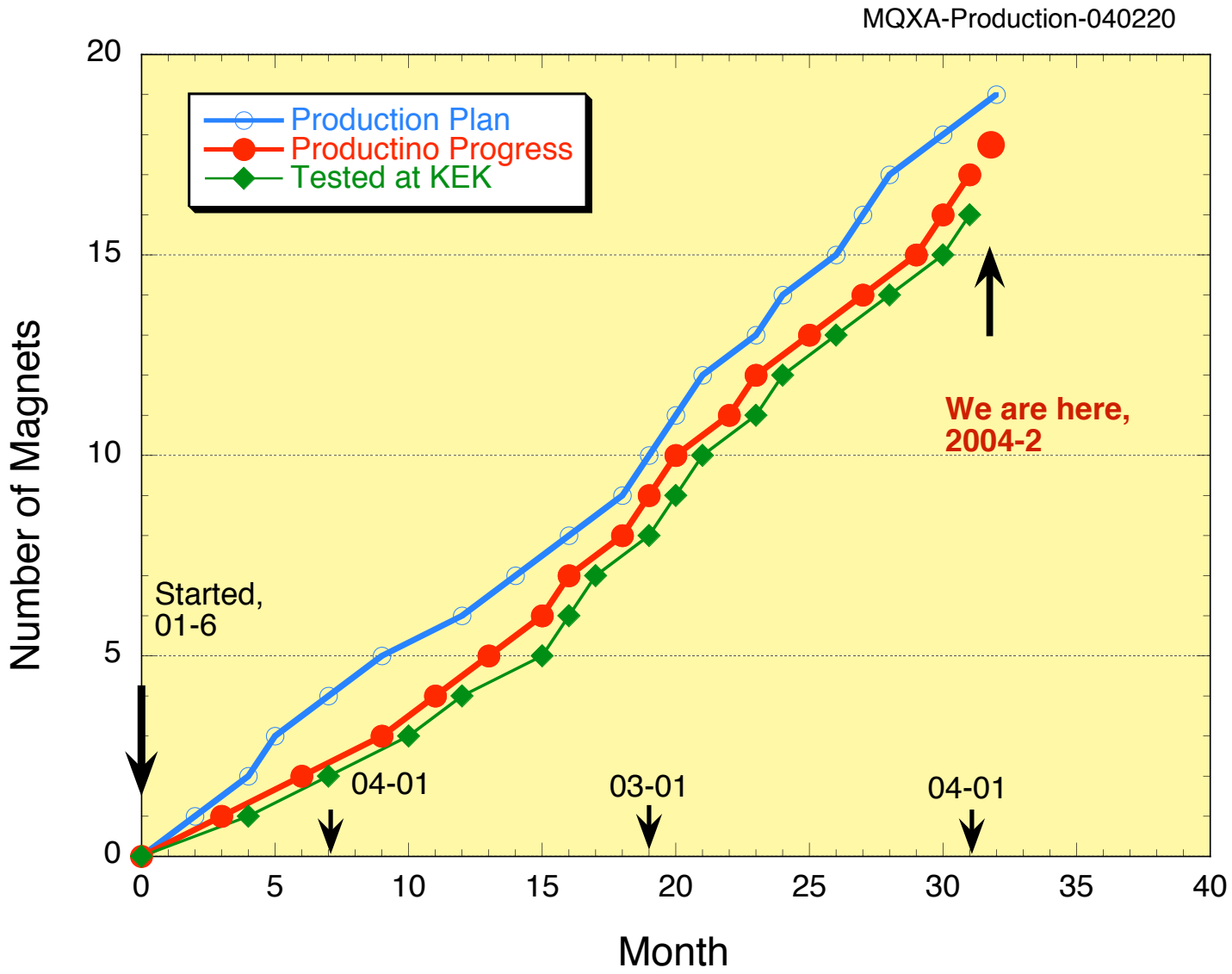
Status of MQXA Fabrication

Akira Yamamoto

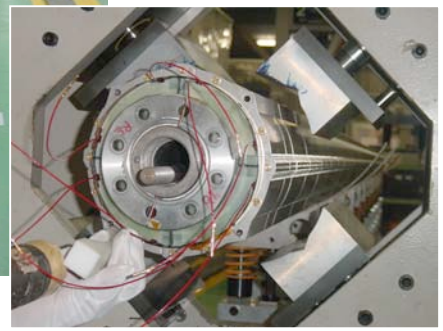
for KEK-Toshiba Cooperation

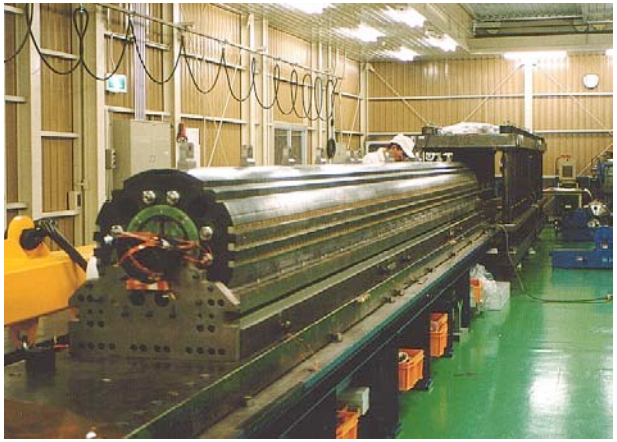
LHC Fermilab/CERN/KEK Collaboration Meeting, 2004-02-24

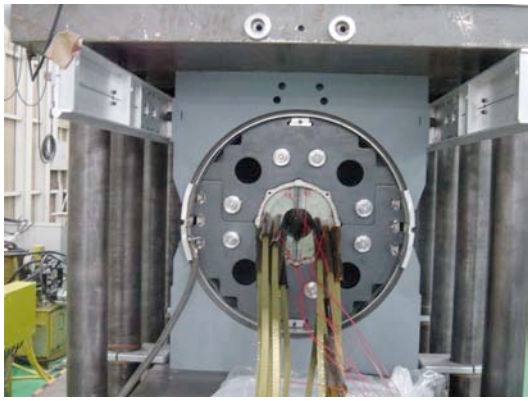
MQXA Production and Test



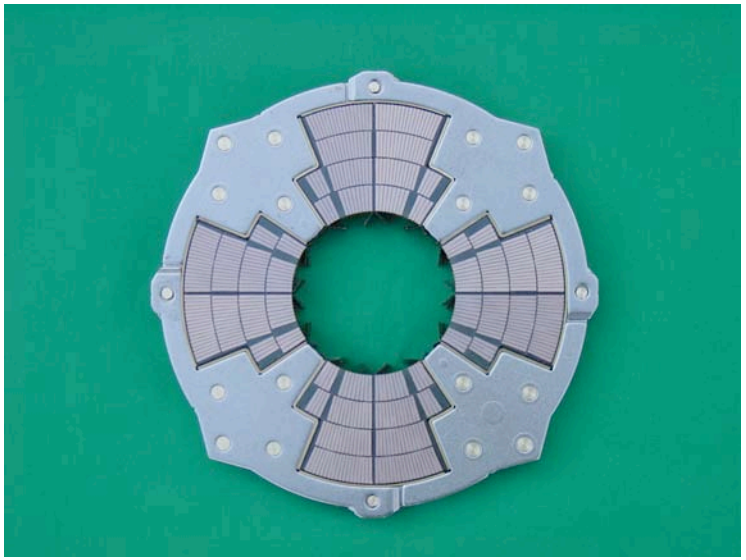
MQXA Production

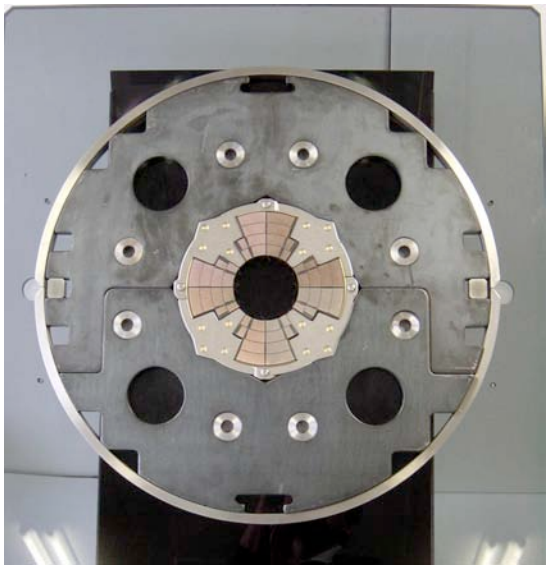






MQXA Magnet



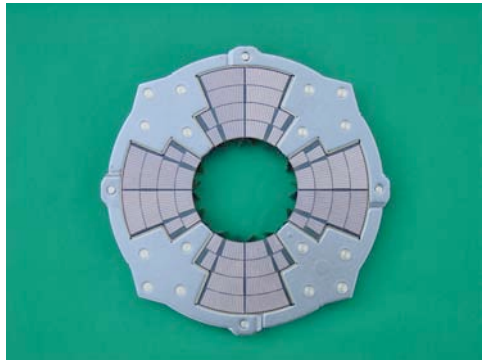


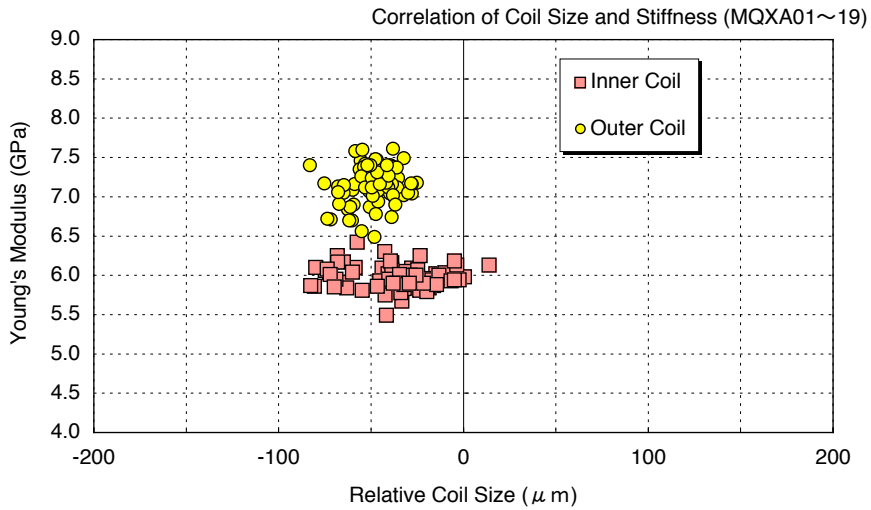
General Status

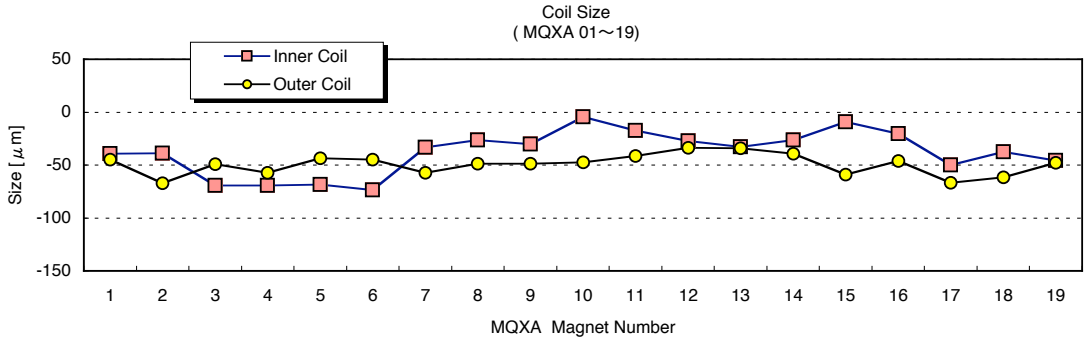
- 18 magnets completed at Toshiba,
- 17 magnets delivered to KEK,
- 16 magnets tested at KEK,
- 13 magnets delivered to Fermilab,

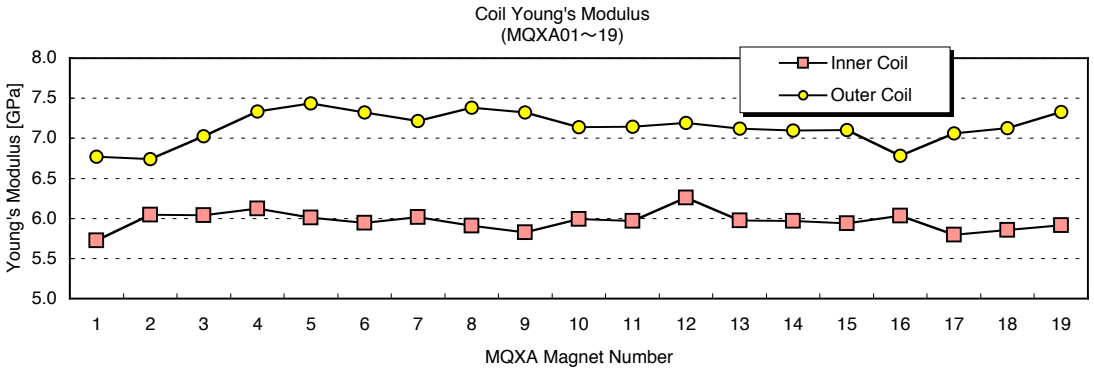
- MQXA-17 test in progress at KEK,

Coil Size




Correlation of Coil Size and Stiffness (MQXA01～19)
Inner Coil
Outer Coil
Young's Modulus (GPa)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
-200
-100
0
100
200
Relative Coil Size (μm)

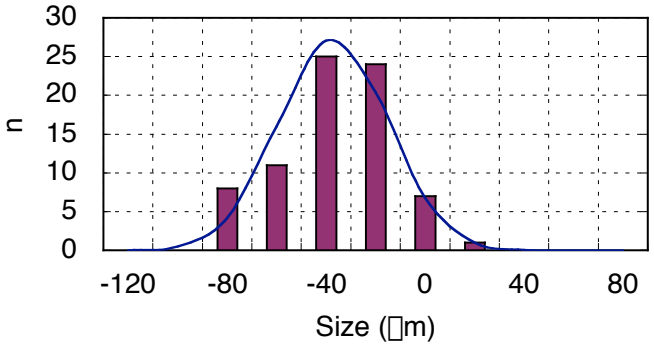

Coil Size
(MQXA 01～19)
Inner Coil
Outer Coil
Size [μm]
50
0
-50
-100
-150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number


Coil Young's Modulus
(MQXA01～19)
Inner Coil
Outer Coil
Young's Modulus [GPa]
8.0
7.5
7.0
6.5
6.0
5.5
5.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number

Coil Size and Rigidity

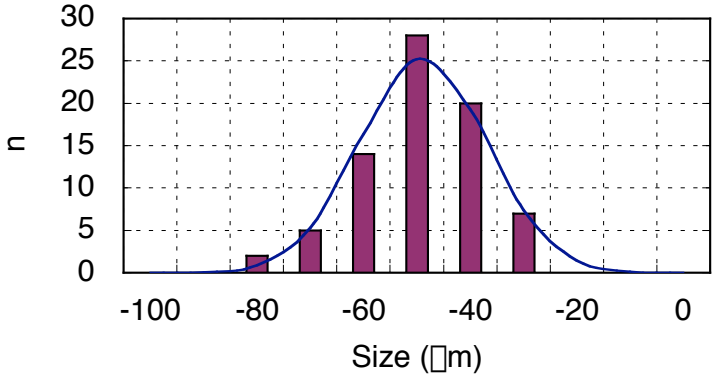
Inner Coil Size
Average = -37 @54MPa

1□ = 22 □m



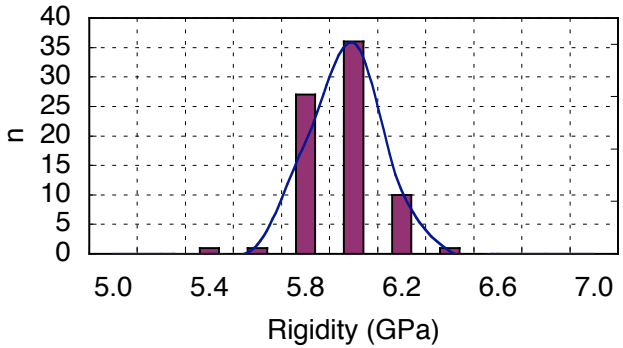
Outer Coil Size
Average = -49 @54MPa

1□ = 12 □m



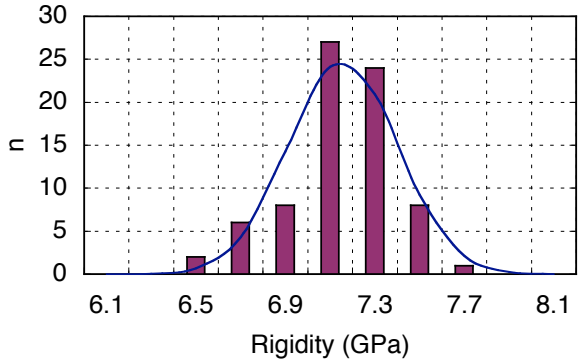
Inner Coil Young's Modulus
Average = 6.0 GPa
1□=0.15 GPa

1□ = 0.15 GPa

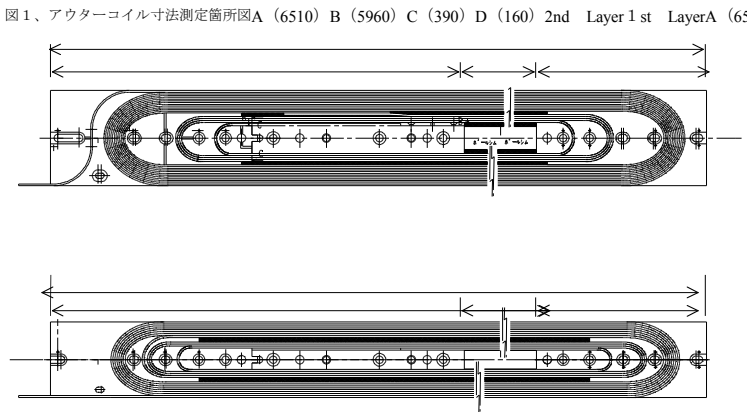


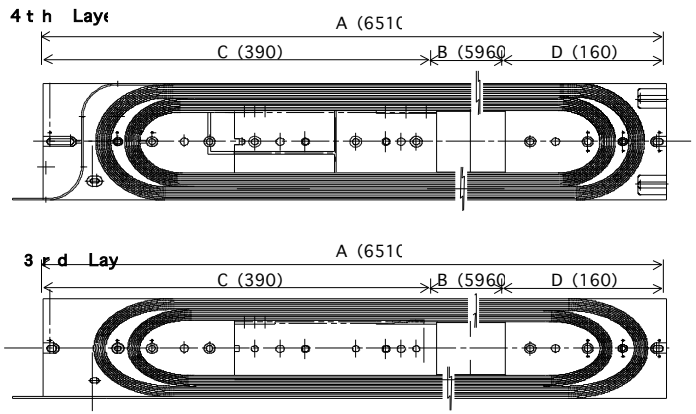
Inner Coil Young's Modulus
Average = 7.2 GPa

1□ = 0.24 GPa



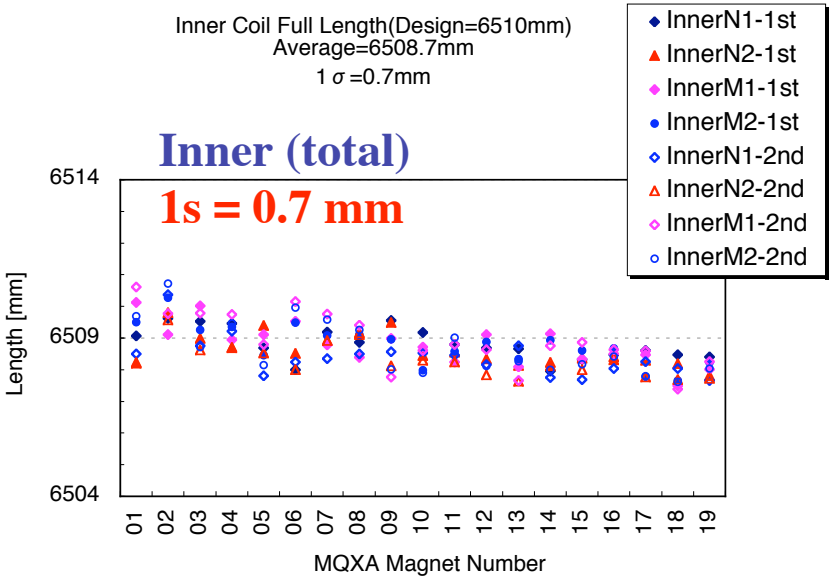
Coil Length

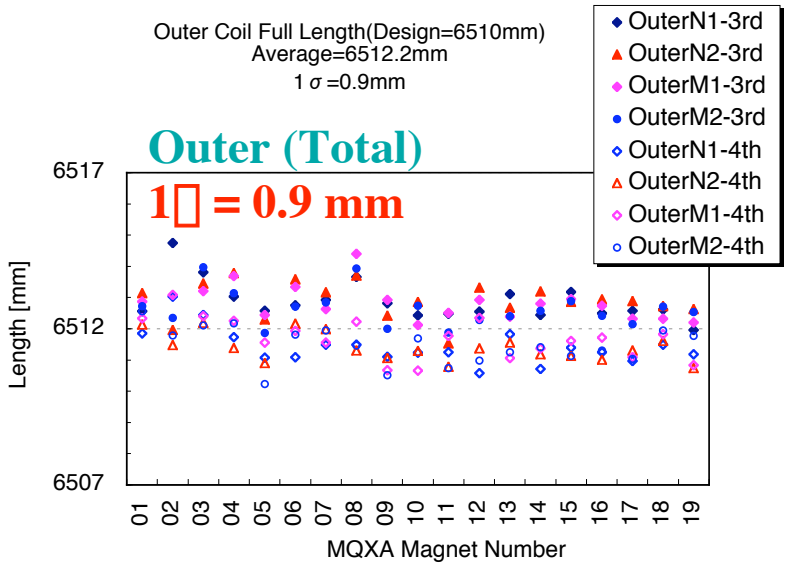


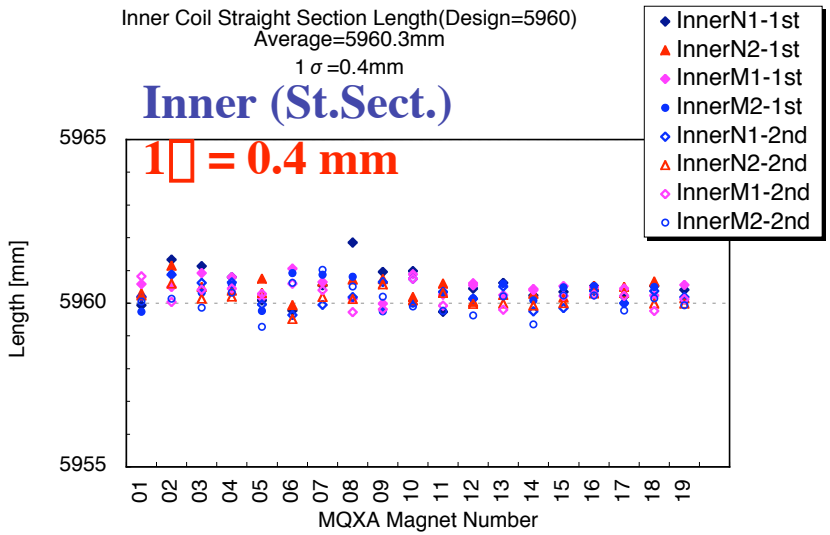


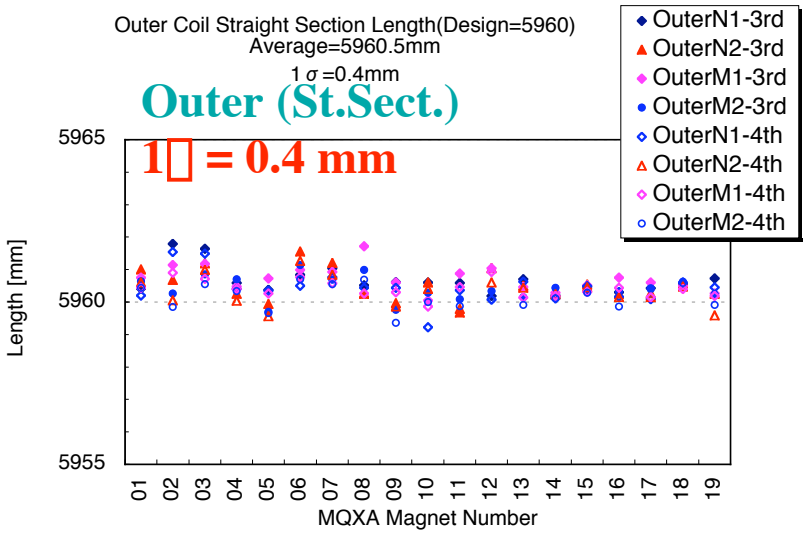
	Inner	Outer
• Total Length = 6510 mm	6509.7 (1□ = 0.7)	6512.2 (1□ = 0.9)
• St. Section = 5960 mm	5960.3 (1□ = 0.4)	5960.5 (1□ = 0.4)

Coil Length


Inner Coil Full Length(Design=6510mm)
Average=6508.7mm
1 σ =0.7mm
Inner (total)
1s = 0.7 mm
InnerN1-1st
InnerN2-1st
InnerM1-1st
InnerM2-1st
InnerN1-2nd
InnerN2-2nd
InnerM1-2nd
InnerM2-2nd
Length [mm]
6514
6509
6504
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number

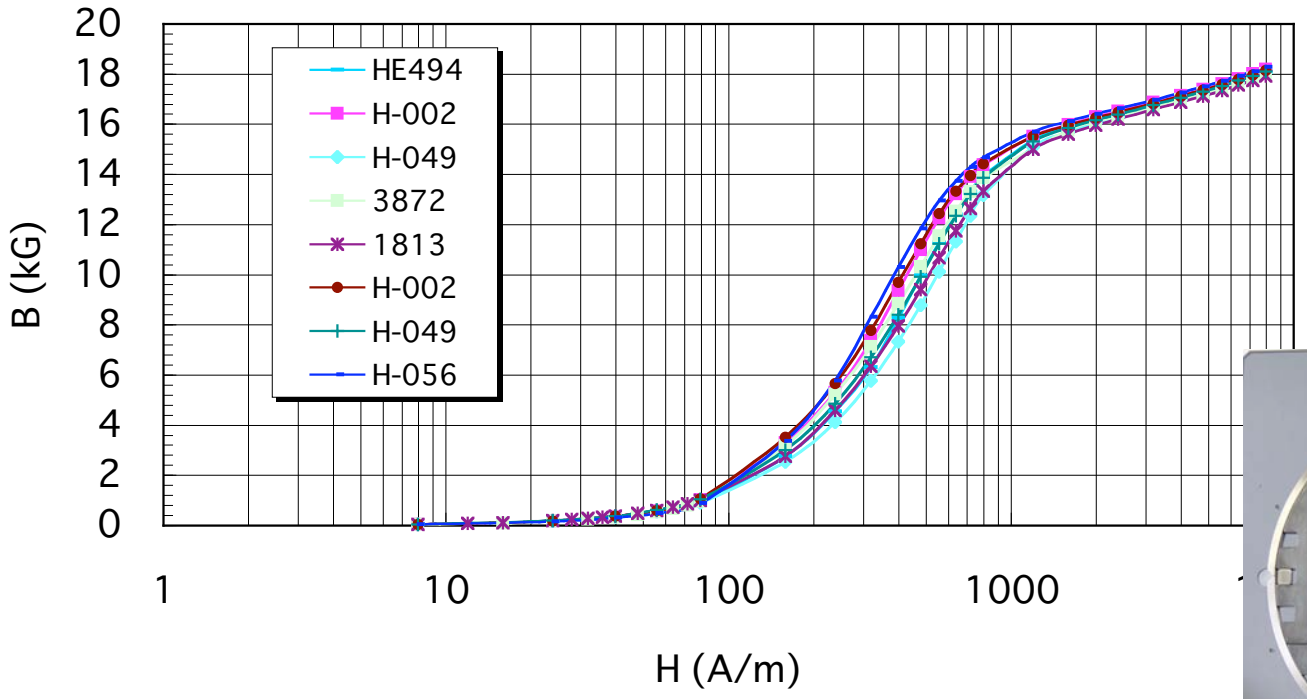

Outer Coil Full Length(Design=6510mm)
Average=6512.2mm
1 σ =0.9mm
Outer (Total)
1 = 0.9 mm
OuterN1-3rd
OuterN2-3rd
OuterM1-3rd
OuterM2-3rd
OuterN1-4th
OuterN2-4th
OuterM1-4th
OuterM2-4th
Length [mm]
6517
6512
6507
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number

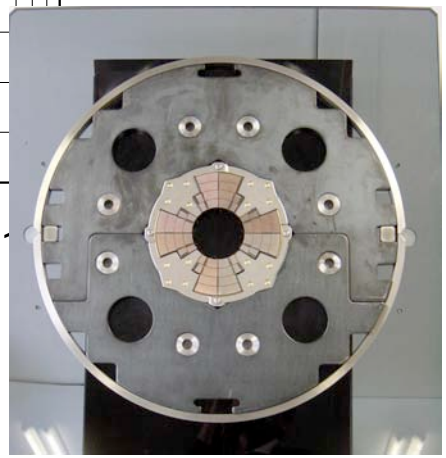

Inner Coil Straight Section Length(Design=5960)
Average=5960.3mm
1 σ =0.4mm
Inner (St.Sect.)
1 = 0.4 mm
InnerN1-1st
InnerN2-1st
InnerM1-1st
InnerM2-1st
InnerN1-2nd
InnerN2-2nd
InnerM1-2nd
InnerM2-2nd
Length [mm]
5965
5960
5955
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number


Outer Coil Straight Section Length(Design=5960)
Average=5960.5mm
1 σ =0.4mm
Outer (St.Sect.)
1 = 0.4 mm
OuterN1-3rd
OuterN2-3rd
OuterM1-3rd
OuterM2-3rd
OuterN1-4th
OuterN2-4th
OuterM1-4th
OuterM2-4th
Length [mm]
5965
5960
5955
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
MQXA Magnet Number

B-H Curves of Iron Yoke

Magnetic Characteristic of Yoke Material
B-H Curve @RT (For MQXA01～19)

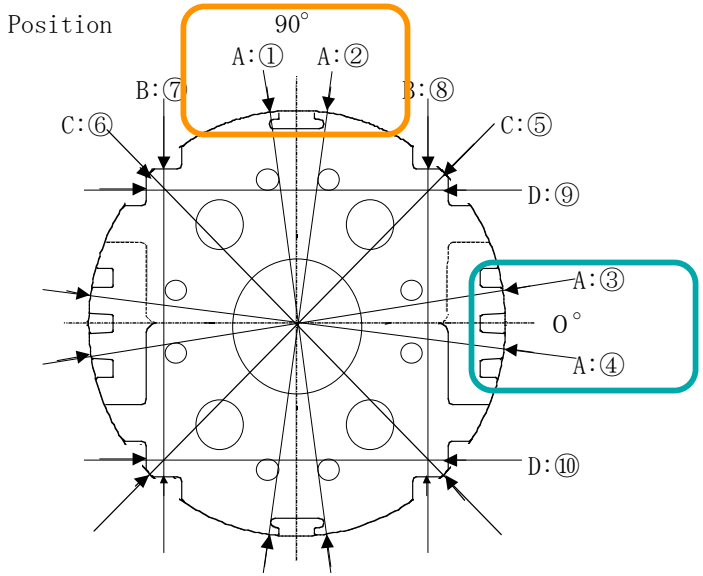


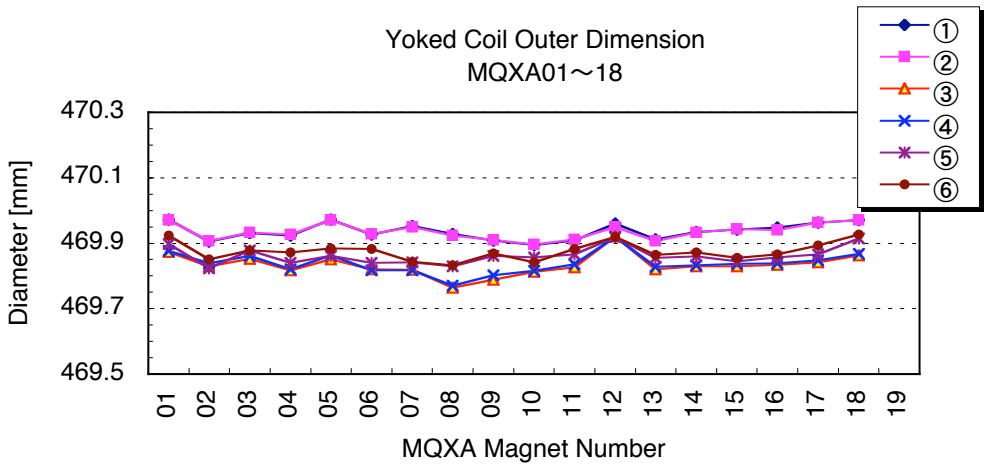


- For MQXA-01 - 19

Yoke Diameter

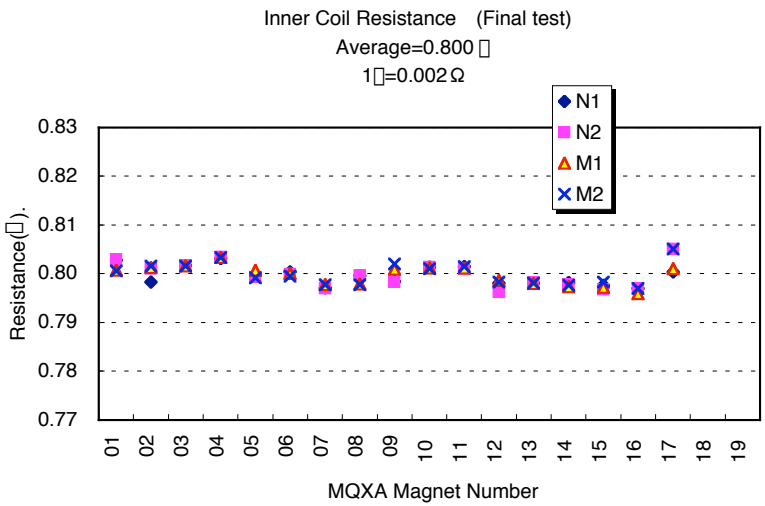
Outer Dimension of Yoked Coil Cross Section	Outer Dimension of Yoked Coil Cross Section	Outer Dimension of Yoked Coil Cross Section	Outer Dimension of Yoked Coil Cross Section
MQXA01～18	MQXA01～18		
Point	Design	Average	1 σ
①	470	469.93	0.03
②	470	469.93	0.03
③	470	469.83	0.03
④	470	469.84	0.03
⑤	470	469.86	0.03
⑥	470	469.87	0.03
⑦	340	339.93	0.02
⑧	340	339.93	0.02
⑨	340	340.02	0.02
⑩	340	340.02	0.02

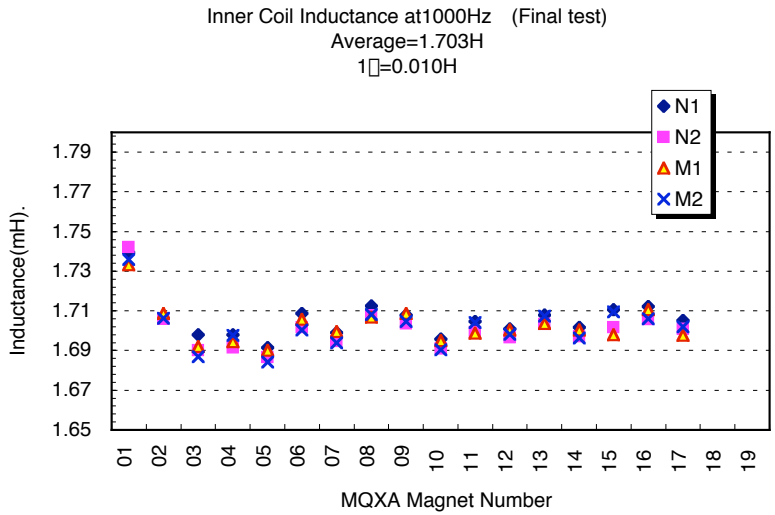




Y - X = ~ 0.1 mm

Coil Resistance and Inductance

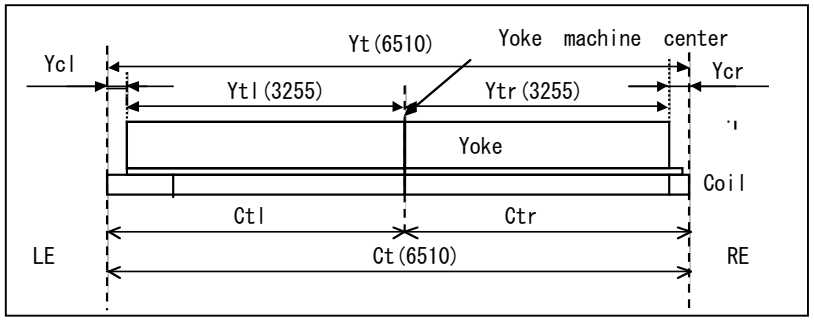


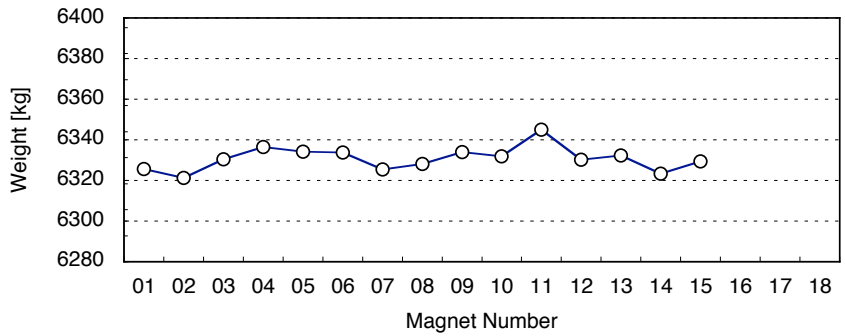


- Resistance (@ RT) = 0.8 □ (1 □ = 0.002 □)
- Inductance (@ 1 kHz) = 1.703 H (1□ = 0.01 H)

Yoke Length

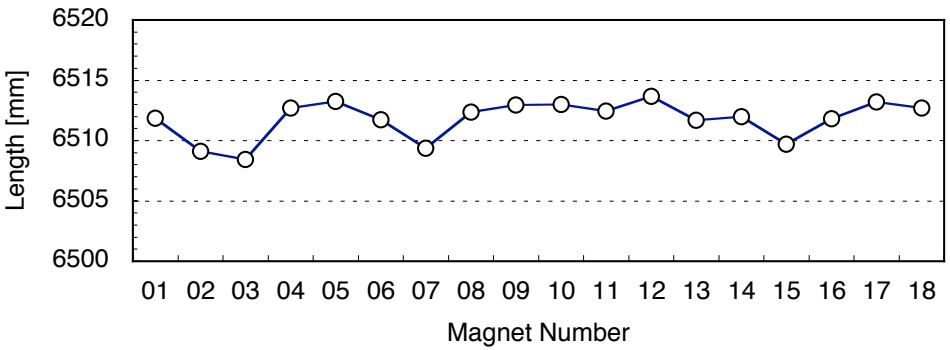
Weight = 6331 kg (1□ = 6 kg)

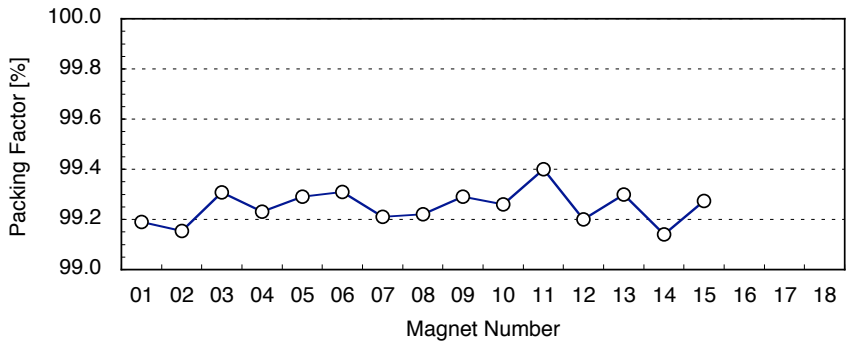




Length = 6511.8 mm (1□ = 1.9 mm)

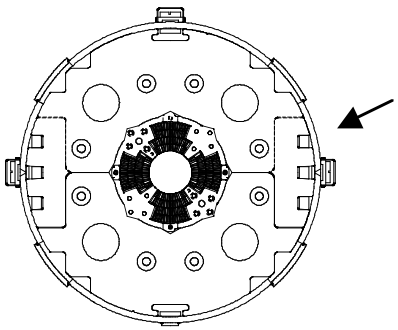
Pack. Factor = 99.25 % (1□ = 0.07 %)



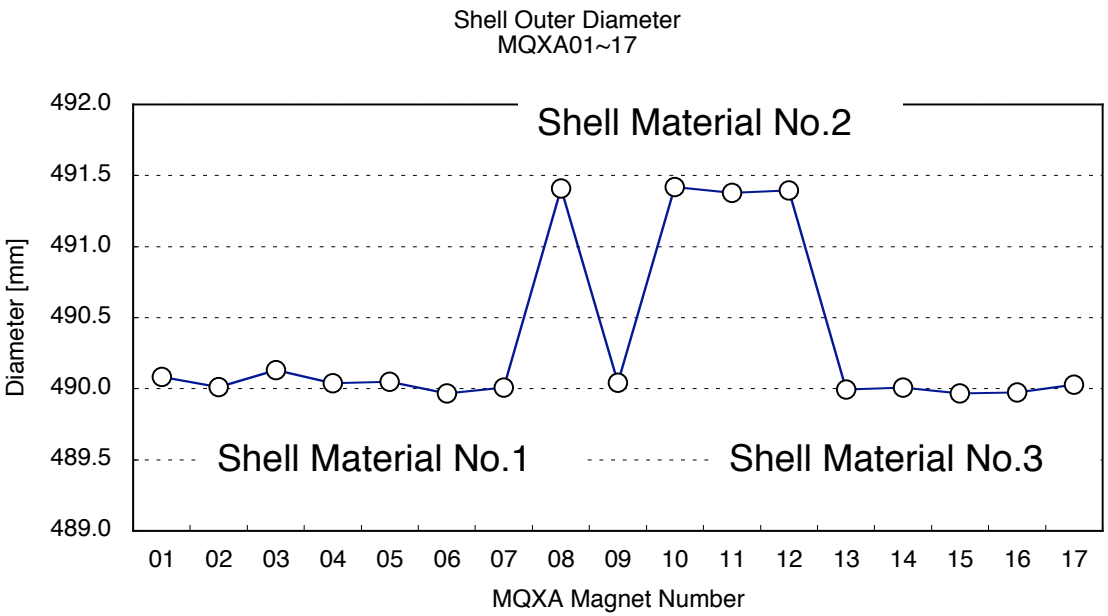


Outer Diameter of Cylinders

Measurement Point90° 0°



Outer diameter: 490 mm

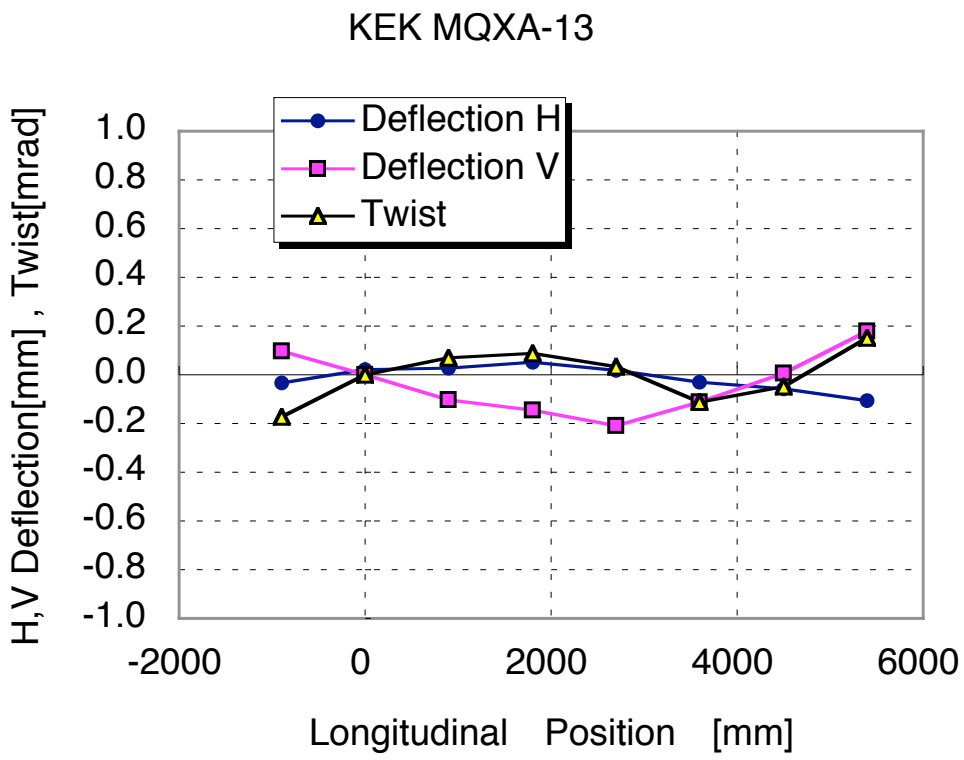


- Stainless steel plates provided in three batch.

Straightness and Twist

MQXA13

Position	Horizontal	Vertical	Twist
mm	mm	mm	mrad
-900	-0.03	0.10	-0.17
0	0.02	0.00	0.00
899	0.03	-0.10	0.07
1799	0.05	-0.15	0.09
2700	0.02	-0.21	0.03
3598	-0.03	-0.11	-0.11
4498	-0.06	0.01	-0.05
5397	-0.10	0.18	0.15

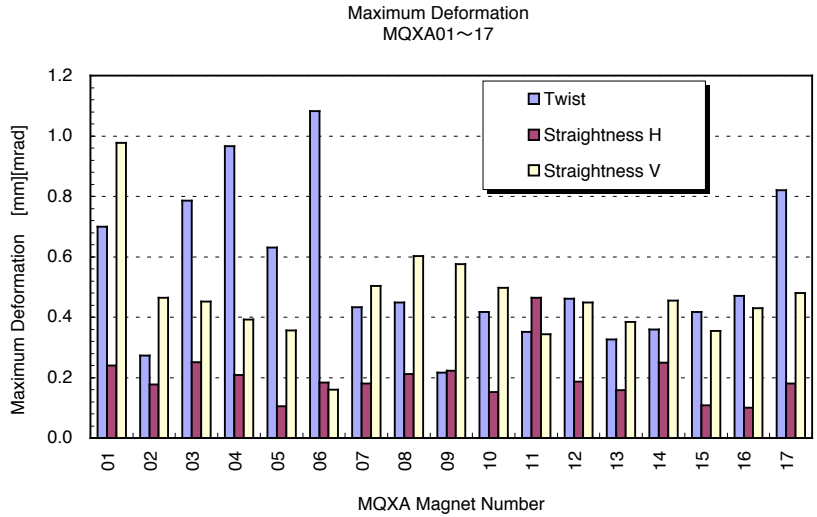


- Typical conditions in final assembly before delivering to KEK

Assembly

Twist & Straightness at Toshiba

	Twist	Strightness H	Strightness V
	mrad	mm	mm
MQXA-01	0.70	0.24	0.98
MQXA-02	0.27	0.18	0.46
MQXA-03	0.79	0.25	0.45
MQXA-04	0.97	0.21	0.39
MQXA-05	0.63	0.11	0.36
MQXA-06	1.08	0.18	0.16
MQXA-07	0.43	0.18	0.50
MQXA-08	0.45	0.21	0.60
MQXA-09	0.22	0.22	0.58
MQXA-10	0.42	0.15	0.50
MQXA-11	0.35	0.46	0.34
MQXA-12	0.46	0.19	0.45
MQXA-13	0.33	0.16	0.39
MQXA-14	0.36	0.25	0.46
MQXA-15	0.42	0.11	0.36
MQXA-16	0.47	0.10	0.43
MQXA-17	0.82	0.18	0.48
average	0.54	0.20	0.46
1 σ	0.25	0.08	0.17



Summary of Production Stability

	Reference	Av-meas	1 □	unit
Coil Size (inn/out)		-37/-49	-12 / -22	□m
Coil Rig. (inn/out)		6.0 / 7.2	0.15 / 0.24	GPa
Coil L.	6510	6509.7 / 6512.2	0.7 / 0.9	mm
Yoke Size (V/H)		469.83/468.84 (d □ = 0.1 mm)	0.03/0.03	mm
Yoke L.	6510	6511.8	1.9	mm
Yoke Weight		6331	6	kg
Yoke Pack. F.		99.25	0.07	%
H. Alignment		0.2	0.08	mm
V. Alignment		0.46	0.17	mm
Twist		0.54	0.25	mrad

Production to Shipment

Production at TSB

↓

Warm Measurements

↓

Cold Test

↓

Warm Measurements

↓

Shipping Preparation at TSB

↓

Cold-Mass Shipped to Fermilab

@ KEK

Summary of Production and Performances

	01	02	02b	03	04	05	06	07	08	09	10	Av.
Completed Cold-Tested	01-09 01-10	01-12 01-12	02-08 02-08	02-01 02-02	02-05 02-06	02-04 02-05	02-10 02-11	02-09 02-10	03-01 03-02	02-12 03-01	03-02	
Fist Quench (aft. T.cycle)	7278A	7056 (7311)	7577	6729 (No Q.)	6751	7550	6894	7364	7256	6902		7066
#Q, to 205 T/m (6850 A)	0	0	0	1	1	0	0	0	0	0		<1
#Q, to 215 T/m (7190 A)	0	1	3	3	1	0	1	0	0	2		1.4
#Q to 230 T/m (7730A)	7	8 (5)	5	9 (0)	1	5	3	4	3	8		5.6
B4 @ 7228 A	1.29	1.22	1.04	1.30 (1.20)	1.15	1.12	1.21	1.37	1.44	1.18	1.28	1.21
B6 @ 7228 A	0.16	0.20	0.29	0.22 (0.27)	0.22	0.23	0.21	0.14	0.16	0.08	-0.07	0.23
B10 @ 7228 A	0.005	0.006	0.000	0.003 (0.001)	-0.007	-0.004	-0.003	0.009	-0.02	-0.01	-0.01	0.0004
General Note:			Reassse mbled		Reassse mbled				Reasse mbled			
Note: Holes on Pole GND-insulation	No	No	Yes	No repair ed	No	No	No repair ed	Yes	Yes	Yes	Yes	

Summary of Production and Performances

pp	11	12	13	14	14	11	15	16	17	18	19	Av.
Completed Cold-Tested	04-04 04-05	03-05 03-06	03-07 03-08	03-09 03-10	03-11	03-12	03-11 03-12	03-12 04-01	04-01	03-02		
Fist Quench (aft. T.cycle)	6671A	7052	6900	6592	7449	7611	6609	7296				
#Q, to 205 T/m (6850 A)	1	0	2	2	0	0	2	0				
#Q, to 215 T/m (7190 A)	4	3	5	3	0	0	2	0				
#Q to 230 T/m (7730A)	21	19	16	18	2	1	6	1				
B4 @ 7228 A		1.20	1.11	1.23		1.09	1.37	1.43				
B6 @ 7228 A		0.07	0.09	0.11		0.18	0.06	0.11				
B10 @ 7228 A		-0.008	-0.017	-0.006		-0.010	-0.004	0.001				
General Note:					2nd Test	2nd Test						
Note: Holes on Pole GND-insulation	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	

Status and Plan

- 18 magnets completed at Toshiba,
- 17 magnets delivered to KEK,
- 16 magnets tested at KEK,
- 13 magnets delivered to Fermilab,

- MQXA-17 test in progress at KEK,
- MQXA-18 to be warm- & cold-tested at KEK,
- MQXA-11, 15, 16, 18 to be shipped to Fermilab in JFY-04,
- MQXA-19 being completed at Toshiba and to be warm-tested at KEK,
- MQXA-P02 to be re-assembled, and to be warm-tested,

- All production and test to be completed before Summer, 2004.
- Quality under control.
- 18 production magnets to be delivered to Fermilab, and 2 backups magnets planned to be delivered to CERN.

Many thanks for All Members of Fermilab-CERN-KEK Collaboration!

Quality Reports

CERN LHC MQXA

Acceptance Test at FNAL

QUALITY RECORD

Cryogenics Science Center

KEK, High Energy Accelerator Research Organization

Magnet ID :_____

Date of approval :_____

Approved by :_____ (FNAL)

:_____ (KEK)

Ver. 0

Ver A (with initial results)

Appendix

Summary of Events

* Shipped to Fermilab

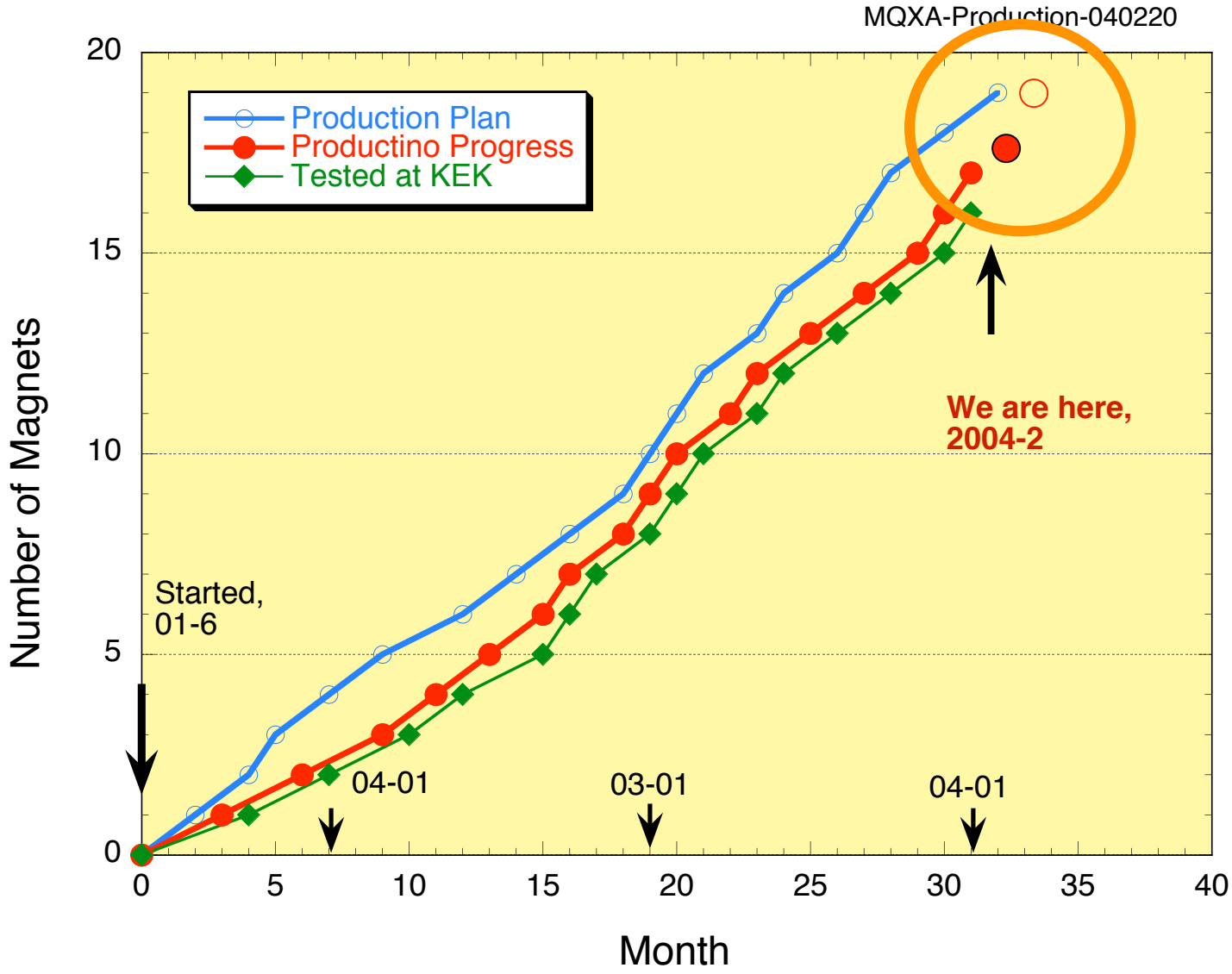
MQX A-	Found in fabrication	How repaired	Found after cold-test	How repaired/improved
01*				
02*			Pole ins-flap peeled	Disassembled
02b*		Re-assembled (New pole-Gnd-Ins.)		
03*			Pole-ins-flap peeled	Removed
04*	Mid-GND insulation mis-folded	Disassembled and Re-assembled	Pole-ins-flap peeled	Removed
05*			Pole-ins-flap peeled	Removed
06*			Pole-ins-flap peeled	Removed
	New pole-GND-insulation with holes introduced			
07*			QPHT lead-wire cut	To be repaired
08*	Plastic-tape left on P-GND-insulation	Disassembled and Re-assembled		
09*				
10*				

Summary of Events

* Shipped to Fermilab

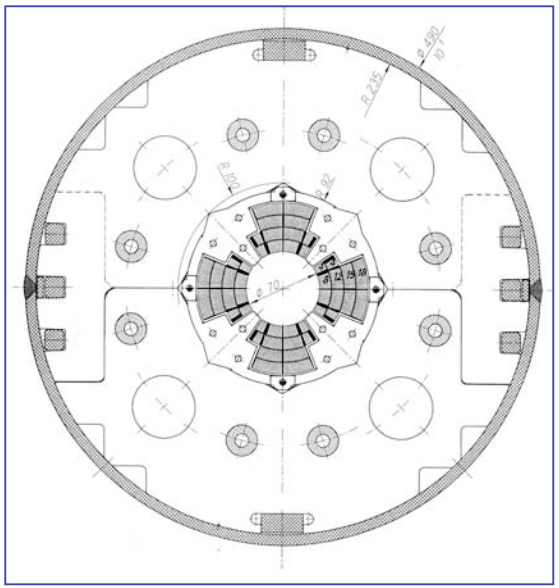
MQX A-	Found in fabrication	How repaired	Found after cold-test	How repaired/improved
11	P-GND-ins. mis-placed	re-assembled		
12*				
13*				
14*				
			Bore Tube shifted	Spacer added
15				
16				
17				
18				
(19)				

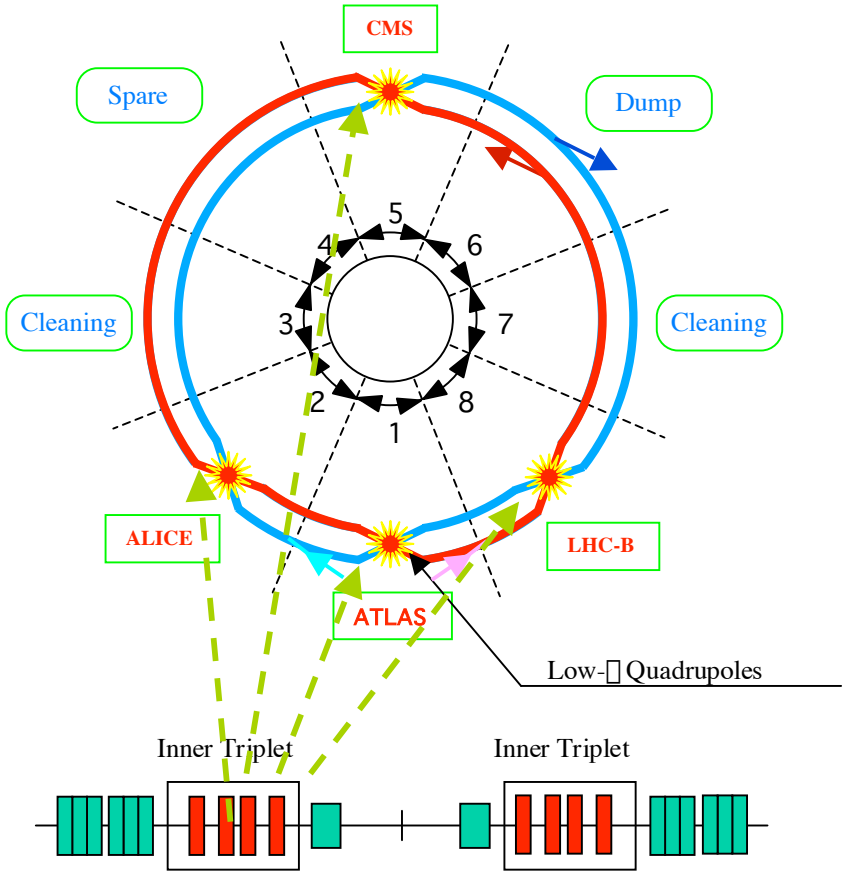
MQXA Production and Test



Requirements for MQXA

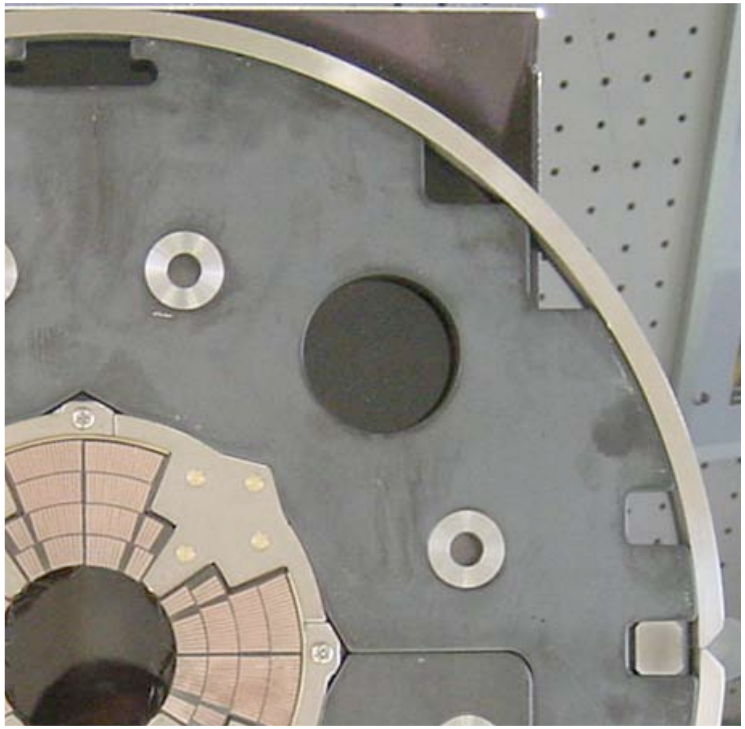
- G = 215 T/m, (B-peak = 8.4 T)
- Aperture = 70 mm
- Multipoles (b_6, b_{10}): < 1 unit (10^{-4})
- Beam Heating: 5 ~ 10 W/m

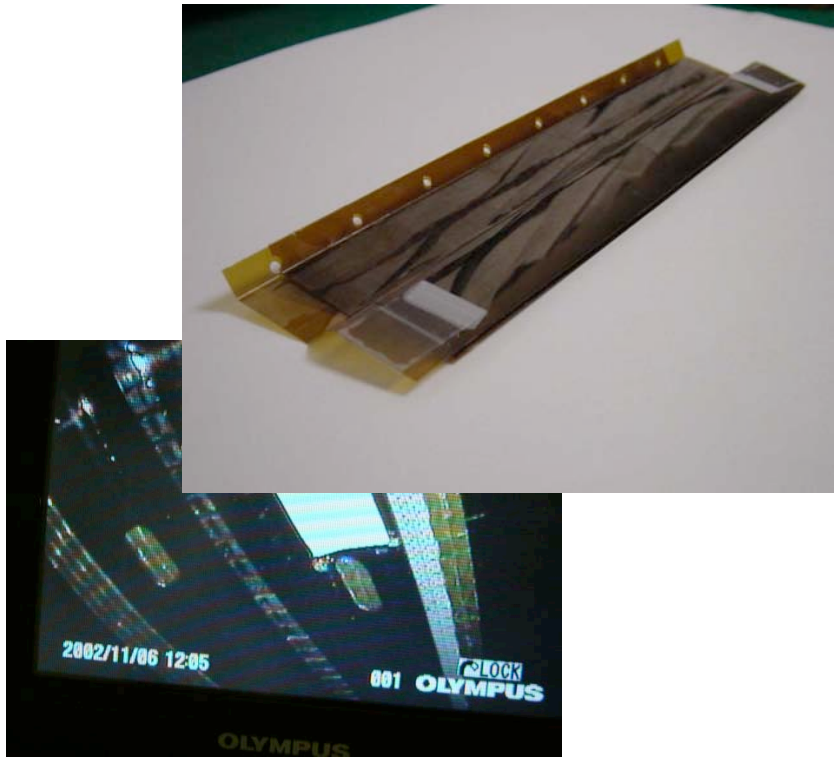


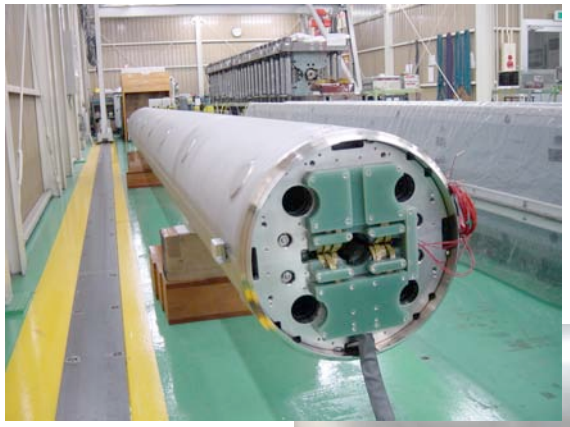
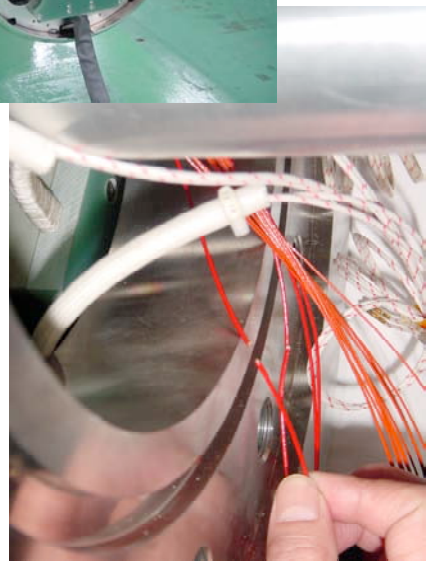


Pole Insulation with Holes

after MQXA-07





Some Events

Plastic tapes (-08), QPHT-wires cut (-09)