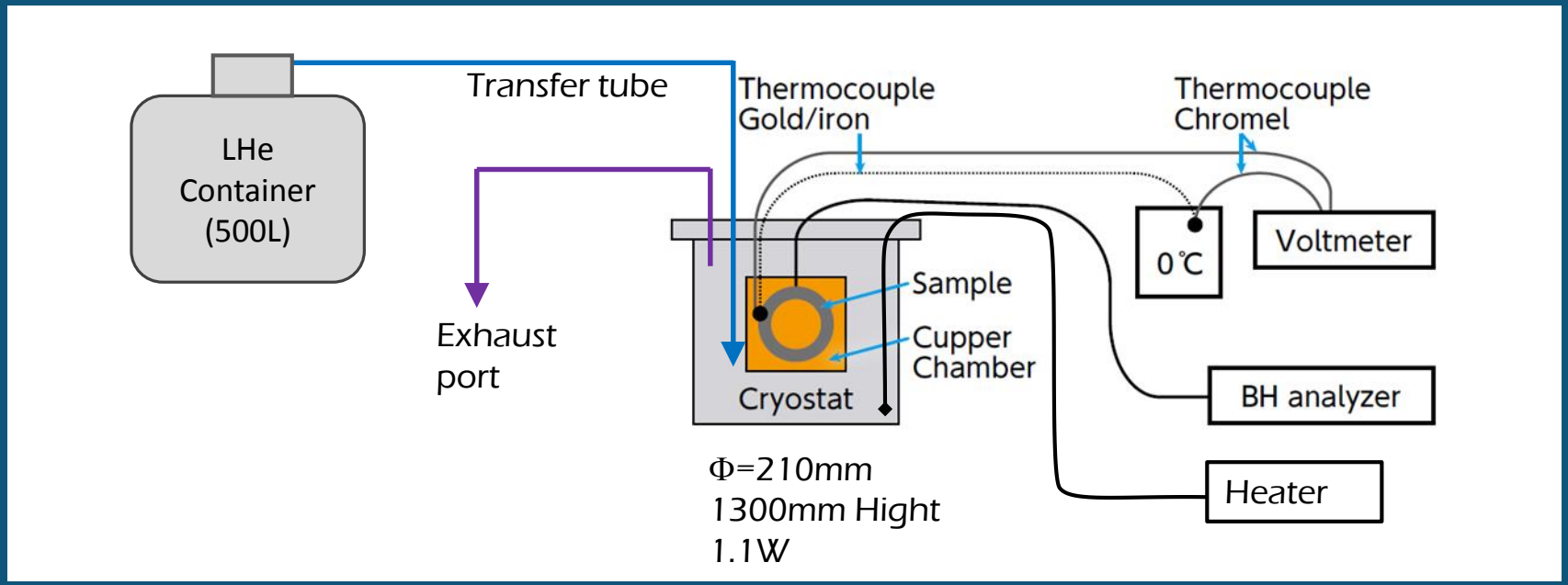


4. Measurement of magnetic properties

OHTAMA and KEK started a joint study. May 2016 – now
The study aims to improve magnetic properties by heat treatment technique.

Measuring magnetic properties at →

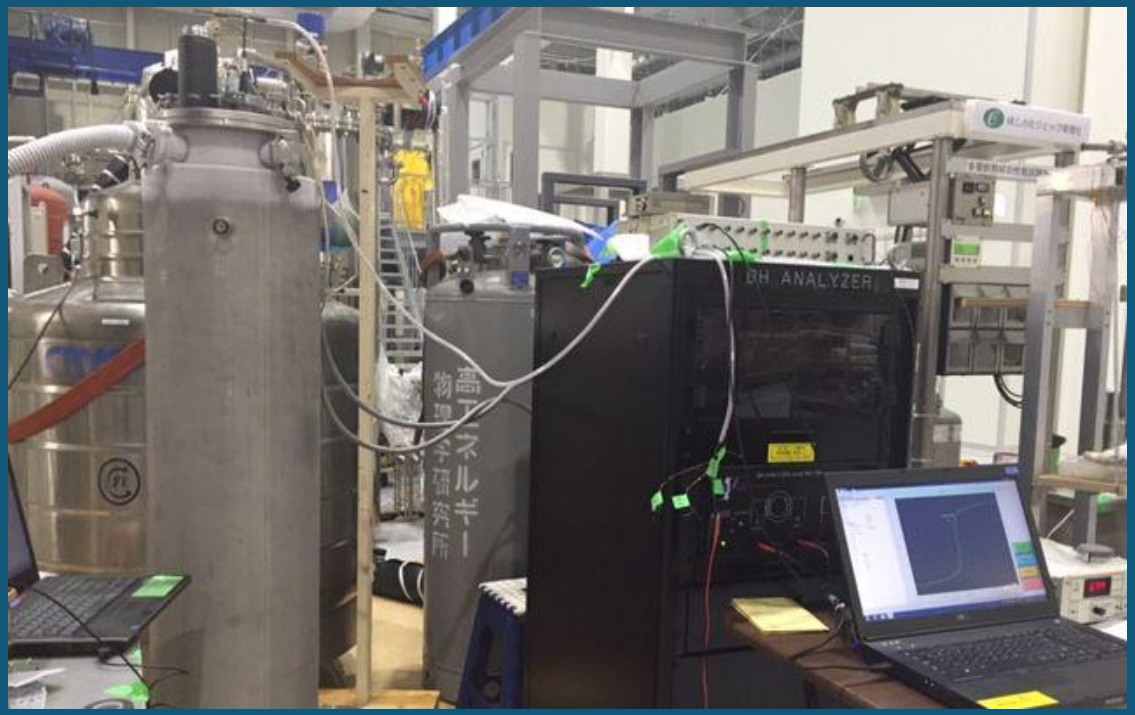
4.2K → 10K → 25K → 100K → 200K → R/T



4. Measurement of magnetic properties

Experiments are done at KEK facility

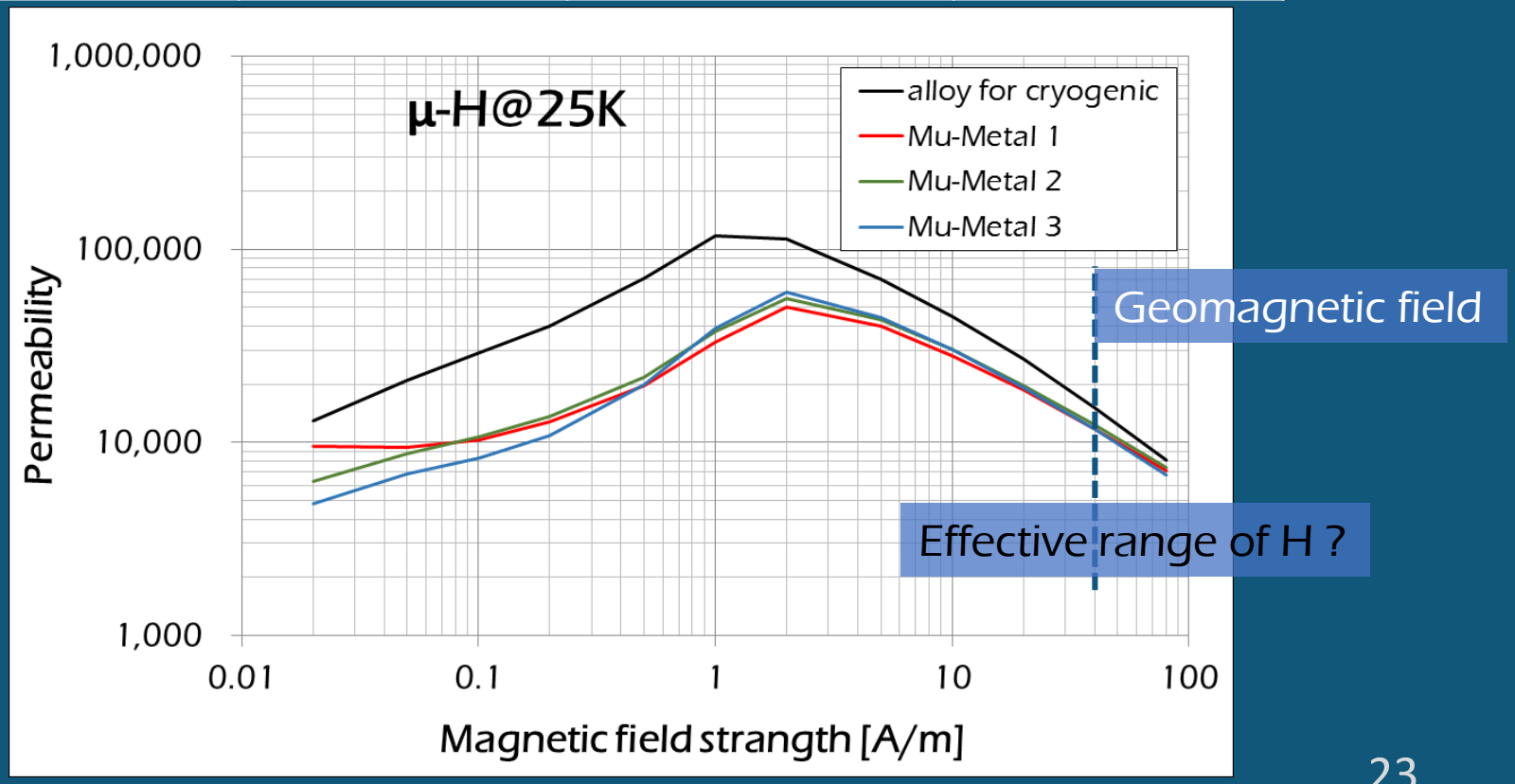
@KEK



4. Measurement of magnetic properties

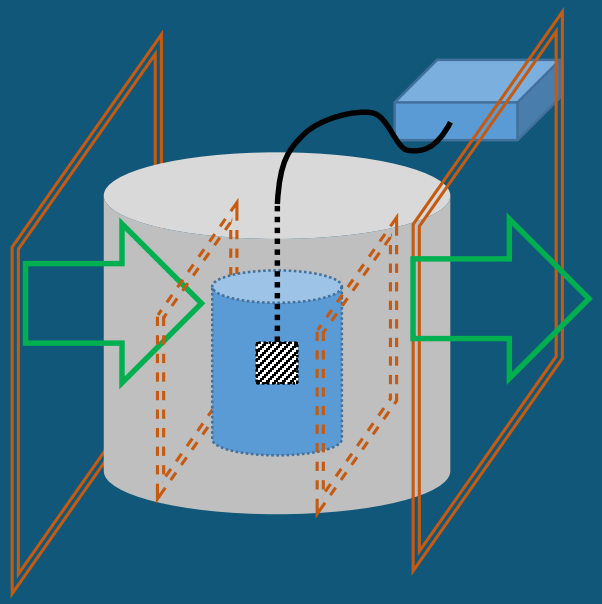
The result of heat treatment at 1170 ° C is shown. The result that Mu-Metal exceeds Cryogenic alloy has not been obtained yet.

Type	Annealing	μ@40A/m	Hc (A/m)
For cryogenic	1170℃	15,000	1.072
Mu-Metal1,2,3	1170℃	11,600 - 12,200	1.715 - 1.615



4. Measurement of magnetic properties

Future work



Data matching of B-H and shield performance

- Set a magnetic shield directly into the cryogenic temperature (LHe), and evaluate magnetic shielding performance, to make a match with the permeability.

Calibration of a flus gate sensor

- To ascertain th accuracy of a flux gate censor in cryogenic temperature, using a rotating coil.

5. Summary

1. For certain customized and specific orders you can talk to a maker.
2. Need discussions to share your ideas/specific details, to have a contract.
3. Magnetic shield performance is generated by heat treatment.(Higher the temperature the higher the risk of deforming)
4. When Zero point is shifted, calibration is necessary.
5. Study of improving magnetic properties by heat treatment, is in progress.

Thank you.