Fermilab

SDC SOLENOID DESIGN NOTE #186

TITLE: Superconductor Mechanical Test

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DATE: Dec. 8, 1992

This design note is one of a series which represents the proceedings of the SDC solenoid subgroup meeting held in Japan on December 8-11, 1992. The plan and purpose of the meeting was to:

- Look at the prototype coil winding and honeycomb vessel R&D in Japan
- Reports of technical progress from each group
- Plan and schedule for the prototype magnet assembly and test
- Discussions on design of the SDC solenoid power supply
- Discussions on cryogenic design for the SDC solenoid
- Discussions on responsibilities for the cryogenics fabrication
- Response to the report of the DOE review sub-committee
- Publications and presentations of the technical progress

SDC Solenoid Subgroup Meeting in Japan

Superconductor Mechanical Test

K. Tanaka (KEK)

Dec. 9, 1992

SDC Solenoid Subgroup Meeting in Japan '92.12.9

SUPERCONDUCTOR FOR SDC SOLENOID

--- MECHANICAL STRENGTH TEST ---

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2. Simple Tensile Load Test Result

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4. Appendix

PARAMETERS OF SDC SOLENOID

Dimensions:		
Cryostat	Inner radius	1.70 m
	Outer radius	2.05 m
	Half length	4.39 m
Coil	Effective radius	1.84 m
	Half length	4.15 m
Transparency (Radiation length)		1.2 Xo
Electrical:		
Central field		2 T
Nominal current		8,000 A
Inductance		4.6 H
Stored Energy		146 MJ
Stored energy / Effective cold mass		7.4 kJ/kg
Mechanical:		
Effective cold mass		20 ton.
Total cold mass		22 ton.
Total magnet weight		apr.30 ton.
Radial magnetic pressure		1.6 MPa
Axial compressive force		13 MN
Axial decentering force (at ΔZ=2.5 cm)		0.4 MN

ELECTRO MAGNETIC STRESS

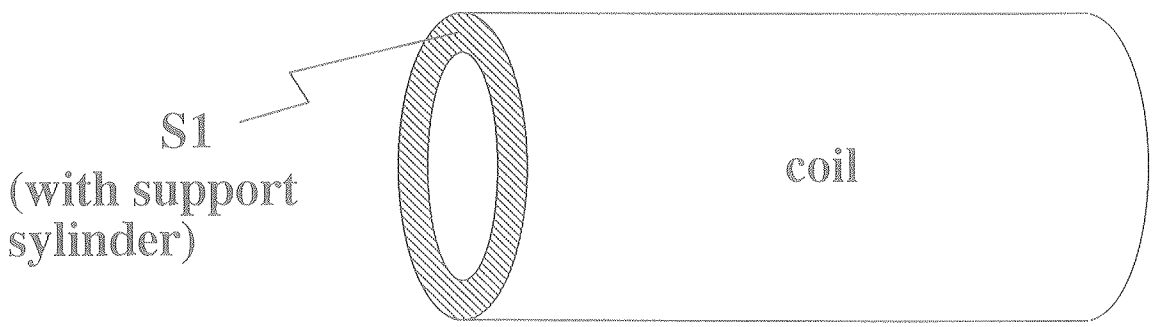
1. Axial compressive stress

F=1300 ton (at z=0) axial comp. force

$$\Longrightarrow \sigma_z = \frac{F}{S1} = \frac{1.3 \times 10^6}{2 \times \pi \times 1855.5 \times 75}$$

$$= 1.49\ [\mathrm{kgf/mm^2}]$$

$$= 14.6\ [\mathrm{MPa}]$$



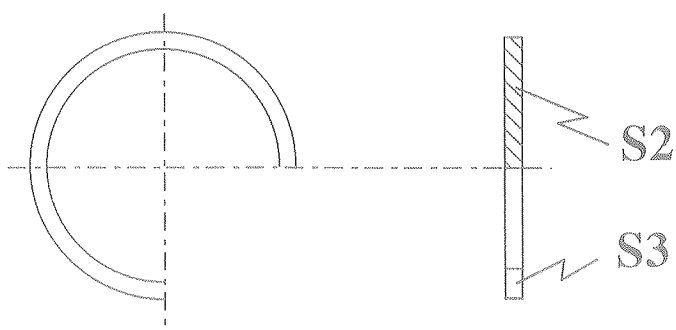
2. Hoop Stress

$\sigma_r = 0.16$ [kgf/mm^2] radial magmetic press.

$$\Longrightarrow \sigma_h = \frac{\sigma_r \times S2}{S3} = \frac{0.16 \times 1855.5 \times 4.4}{75 \times 4.4}$$

$$= 3.96 \text{ [kgf/mm}^2\text{]}$$

$$= 38.8 \text{ [MPa]}$$



(with support sylinder)

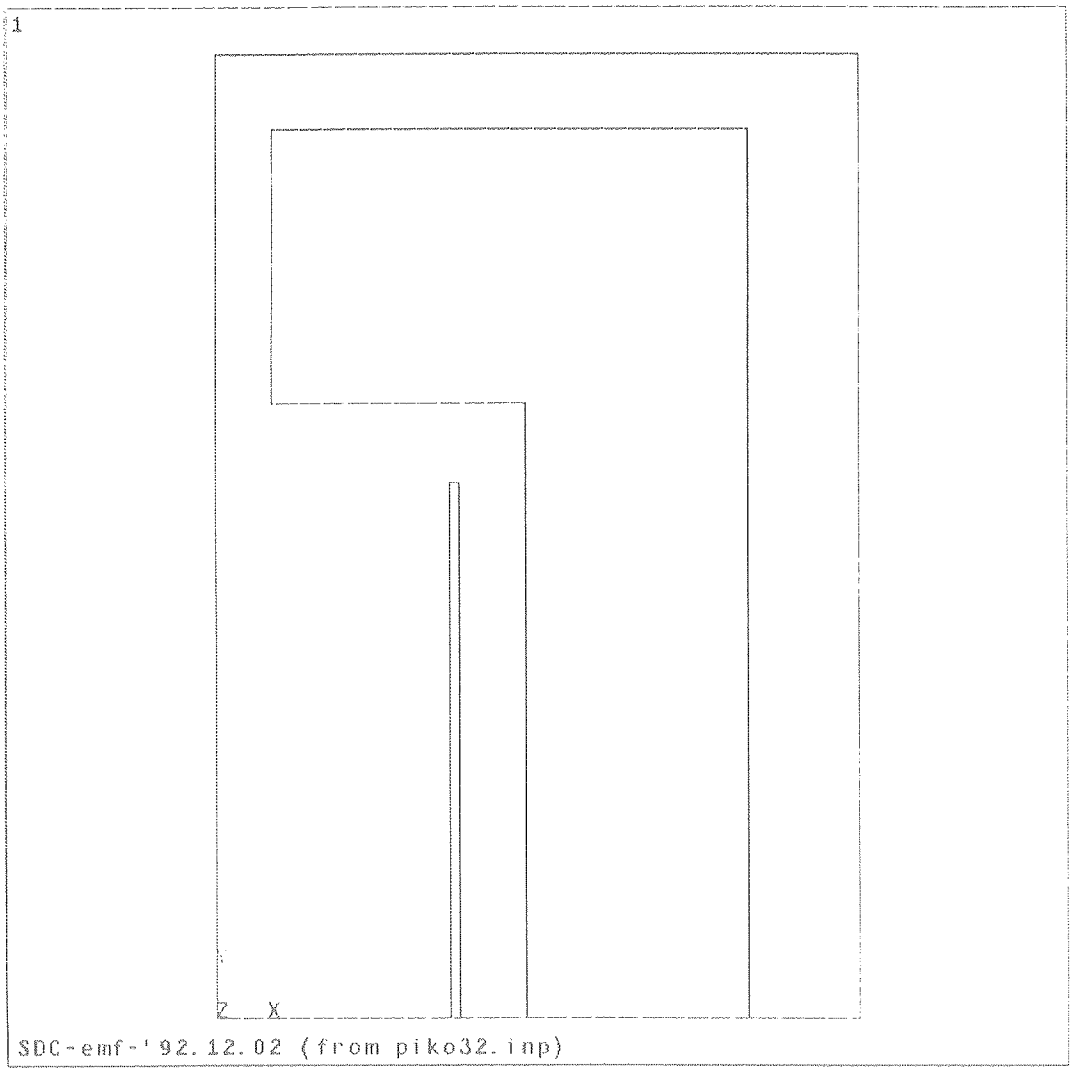
1-turn

simulation with "ANSYS" code

The magnetic field , magnetic force and stress was simulated with "ANSYS" code.

The following are parameters used for simulation.

coil effective radius	1.84 m
half length	4.15 m
thickness (conductor)	0.044 m
thickness (support cyl.)	0.036 m
coil-end-end-cap distance	0.616 m
end cap thickness	2.143 m
	1.72 m
nominal current	8000 A
Young's modulus	7.2×10^{10} N/m^2
Poisson ratio	0.345

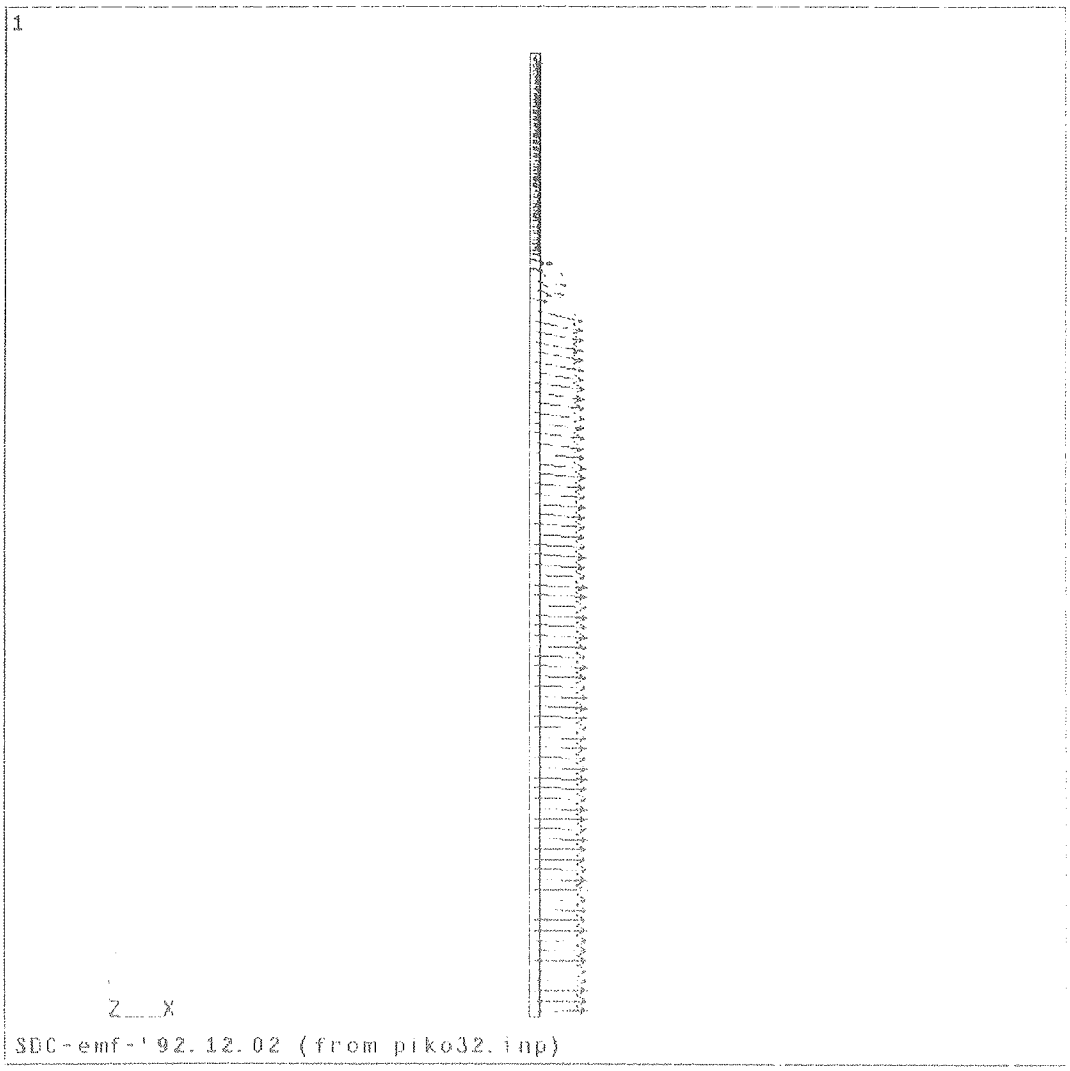


ANSYS 4.4A
DEC 7 1992
18:51:30
POST1 ELEMENTS
MAT NUM

ZV =1
DIST=4.125
XF =2.5
YF =3.75
EDGE

POST1 ELEMENTS
MAT NUM

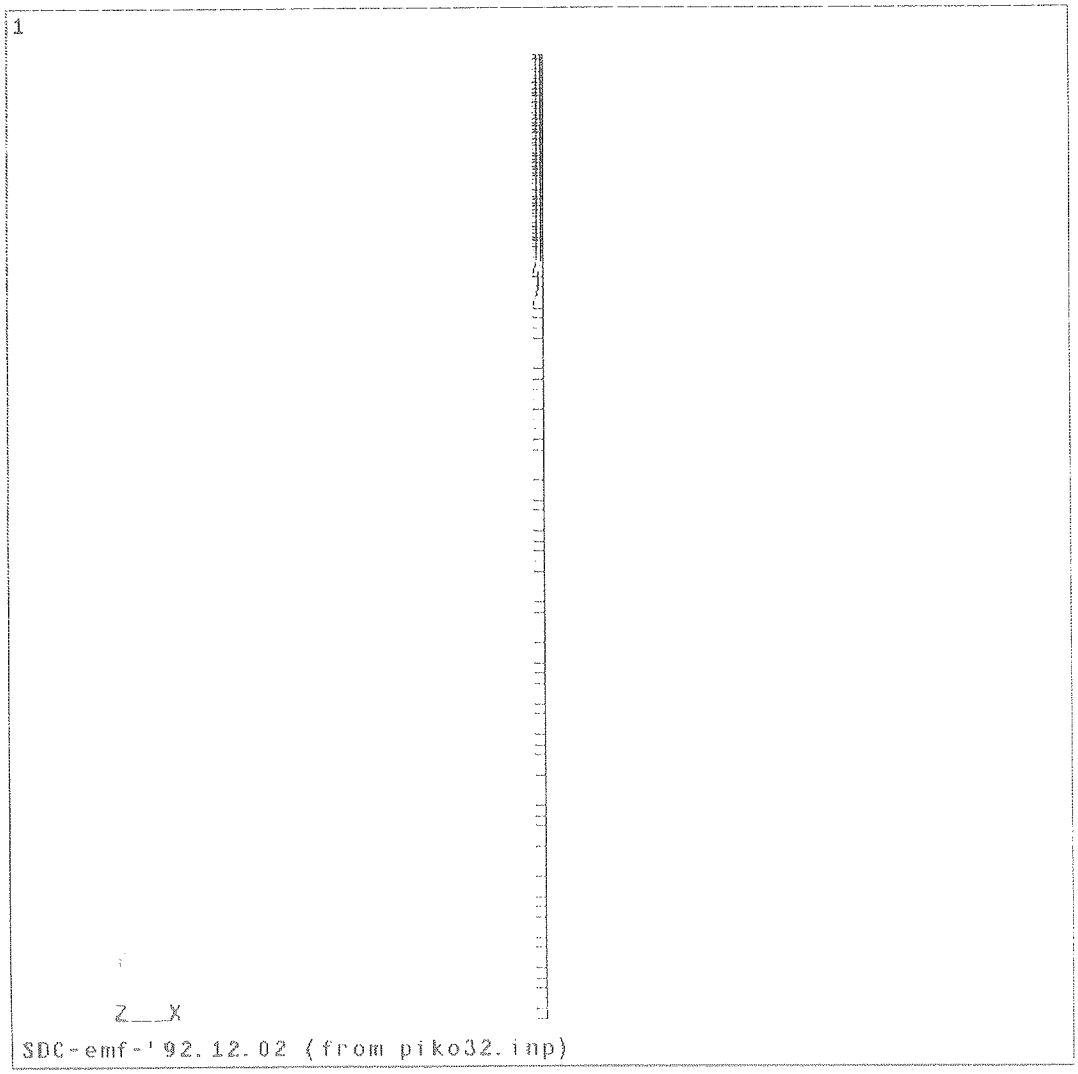
ZV =1
DIST=4.125
XF =2.5
YF =3.75
EDGE



ANSYS 4.4A
DEC 9 1992
6:49:18
POST1 VECTOR
STEP=2
ITER=20
FFX
ELEM=184
18356
32464
46573
60681
74789
88897

117114
131222

ZV =1
DIST=2.292
XF =1.84
YF =2.083
EDGE



ANSYS 4.4A
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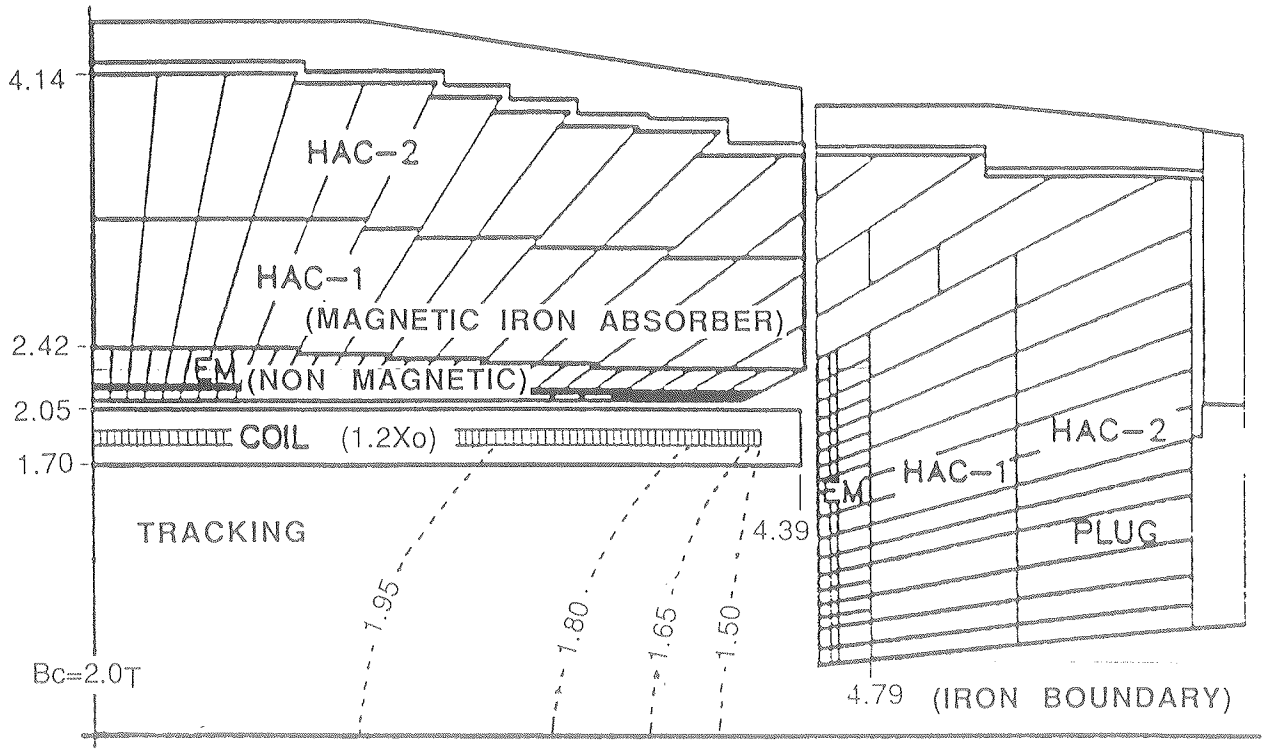
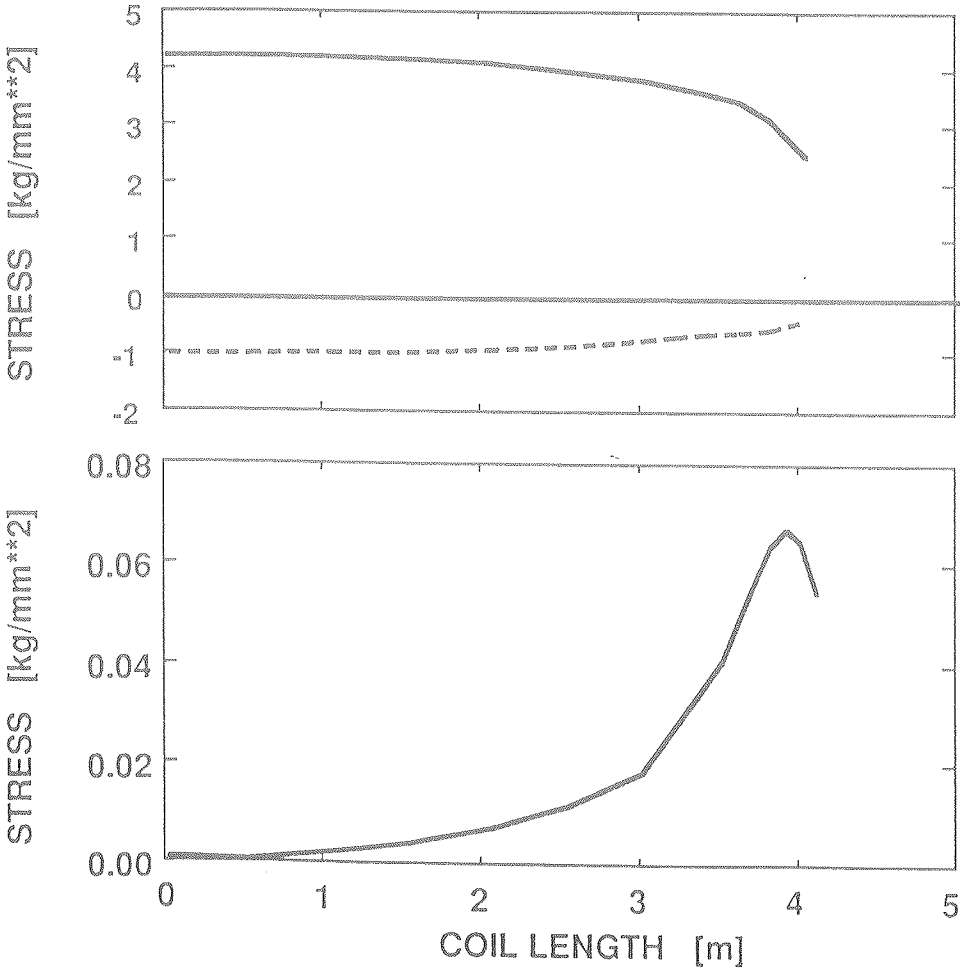
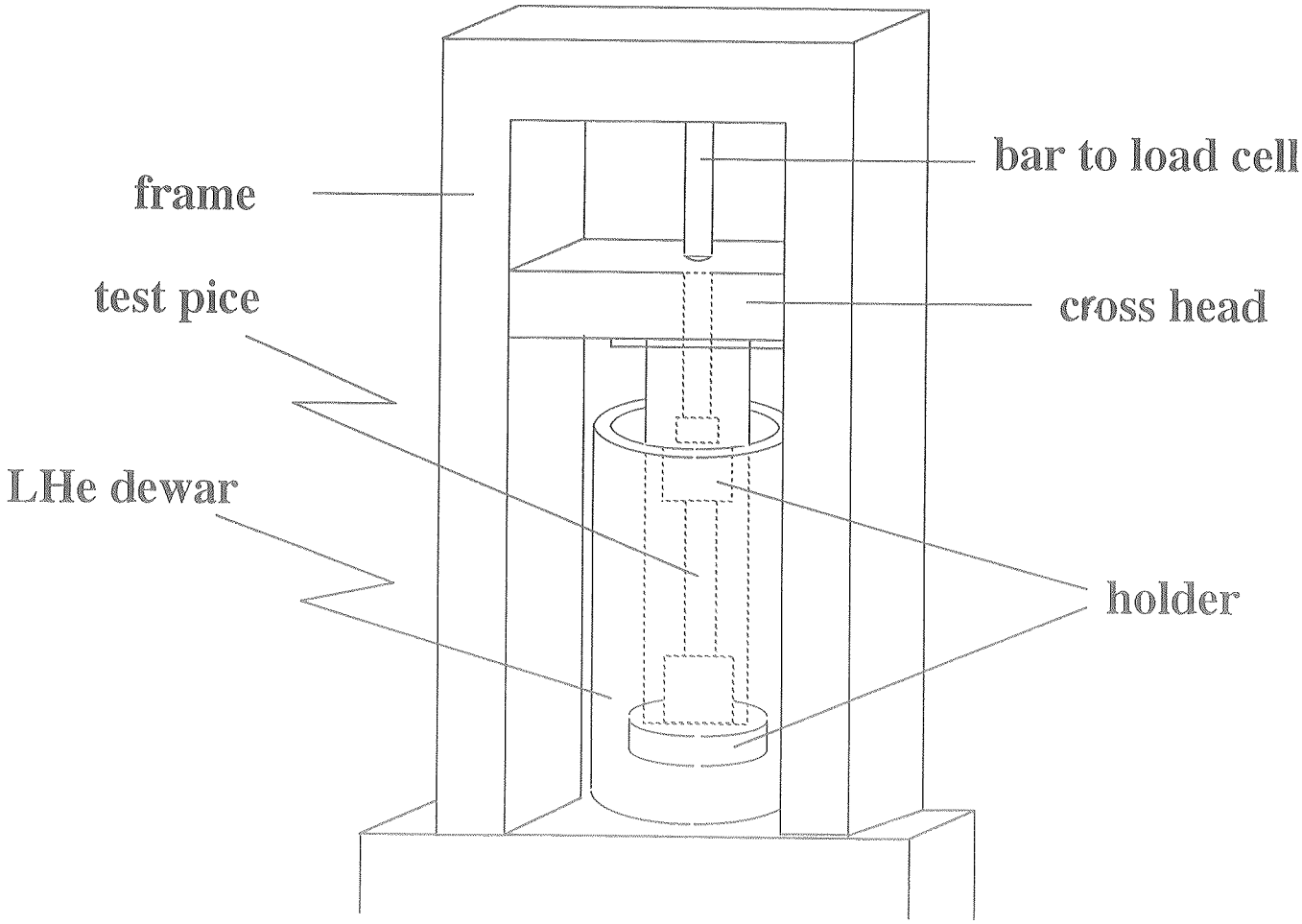
6:41:55
POST1 ELEMENTS
TYPE NUM

ZV =1
DIST=2.292
XF =1.84
YF =2.083


4.14
HAC-2
HAC-1
(MAGNETIC IRON ABSORBER)
2.42
EM
(NON MAGNETIC)
2.05
COIL (1.2Xo)
1.70
TRACKING
4.39
1.95
1.80
1.65
1.50
Bc=2.0T
EM
HAC-1
HAC-2
PLUG
4.79 (IRON BOUNDARY)


STRESS [kg/mm**2]
5
4
3
2
1
0
-1
-2
STRESS [kg/mm**2]
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
COIL LENGTH [m]



testing machine and test setup

RESULTS OF SIMPLE TENSILE LOAD TEST

	TENSILE STRENGTH [kgf/mm2]		
	R.T.	LN2	LHe
lot1-1	10.9	17.2	20.9
lot1-2	10.9	17.3	20.9
lot2-1	10.3	16.3	20.5
lot2-2	10.3	16.3	20.3
lot3-1	10.5	16.4	20.0
lot3-2	10.5	16.1	20.3

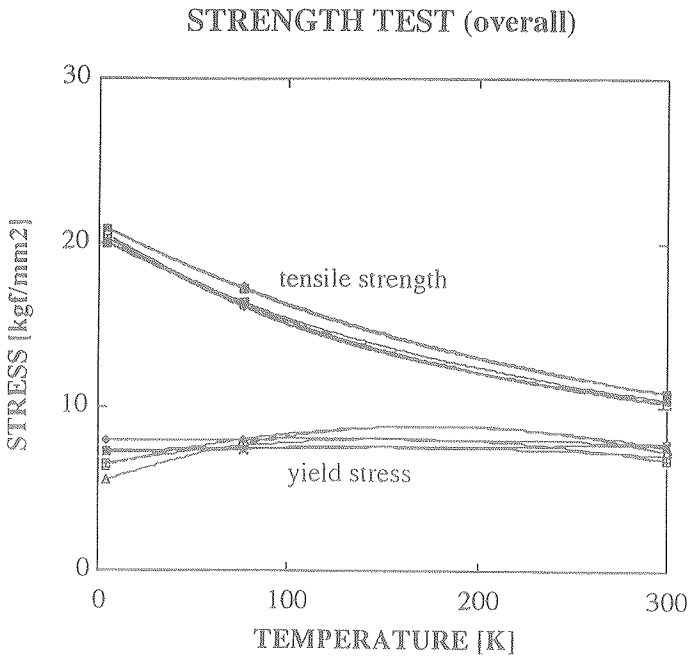
	TENSILE STRENGTH [kgf/mm2]		
	R.T.	LN2	LHe
lot1-1	5.7	14.9	29.5
lot1-2	6.0	14.8	29.6
lot2-1	5.9	13.7	29.3
lot2-2	5.8	13.5	29.1
lot3-1	5.7	13.7	29.4
lot3-2	5.7	13.6	29.5

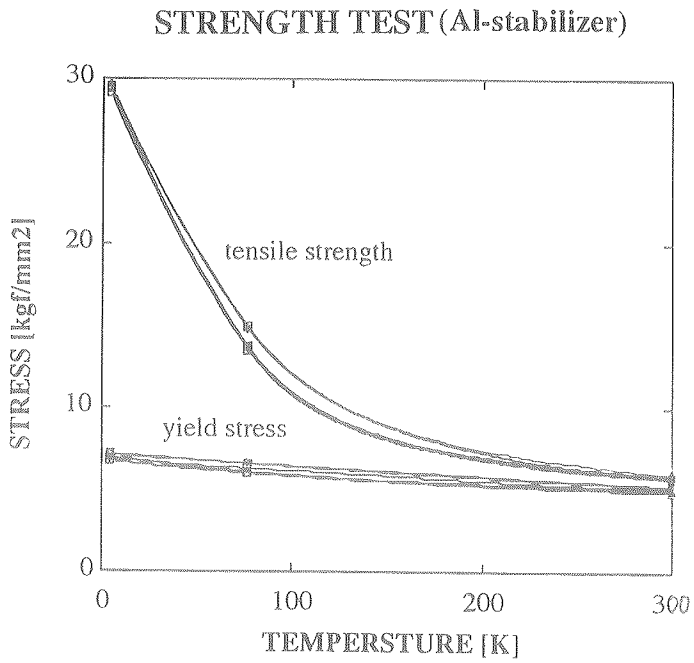
	YIELD STRESS [kgf/mm2]		
	R.T.	LN2	LHe
lot1-1	7.1	7.5	7.3
lot1-2	7.8	8.0	7.9
lot2-1	7.6	8.0	6.4
lot2-2	7.3	7.7	5.5
lot3-1	6.8	7.6	6.5
lot3-2	7.7	7.4	7.2

Superconducter Overall

	YIELD STRESS [kgf/mm2]		
	R.T.	LN2	LHe
lot1-1	5.2	5.2	7.2
lot1-2	5.3	5.3	7.1
lot2-1	5.0	6.1	6.9
lot2-2	4.9	6.0	6.7
lot3-1	5.0	6.3	6.8
lot3-2	5.1	6.1	7.0

Al-Stabilizer Only





SIMPLE TENSILE LOAD TEST RESULT

COMBINED STRESS

1. Objective

There are two stress in the coil at the same time (axial compressive & hoop) .
Therefore it is nesessary to evaluate conductor mechanical performance under combined stress condition.

2. How to make stress

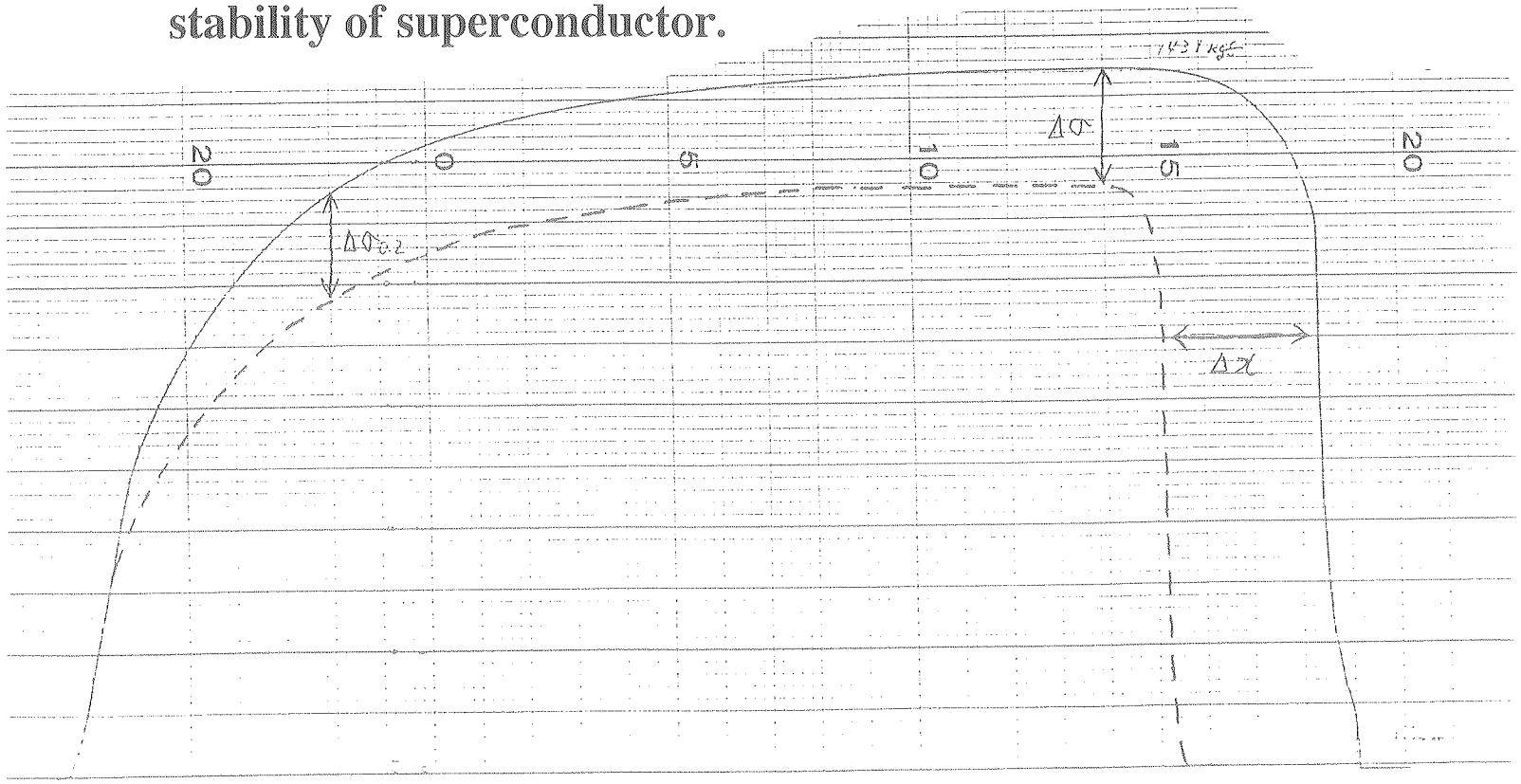
tensile stress : by using testing machine
compressive stress : by using springs

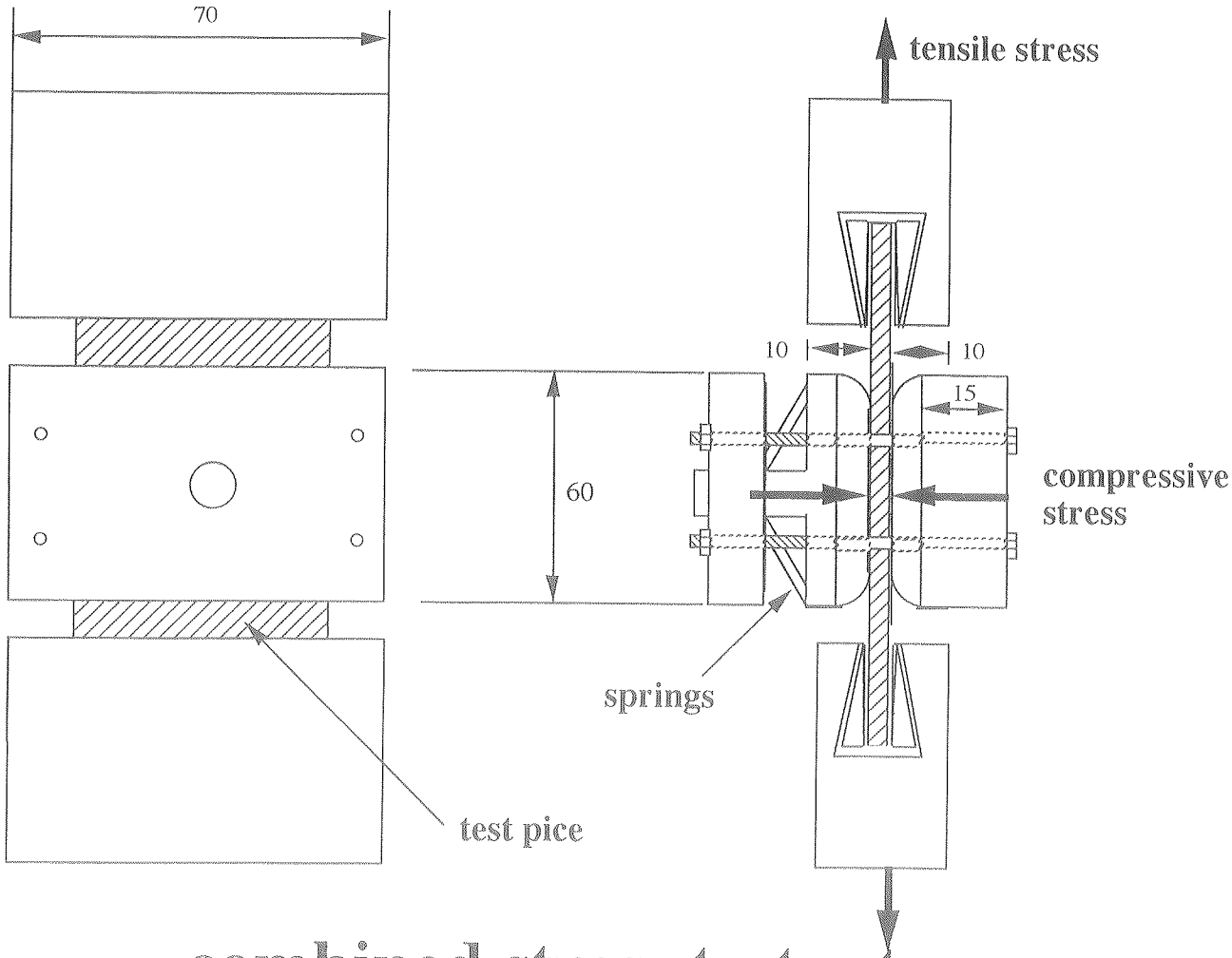
3. Present status

We have finished making parts for the test.
We are checking the parts and test set now.

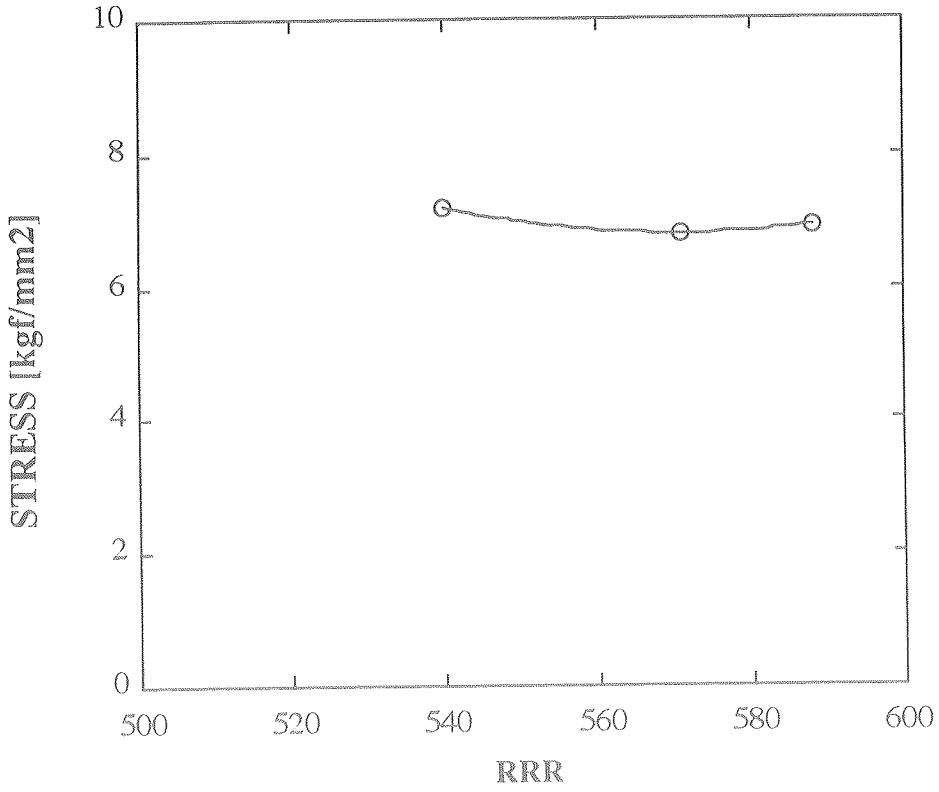
In this graph, solid line means measured load under simple tensile load condition.

We must obtain $\Delta\sigma_{0.2}$,$\Delta\sigma$ and Δx to evaluate the mechanical stability of superconductor.

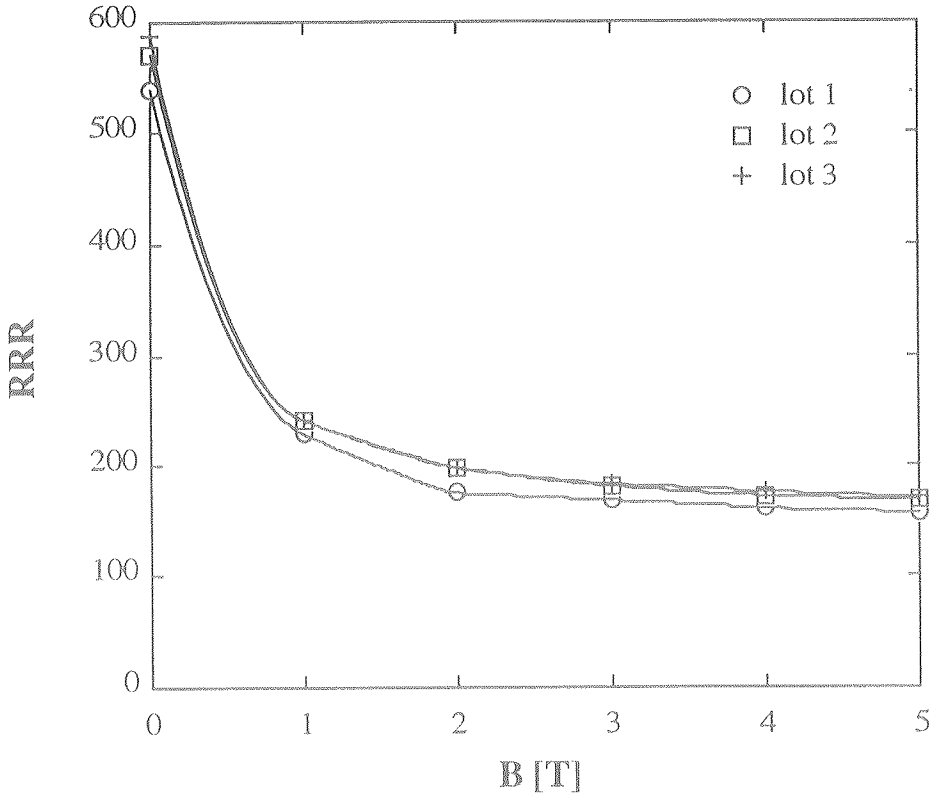




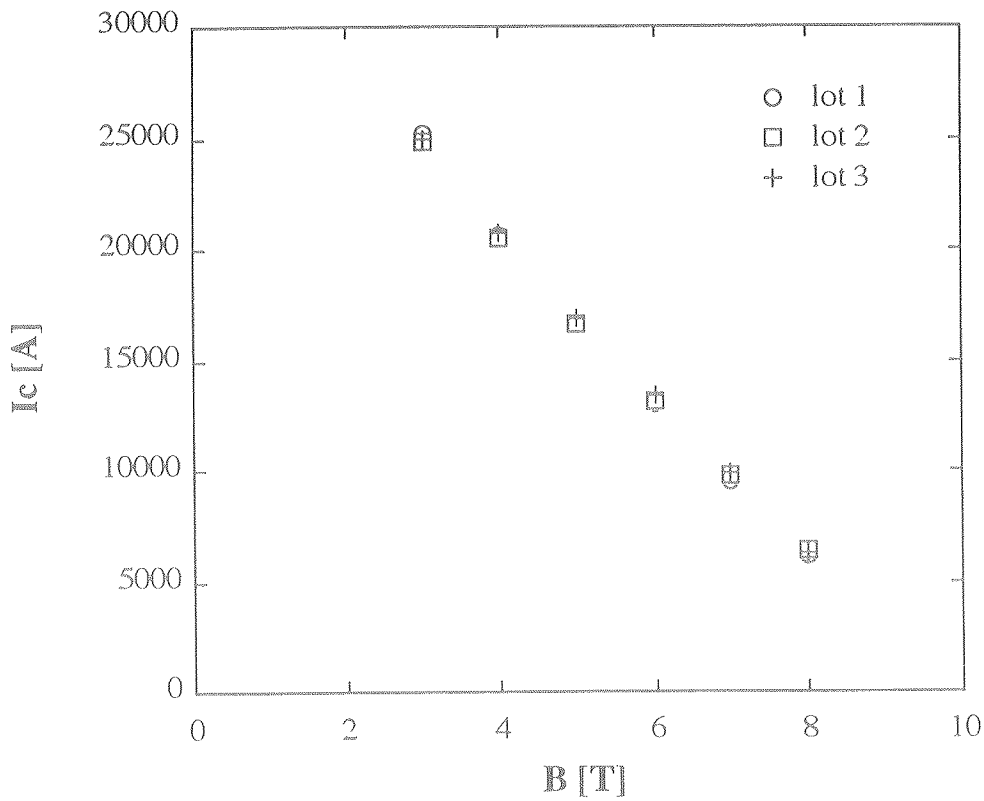
combined stress test setup



Yield Strength vs. RRR

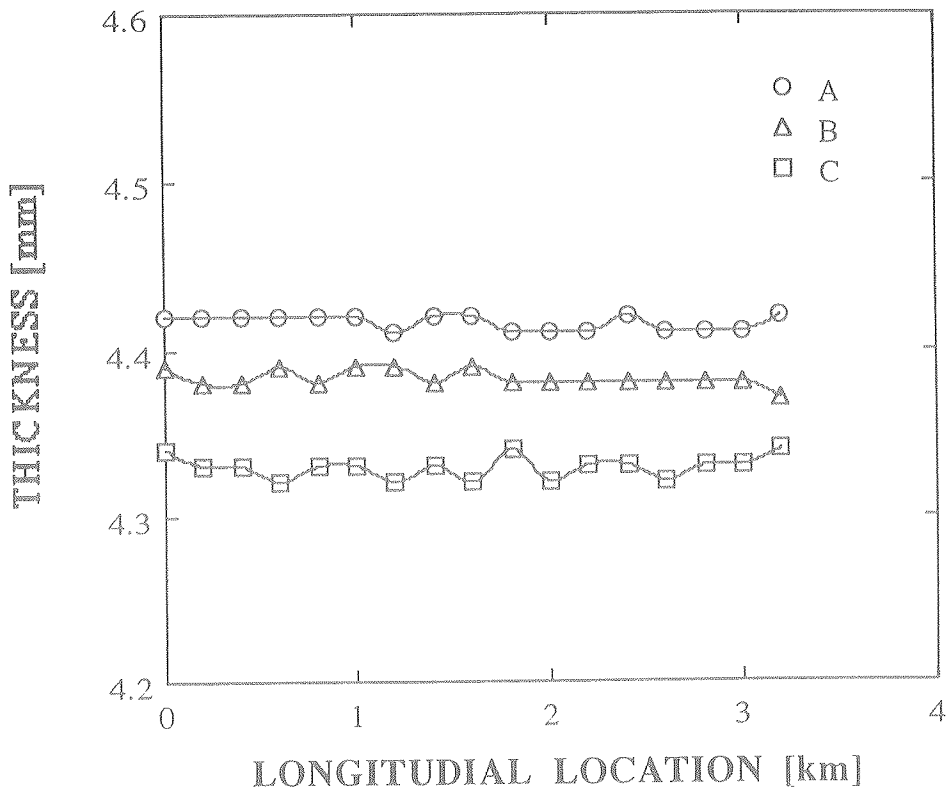


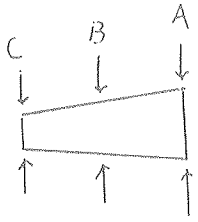
RRR vs. Magnetic Field



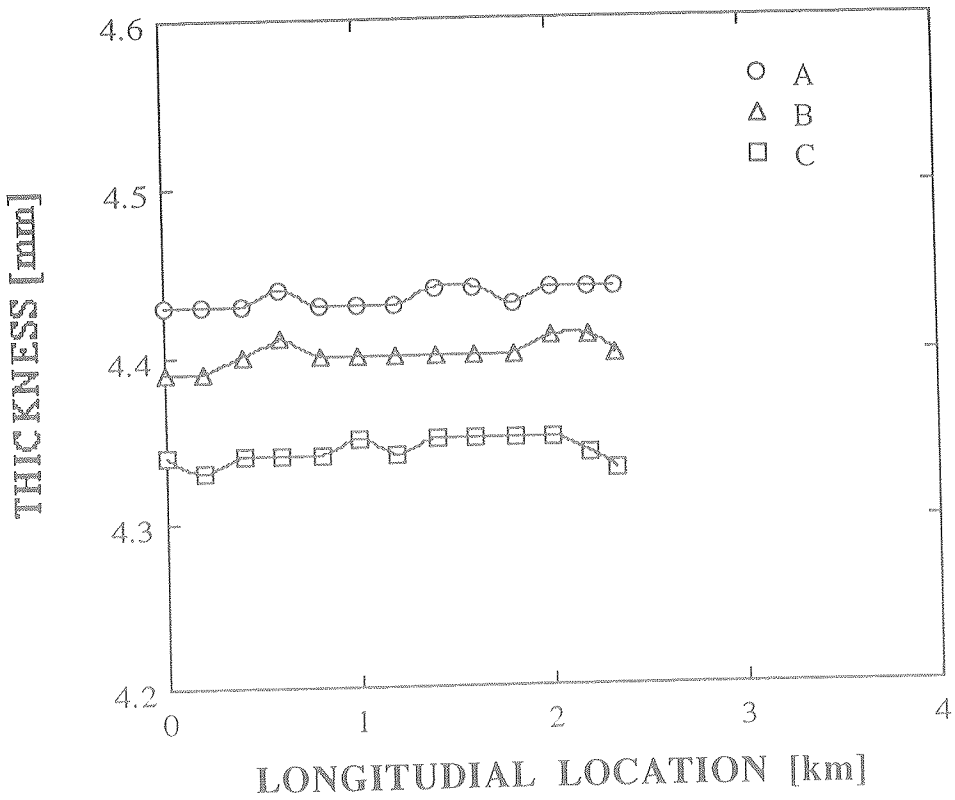
Critical Current vs. Magnetic Field

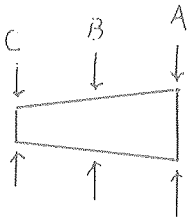
LOT - 1


4.6
4.5
4.4
4.3
4.2
THICKNESS [mm]
0
1
2
3
4
LONGITUDIAL LOCATION [km]
A
B
C

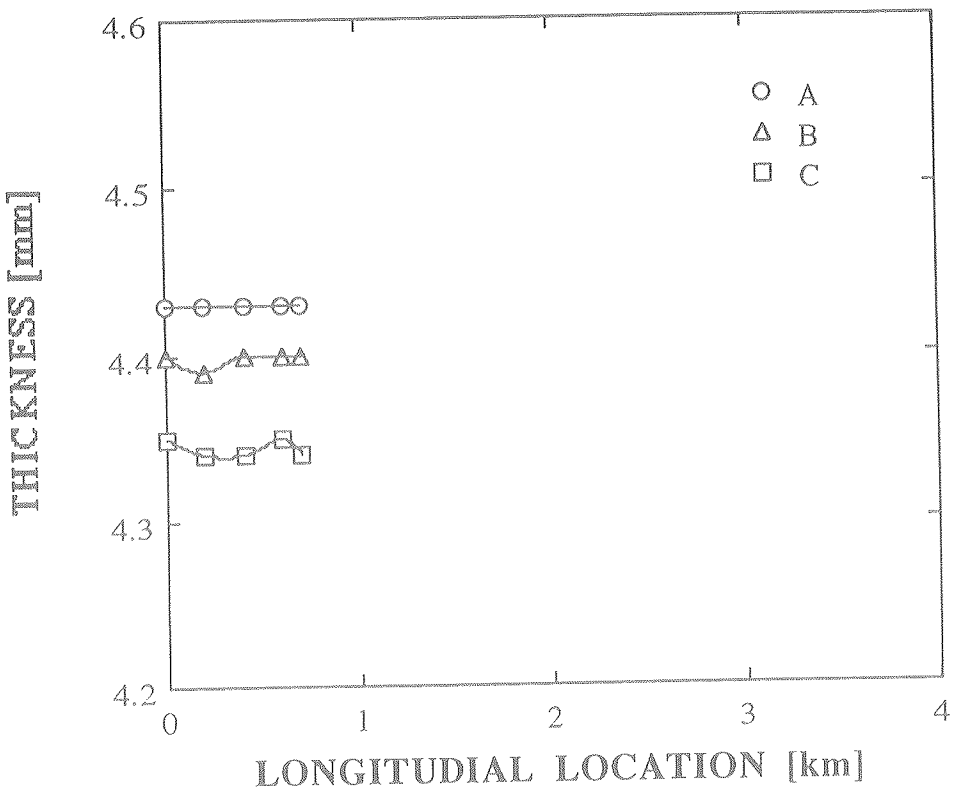

C
B
A

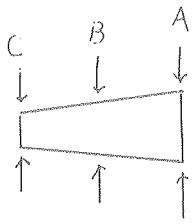
LOT - 2


4.6
4.5
4.4
4.3
4.2
THICKNESS [mm]
0
1
2
3
4
LONGITUDIAL LOCATION [km]
A
B
C


C
B
A

LOT - 3


4.6
4.5
4.4
4.3
4.2
THICKNESS [mm]
0
1
2
3
4
LONGITUDIAL LOCATION [km]
A
B
C


C
B
A