IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), April 2015.
Invited Presentation given at CCA 2014, Jeju Island, Korea, Nov. 30 - Dec. 03, 2014.

Mechanical and Superconducting Properties of Practical REBCO Wires

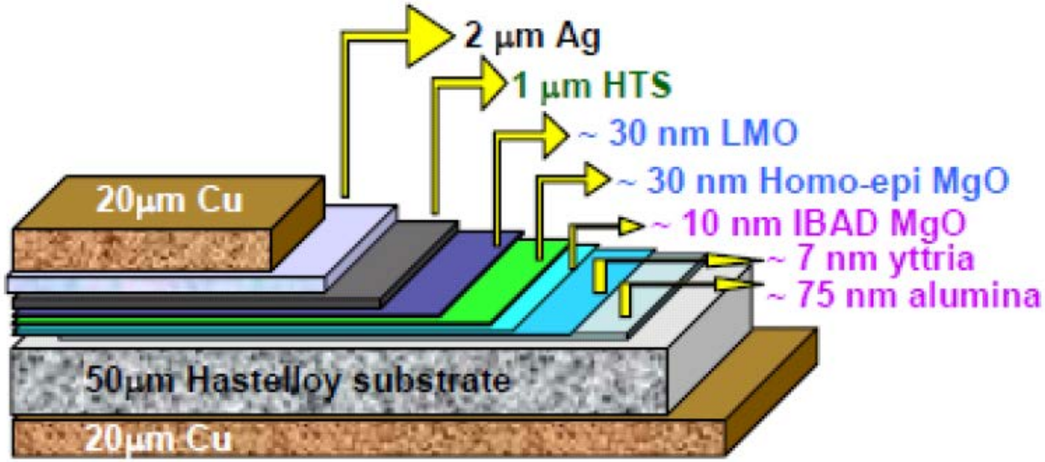
Kozo Osamura
Research Institute for Applied Sciences

OUTLINE

1. Characteristics of practical REBCO wires
2. Necessity of international standards
3. Standardization of room temperature tensile test method
4. Mechanical – superconducting properties and their test method
5. Summary

IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), April 2015.
Invited Presentation given at CCA 2014, Jeju Island, Korea, Nov. 30 - Dec. 03, 2014.

REBCO Group



superconductor	
matrix	substrate
	buffer layer
	cap layer
	protection layer
stabilizer	
reinforcing member	

Practical SC wires are typically composite materials consisting of several functional materials for responding various demands.

Those functional components give influences directly for the mechanical and superconducting properties of SC layer.

A wire is considered as being *practical* if it can be procured in sufficiently continuous lengths under ordinary commercial transactions to build devices.

Commercial REBCO wires used for the present RRT

Sample Name	A	B	C	D
Thickness (mm)	0.22	0.10	0.19	0.19
Width (mm)	5.0	4.1	4.1	4.8
Substrate	Hastelloy	Hastelloy	Hastelloy	Ni-W
Laminated Material	Cu	Cu	Cu/Brass	Cu

IEC-TC90 prepares international standards related to SC materials and devices

Terminology IEV 815	+	Test Methods 21 IS's	+	Products 1 IS

- *is used as a common measure for commercial transactions.*
- *provides a tool for characterizing property of advanced materials*
- *facilitates easier communication among project members for many ongoing and forthcoming international scientific and industrial projects.*
- *accelerates to open market and improve cost/performance.*

International standards give many advantages.

IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), April 2015.
Invited Presentation given at CCA 2014, Jeju Island, Korea, Nov. 30 - Dec. 03, 2014.

Committee Draft on Room Temperature Tensile Test Method of REBCO Wires

1. **Scope**
2. Normative references
3. Terms and definitions
4. Principle
5. **Apparatus**
   tensile machine, extensometer
6. **Specimen preparation**
   length, thickness, width
7. **Testing conditions**
   gripping, testing speed, test procedure
8. **Calculation of results**
   modulus of elasticity, 0.2% proof strength
9. **Uncertainty of measurand**
10. Test report

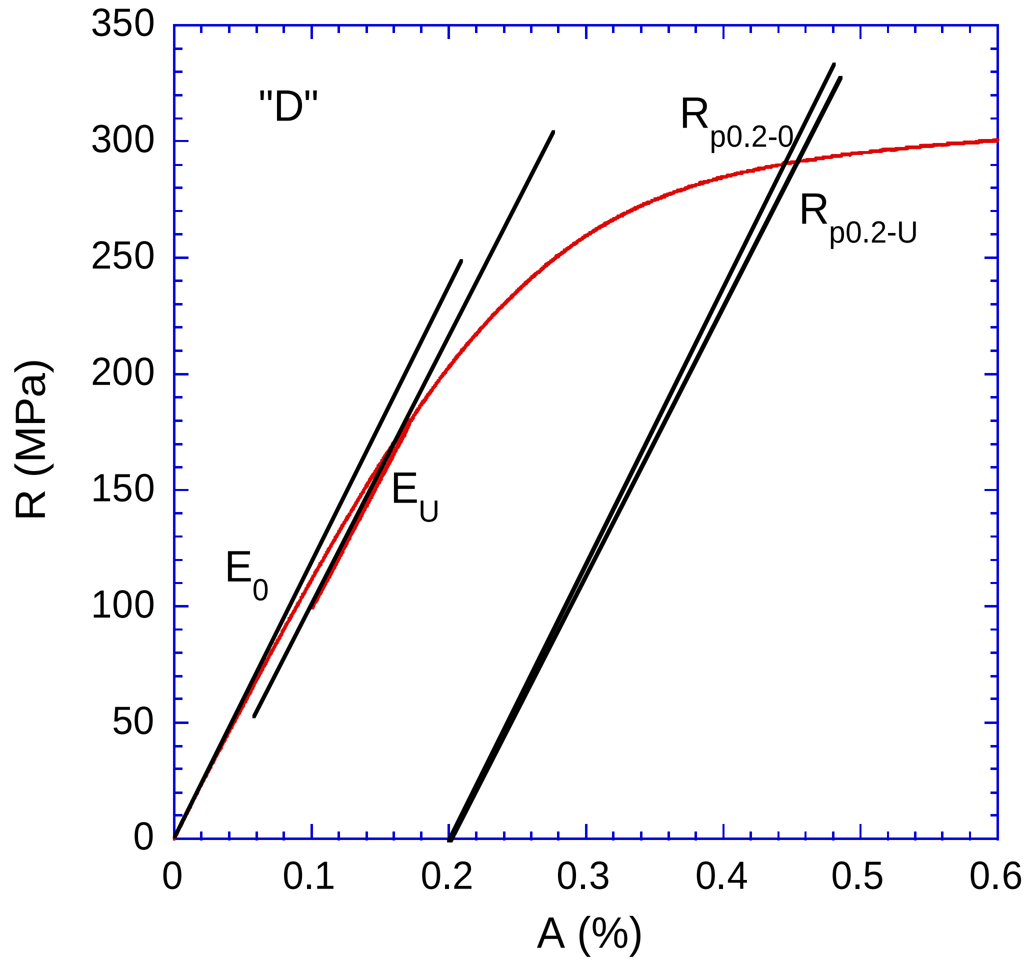
1. Scope

This part of IEC XX covers a test method detailing the tensile test procedures to be carried out on REBCO superconductive composite tapes at room temperature.

This test is used to measure the ***modulus of elasticity*** (E) and ***0,2 % proof strength*** ($R_{p0.2}$).

The values for elastic limit, fracture strength and percentage elongation after fracture shall serve only as a reference.

The sample covered by this test procedure should have a rectangular cross-section with an area of 0,12 mm² to 5,0 mm² (corresponding to the tapes with width of 2,0 mm to 10,0 mm and thickness of 0,060 mm to 0,5 mm).



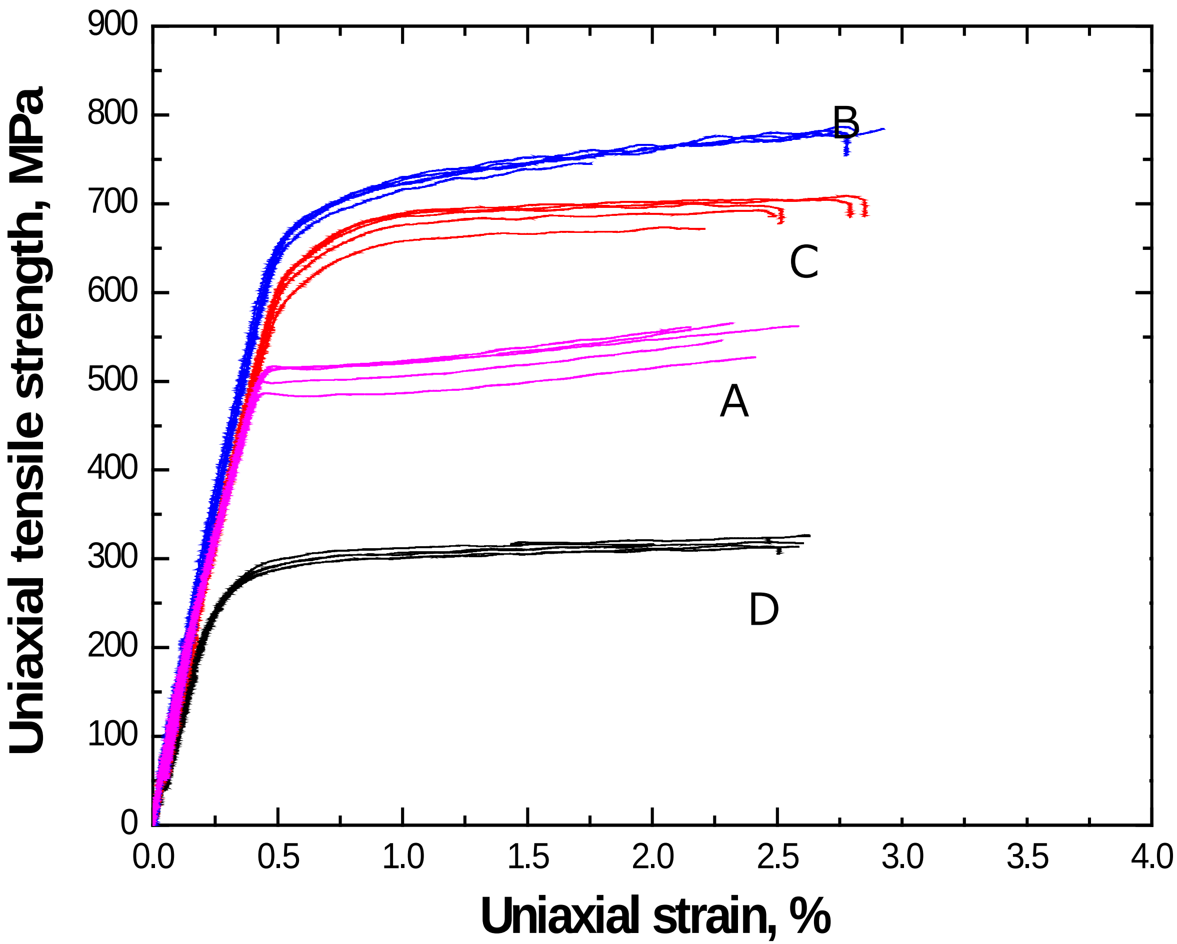
Qualification Test

$$1-\Delta < \frac{E_0}{E_U} < 1+\Delta$$

$\Delta=0.3$

Enlarged stress versus strain curve of the “D” tape and mechanical properties, which shall be determined for the present RRT.

Summary by Andong National University



Contributor
K.Osamura (RIAS)
H.-S. Shin (Andong NU)
K.-P. Weiss (KIT)
A. Nyilas (CEME)
A. Nijhuis (Univ Twente)
K. Yamamoto (Furukawa El)
S. Machiya (Daido Univ)

Total average of the modulus and their relative standard uncertainty, where *N* is the total number of experiments.

Sample	N	E_0		E_U	
		$<E_0>$ (GPa)	RSU (N) (%)	$<E_U>$ (GPa)	RSU(N) (%)
A	35	143.0	1.28	155.5	0.70
B	35	142.3	2.23	142.4	0.92
C	35	130.2	0.72	133.6	0.83
D	35	109.2	0.91	112.9	0.78

$$\langle COV \rangle = \frac{\sqrt{N_A}RSU(N_A)+\sqrt{N_B}RSU(N_B)+\sqrt{N_C}RSU(N_C)+\sqrt{N_D}RSU(N_D)}{4}$$

9. Uncertainty of measurand

The relative standard uncertainty corresponding to the number of specimens (N) tested shall be calculated using equation (6) given below:

$$RSU(N) = \langle COV \rangle / \sqrt{N} \qquad (6)$$

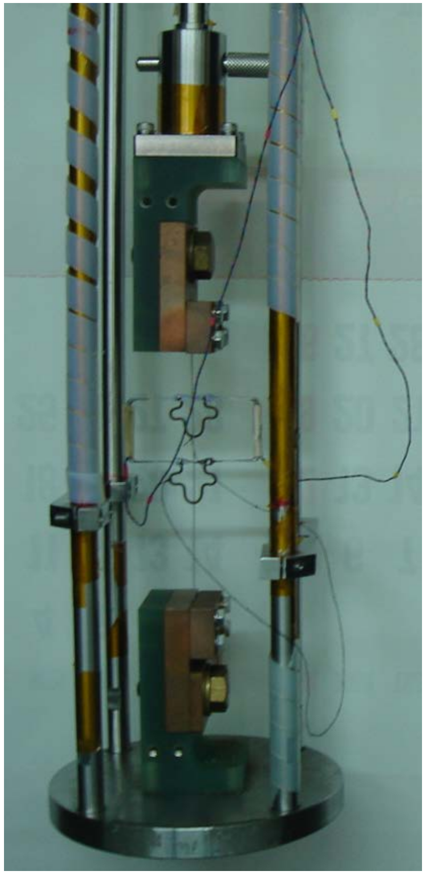
According to the international round robin test (see Clause A.5), the parameter <COV> has been determined as follows:

	E_0	E_U	$R_{p0.2\text{-}0}$	$R_{p0.2\text{-}U}$
<COV> (%)	7,0	4,6	4,3	4,1

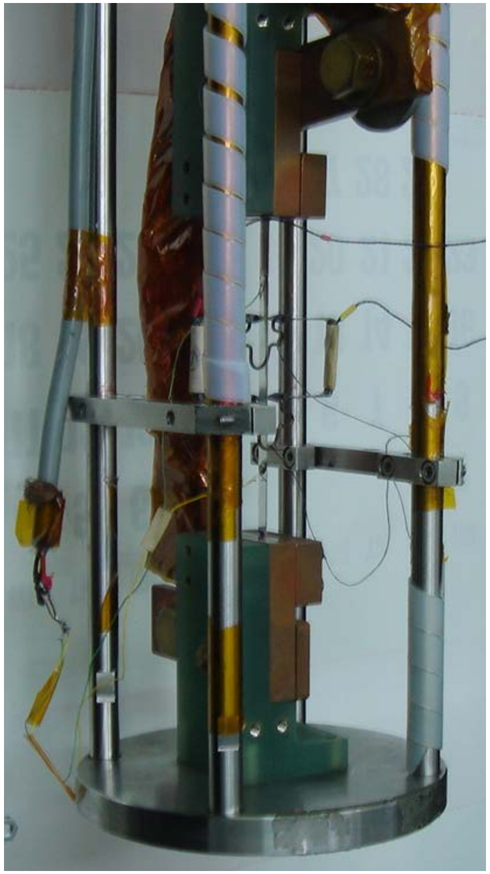
Standardization of measurement methods for practical REBCO tapes

- Tensile test at R.T.
- Tensile test at 77 K
    - Tensile strain dependence of Ic
    - Uniaxial strain dependence of Ic
    - Bending strain dependence of Ic

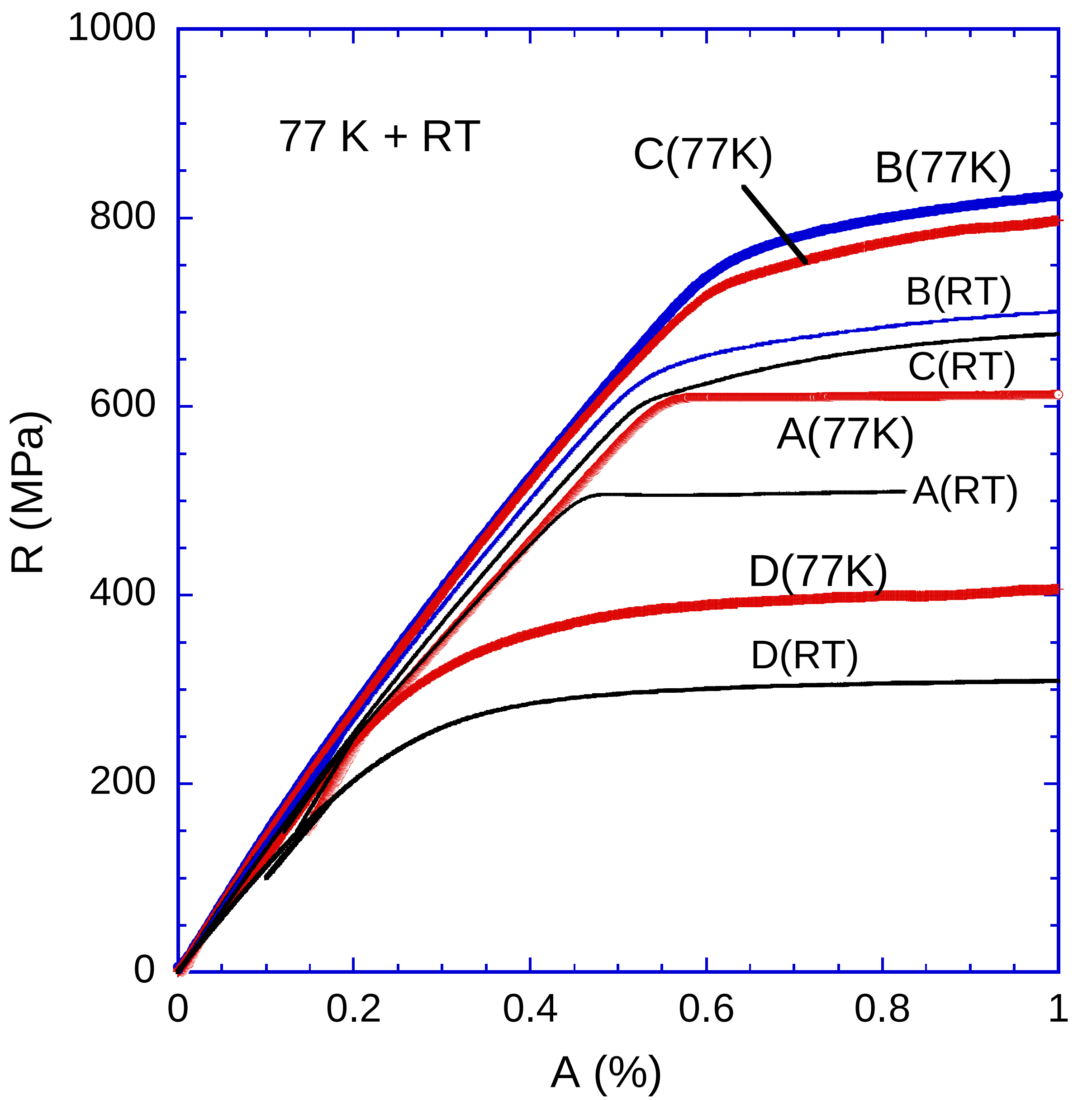
Open cryostat system for tensile test and tensile Ic measurement at liquid nitrogen temperature



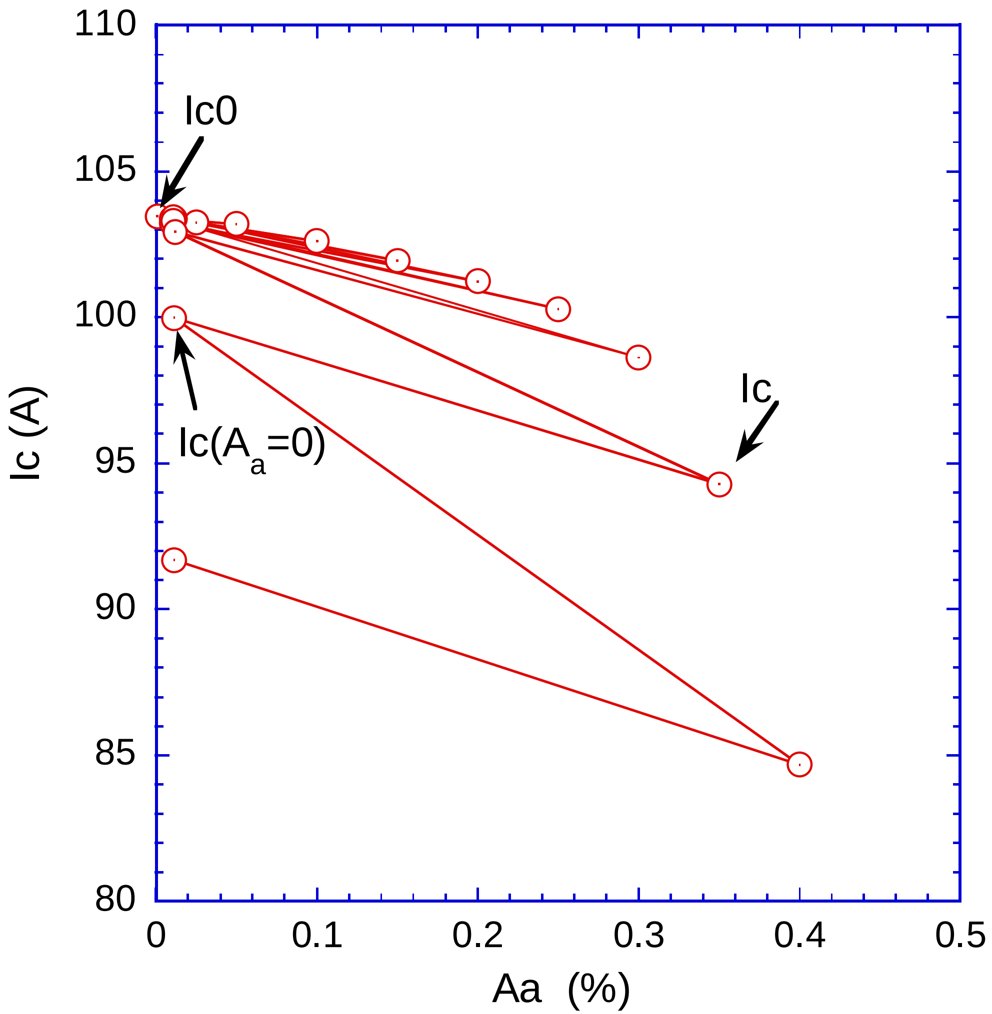
Tensile Test



Tensile Ic


77 K + RT
C(77K)
B(77K)
B(RT)
C(RT)
A(77K)
A(RT)
D(77K)
D(RT)
R (MPa)
A (%)
1000
800
600
400
200
0
0.2
0.4
0.6
0.8
1

I_c measurements



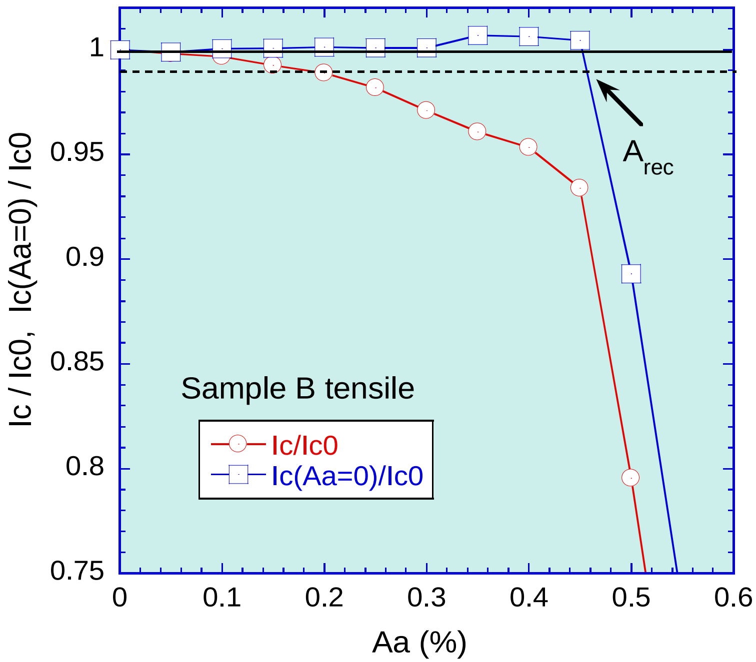
I_{co} : initial critical current at zero applied strain

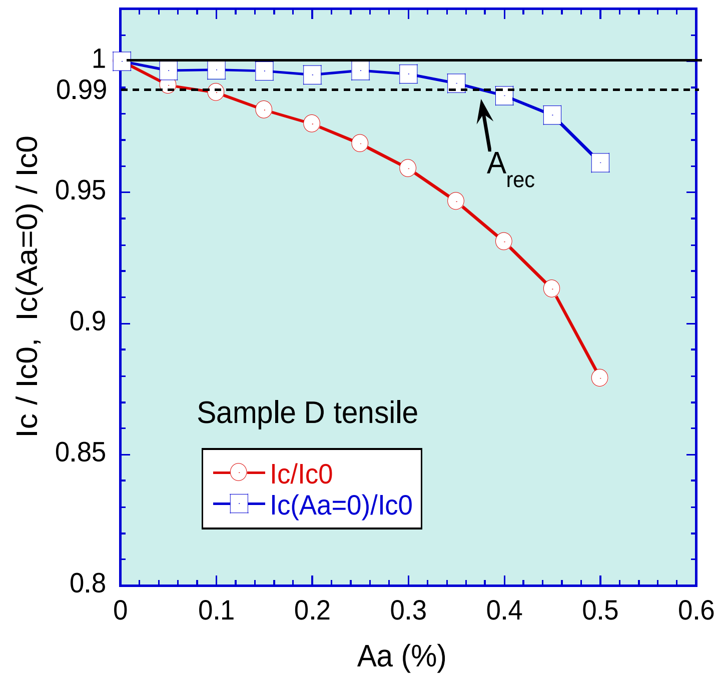
I_c : critical current at A_a

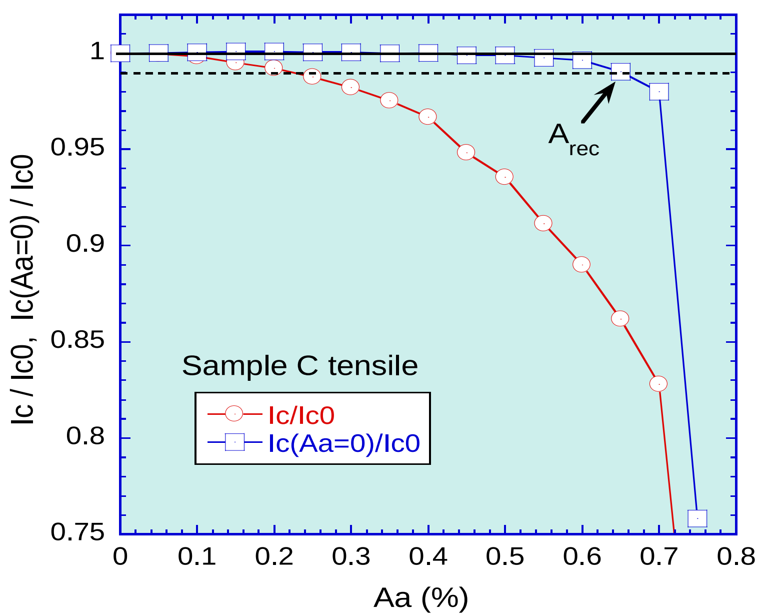
$I_c(A_a=0)$: critical current at zero applied strain after I_c measurement at A_a , which gives contribution from the reversible part, is called as ***recovered critical current***.

Ic /Ic0
Ic(Aa=0)/Ic0

Ic/Ic(Aa=0)







A_{rec} :

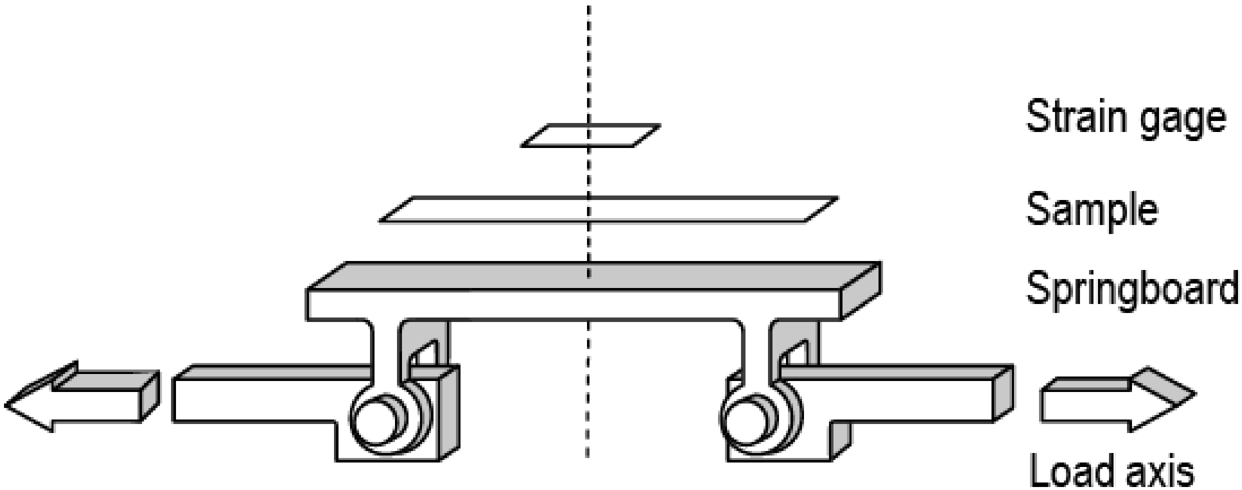
99%Ic
Recovery
Strain

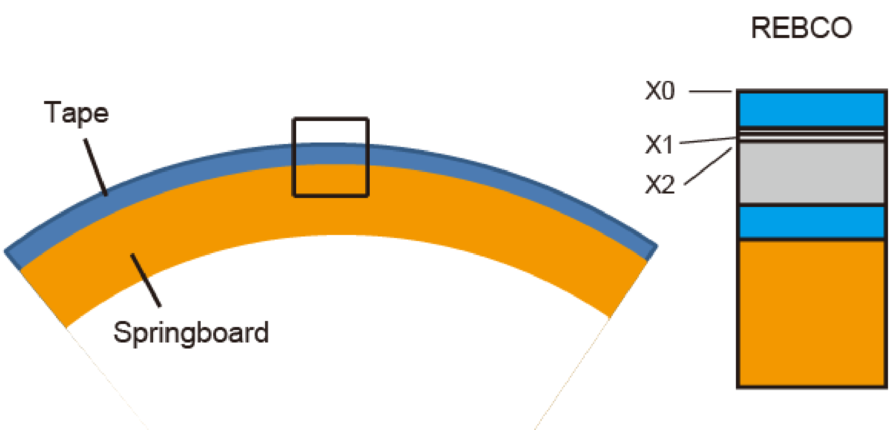
99%Ic Recovery and Ic maximum from tensile and SB tests

	Arec (%) from tensile	Arec (%) from SB	Am (%) From SB
B	0.46	> 0.4	0.12
C	0.65	> 0.4	-0.033
D	0.37	0.31	-0.075

"***99%Ic recovery strain***" (Arec) is important as a practical measure of the reversible strain region, beyond which a degradation starts.

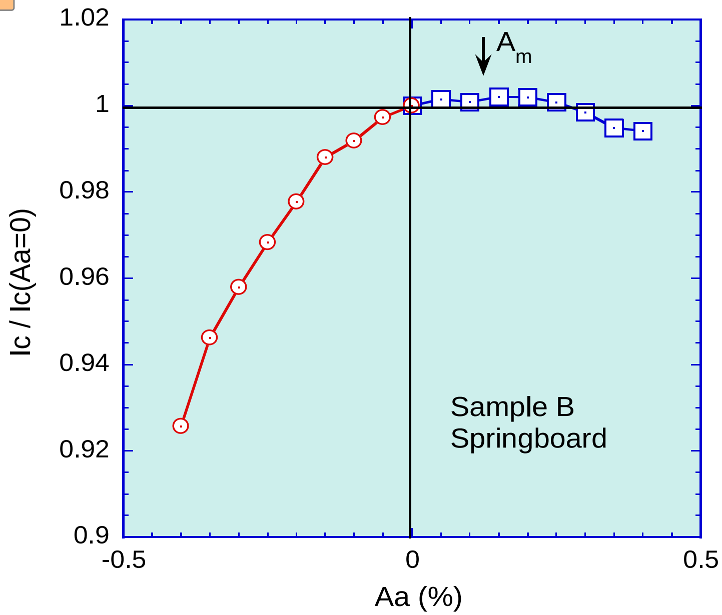
Application of uniaxial compressive and tensile strain by the springboard after Hampshire, Durham university

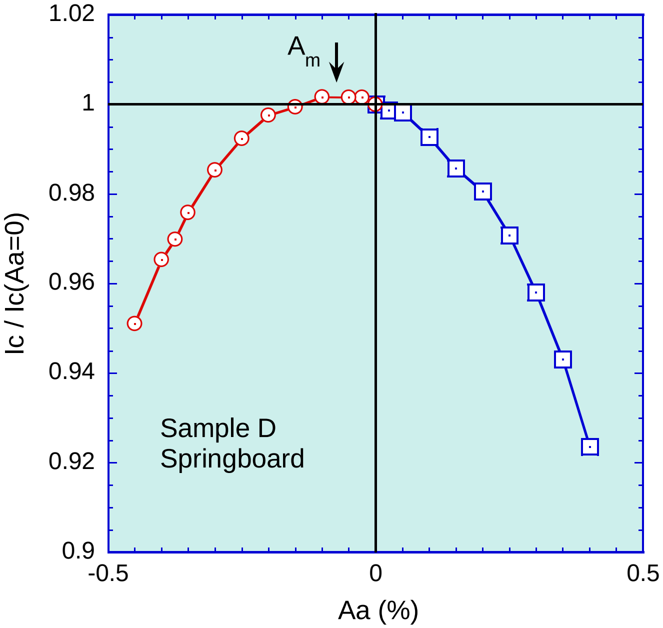


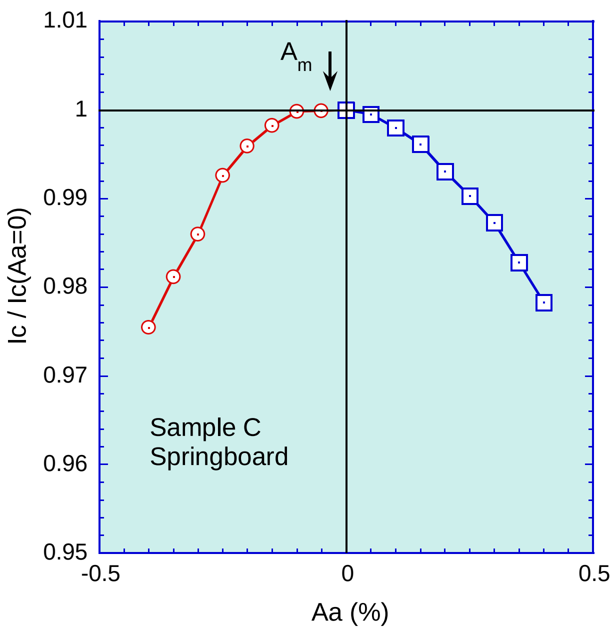


Example

	REBCO (SP)
X0	1.0%
X1	0.98%
X2	0.98%

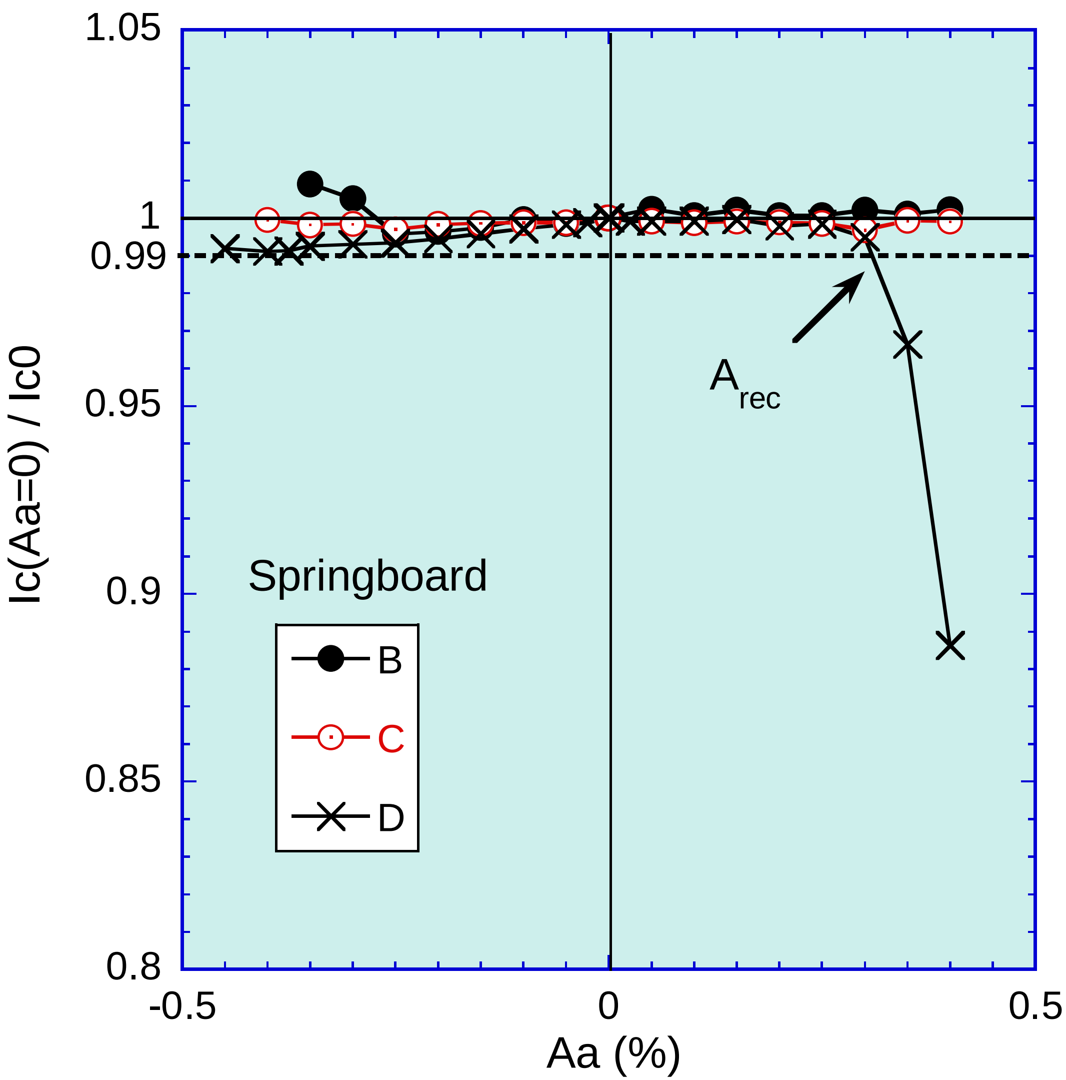






Am:
Strain at
Ic
Maximum

A practical definition for the reversible strain limit is A_{rec} as 99% Ic recovery.



99%Ic Recovery and Ic maximum from tensile and SB tests

	Arec (%) from tensile	Arec (%) from SB	Am (%) From SB
B	0.46	> 0.4	0.12
C	0.65	> 0.4	-0.033
D	0.37	0.31	-0.075

"***99%Ic recovery***" (Arec) is important as a practical measure of the reversible strain region, beyond which a degradation starts.

Discrepancy of Arec determined by tensile and SB tests is attributed to the influence of SB.

"***Maximum strain***" (Am) is a central parameter to characterize the reversible strain dependence of Ic.

Summary

Activity of international standardization is introduced here, Mainly in the aspect of mechanical and superconducting properties of practical REBCO wires.

1 Introduction of CD of room temperature tensile test method of REBCO wire.

2 Suggestion of the successive items for standardization;

- tensile test of REBCO wire at 77 K
- critical current measurement of REBCO wire as a function of tensile strain
- critical current measurement of REBCO wires as a function of uniaxial strain

Acknowledgments: the activity of IEC-TC90 is partially supported by VAMAS-TWA16 committee.

Public Standards

<table>
<tr><td colspan="4">Open Standards</td><td colspan="2">Closed Standards</td></tr>
<tr><td colspan="3">de jure Standards</td><td colspan="3">de facto Standards</td></tr>
<tr><td>Legal Standards</td><td colspan="4">Consensus-based Standards</td><td>Single-handed Standards</td></tr>
<tr><td>Mandatory Statute</td><td>International Standards</td><td>Domestic (National) Standards</td><td>Forum (Industry) Standards</td><td>Consortium Standards</td><td>In-house Standards</td></tr>
<tr><td></td><td>IEC, ISO</td><td>ASTM,CSB
TS
DIN,
JIS,KIS</td><td>ICFA,
CIGRE</td><td></td><td></td></tr>
</table>