Superconductivity Lab: Week 2

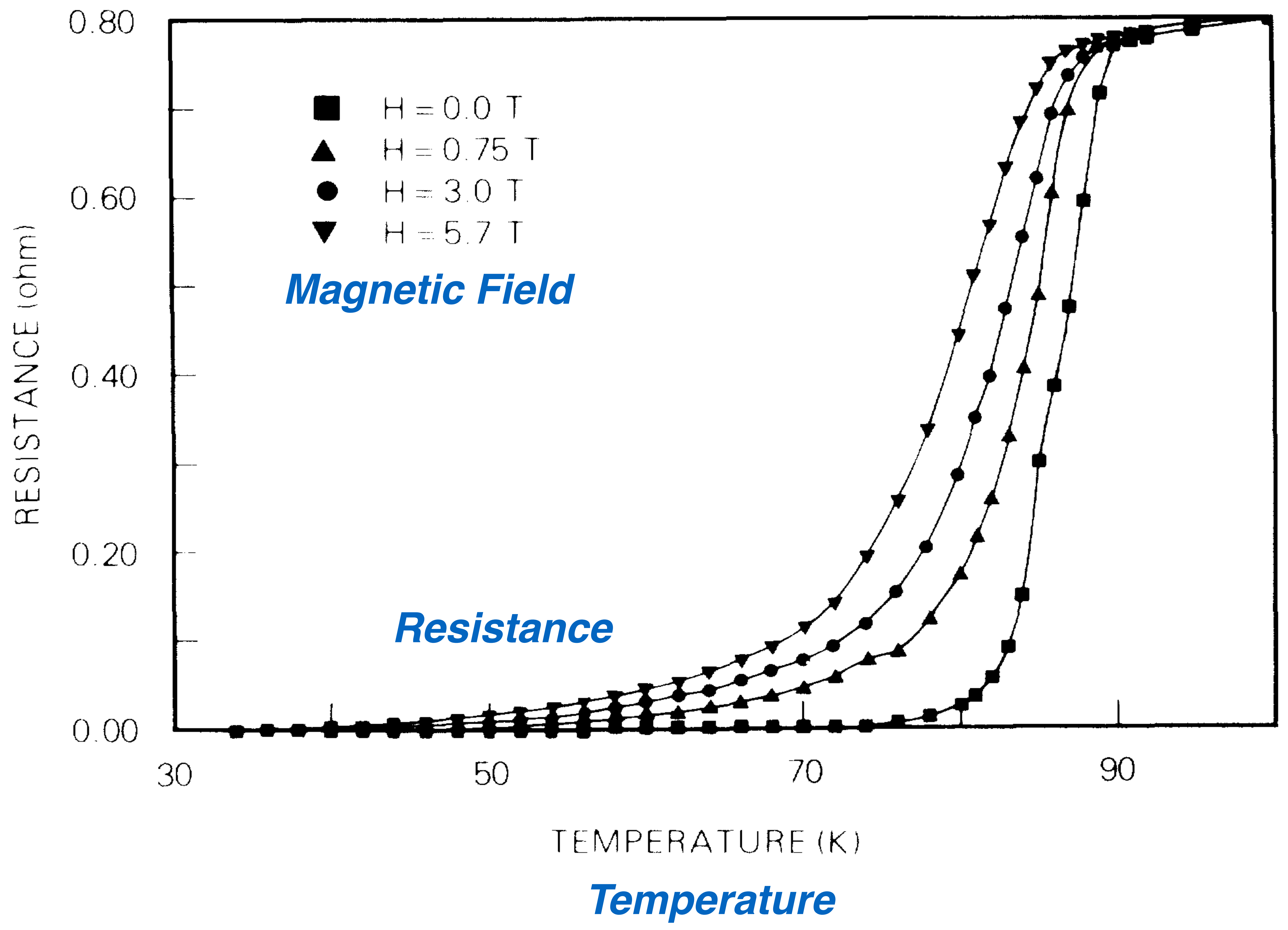
AP 4018
Columbia University (Spring 2021)

Objective

- Measure the resistance vs. temperature

- Measure the influence of magnetic field on the resistance and critical temperature

From M. K. Wu, et al., *PRL* 1987



This Lab: Repeat the Famous Experiments Reported by M.K. Wu and co-authors, *PRL*, 2 March 1987

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Superconductivity at 93 K in a New Mixed-Phase Y-Ba-Cu-O Compound System at Ambient Pressure

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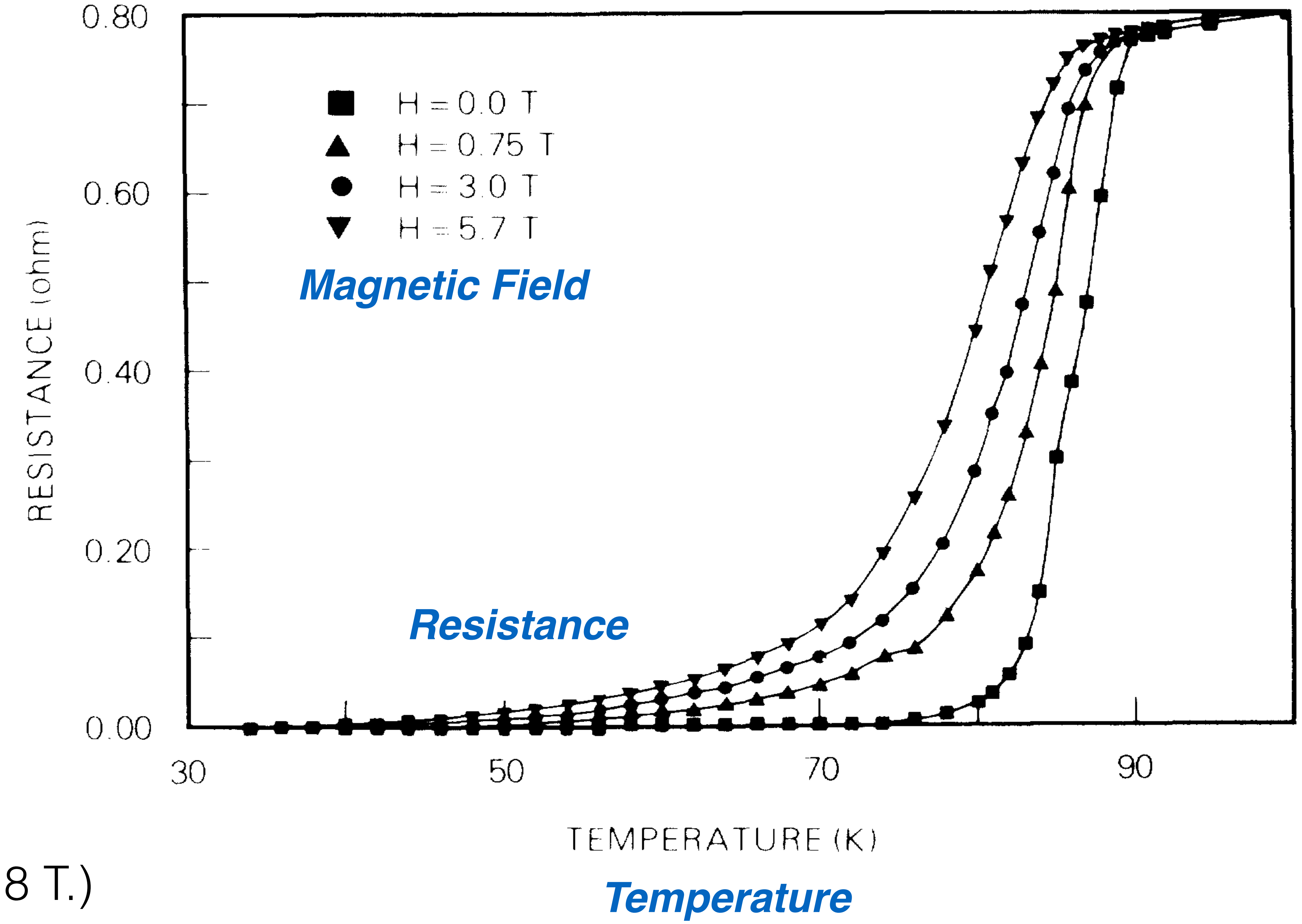
A stable and reproducible superconductivity transition between 80 and 93 K has been unambiguously observed both resistively and magnetically in a new Y-Ba-Cu-O compound system at ambient pressure. An estimated upper critical field $H_{c2}(0)$ between 80 and 180 T was obtained.

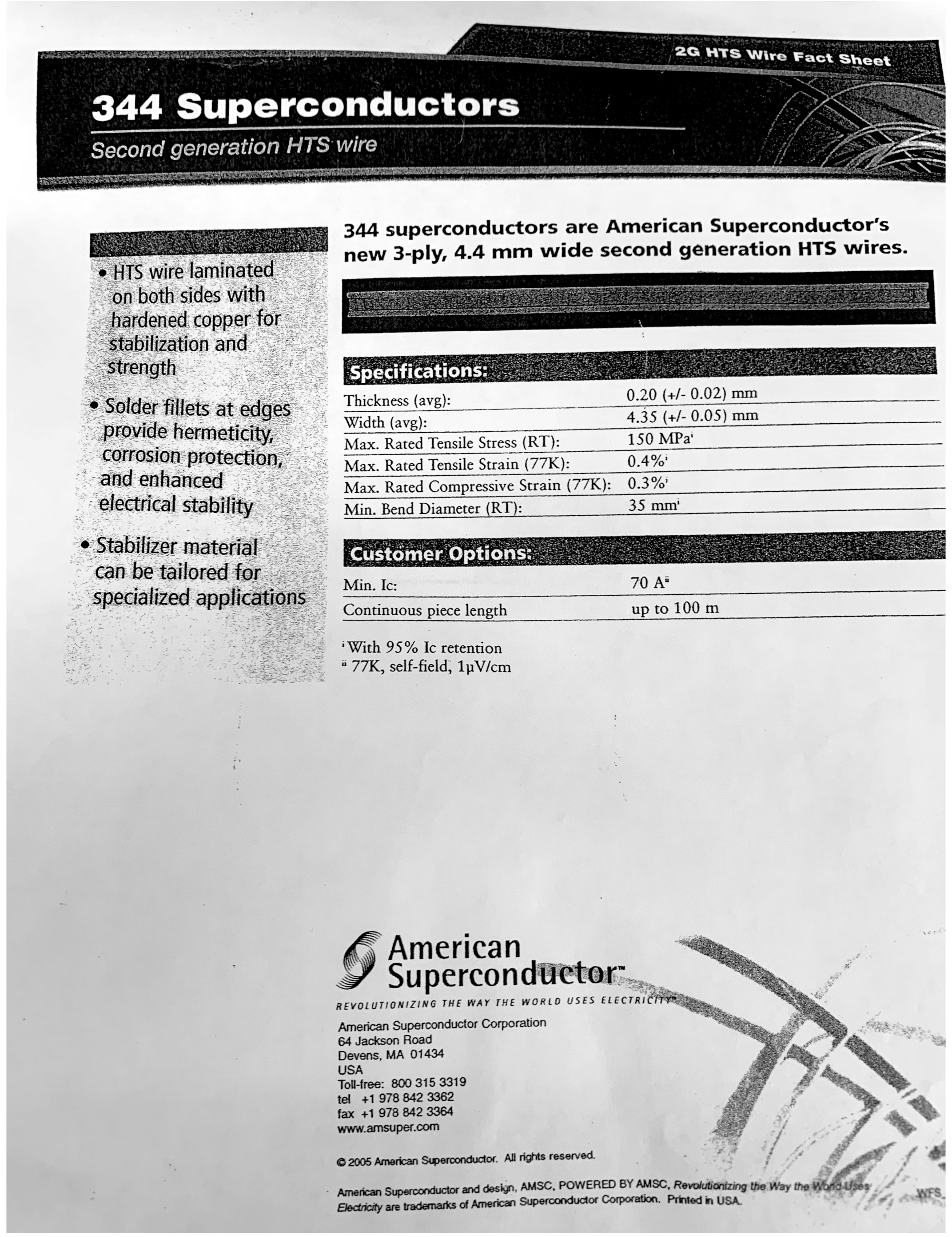
Superconductivity is influenced by temperature, magnetic field, and mechanical strain

The temperature dependence of *R* determined in a simple liquid-nitrogen Dewar is shown in Fig. 1. *R* initially drops almost linearly with temperature *T*. A deviation of *R* from this *T* dependence is evident at 93 K and a sharp drop starts at 92 K. A "zero-*R*" state is achieved at 80 K. The variation of χ with *T* is shown in Fig. 2. It is evident that a diamagnetic shift starts at 91 K and the size of the shift increases rapidly with further cooling. At 4.2 K, the diamagnetic signal corresponds to 24% of the superconducting signal of a Pb sample with similar dimensions. In a magnetic field, the *R* drop is shifted toward lower *T*. At our maximum field of 5.7 T, the "zero-*R*" state remains at a *T* as high as 40 K.



(In our experiment, the applied magnetic field is only 0.18 T.)

Two Commercial Samples from American Superconductor (https://www.amsc.com)



2G HTS Wire Fact Sheet

344 Superconductors

Second generation HTS wire

- HTS wire laminated on both sides with hardened copper for stabilization and strength
- Solder fillets at edges provide hermeticity, corrosion protection, and enhanced electrical stability
- Stabilizer material can be tailored for specialized applications

344 superconductors are American Superconductor's new 3-ply, 4.4 mm wide second generation HTS wires.

Specifications:

Thickness (avg):	0.20 (+/- 0.02) mm
Width (avg):	4.35 (+/- 0.05) mm
Max. Rated Tensile Stress (RT):	150 MPa[i]
Max. Rated Tensile Strain (77K):	0.4%[i]
Max. Rated Compressive Strain (77K):	0.3%[i]
Min. Bend Diameter (RT):	35 mm[i]

Customer Options:

Min. Ic:	70 A[ii]
Continuous piece length	up to 100 m

[i] With 95% Ic retention
[ii] 77K, self-field, 1μV/cm

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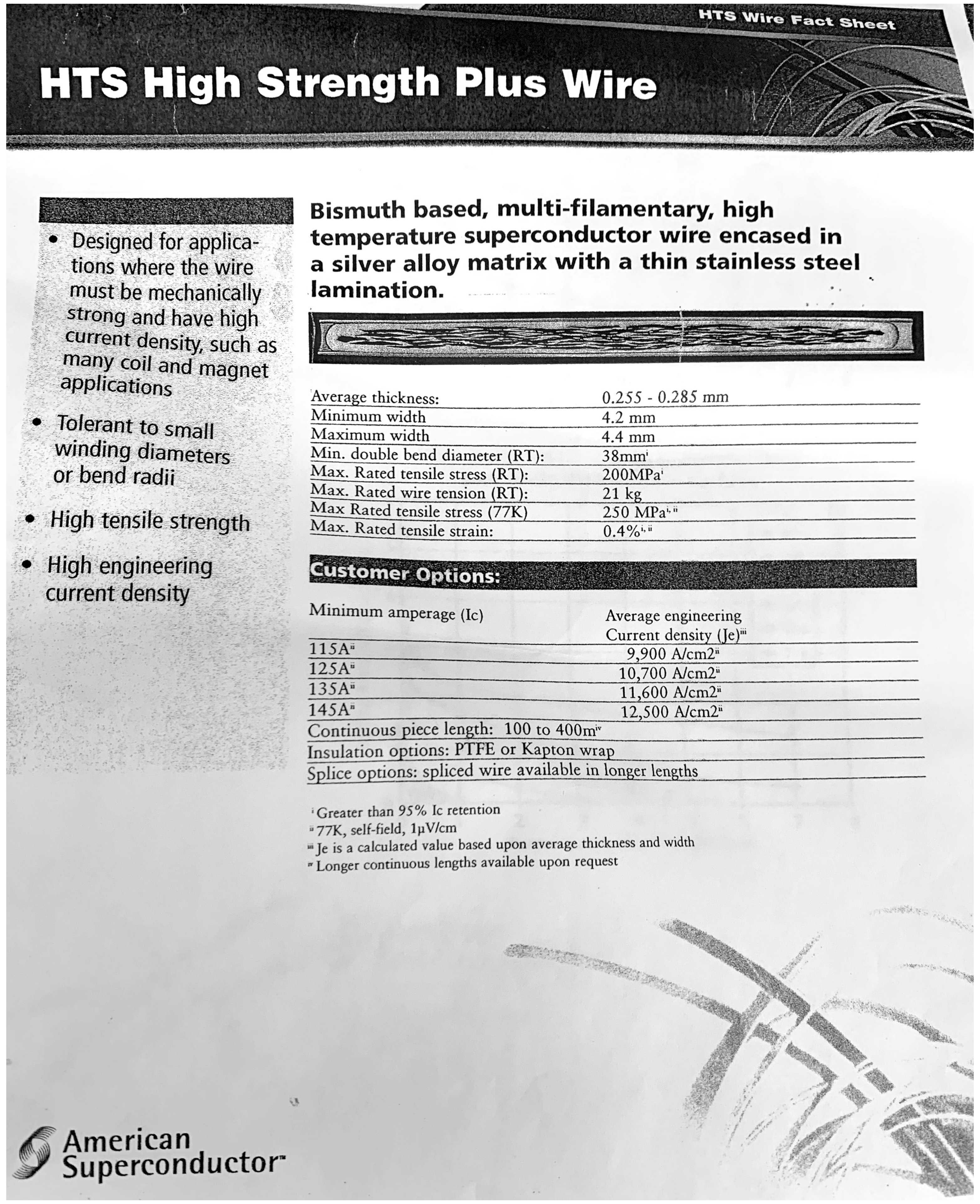
WFS

Yttrium Barium Copper Oxide
(YBCO or Rare-Earth Barium Oxide)



HTS Wire Fact Sheet

HTS High Strength Plus Wire

- Designed for applications where the wire must be mechanically strong and have high current density, such as many coil and magnet applications
- Tolerant to small winding diameters or bend radii
- High tensile strength
- High engineering current density

Bismuth based, multi-filamentary, high temperature superconductor wire encased in a silver alloy matrix with a thin stainless steel lamination.

Average thickness:	0.255 - 0.285 mm
Minimum width	4.2 mm
Maximum width	4.4 mm
Min. double bend diameter (RT):	38mm[i]
Max. Rated tensile stress (RT):	200MPa[i]
Max. Rated wire tension (RT):	21 kg
Max Rated tensile stress (77K)	250 MPa[i, ii]
Max. Rated tensile strain:	0.4%[i, ii]

Customer Options:

Minimum amperage (Ic)	Average engineering Current density (Je)[iii]
115A[ii]	9,900 A/cm2[ii]
125A[ii]	10,700 A/cm2[ii]
135A[ii]	11,600 A/cm2[ii]
145A[ii]	12,500 A/cm2[ii]

Continuous piece length: 100 to 400m[iv]
Insulation options: PTFE or Kapton wrap
Splice options: spliced wire available in longer lengths

[i] Greater than 95% Ic retention
[ii] 77K, self-field, 1μV/cm
[iii] Je is a calculated value based upon average thickness and width
[iv] Longer continuous lengths available upon request

American Superconductor™

bismuth strontium calcium copper oxide
$Bi_2Sr_2Ca_2Cu_3O_{10}$

Two Commercial Samples from American Superconductor (https://www.amsc.com)

Most promising today…
but with stronger support wraps

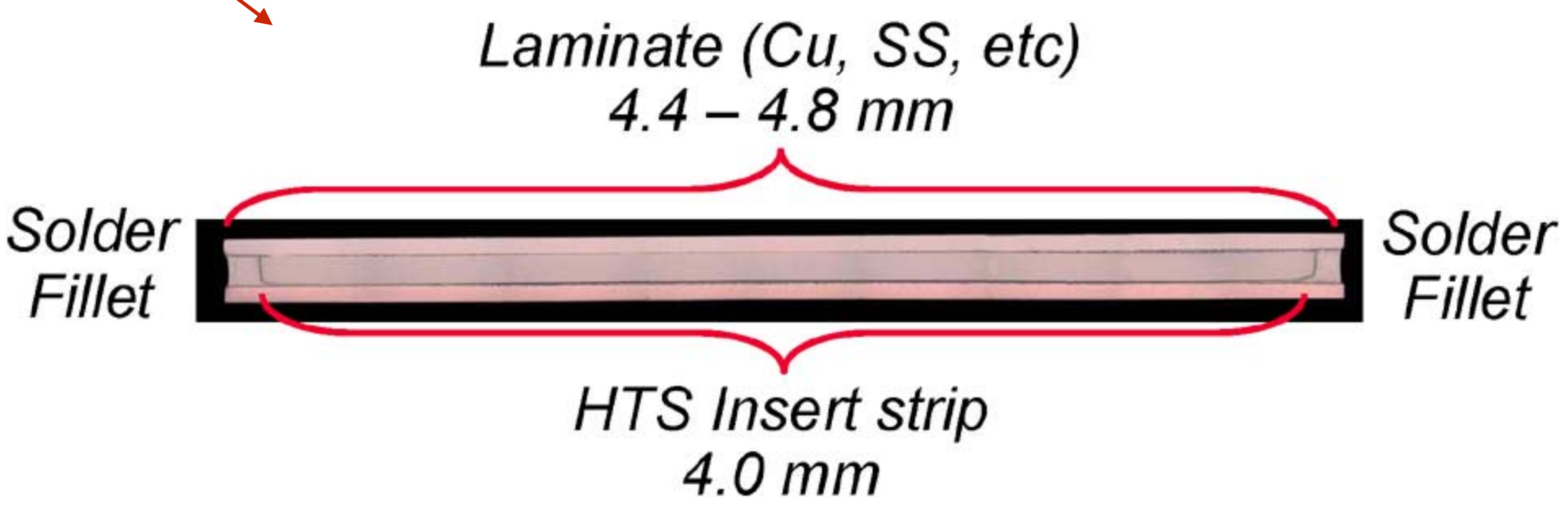
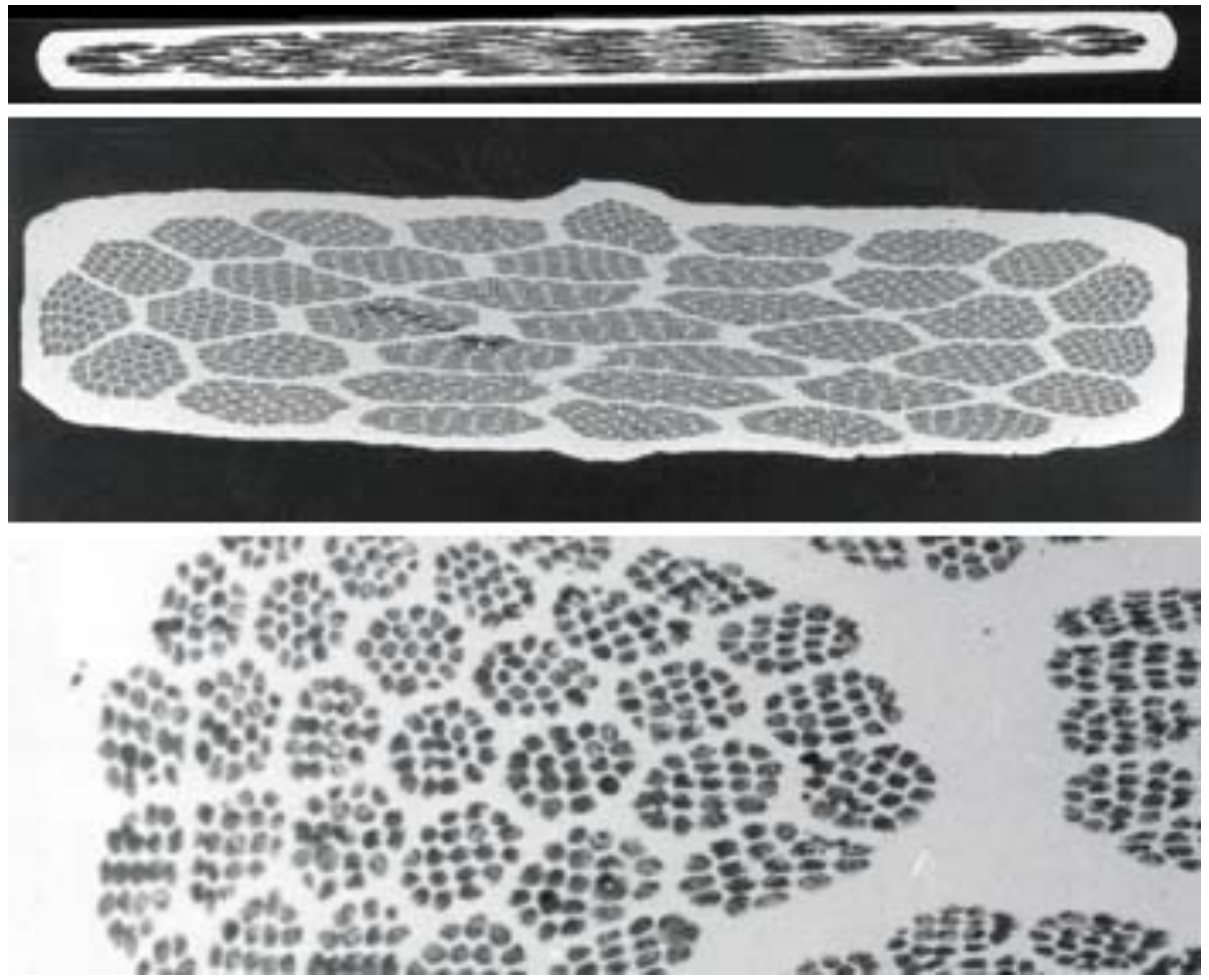


Fig. 2. Cross-section micrograph of AMSC's standard 2G HTS wire, called 344 (or 348) superconductors.

IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 17, NO. 2, JUNE 2007

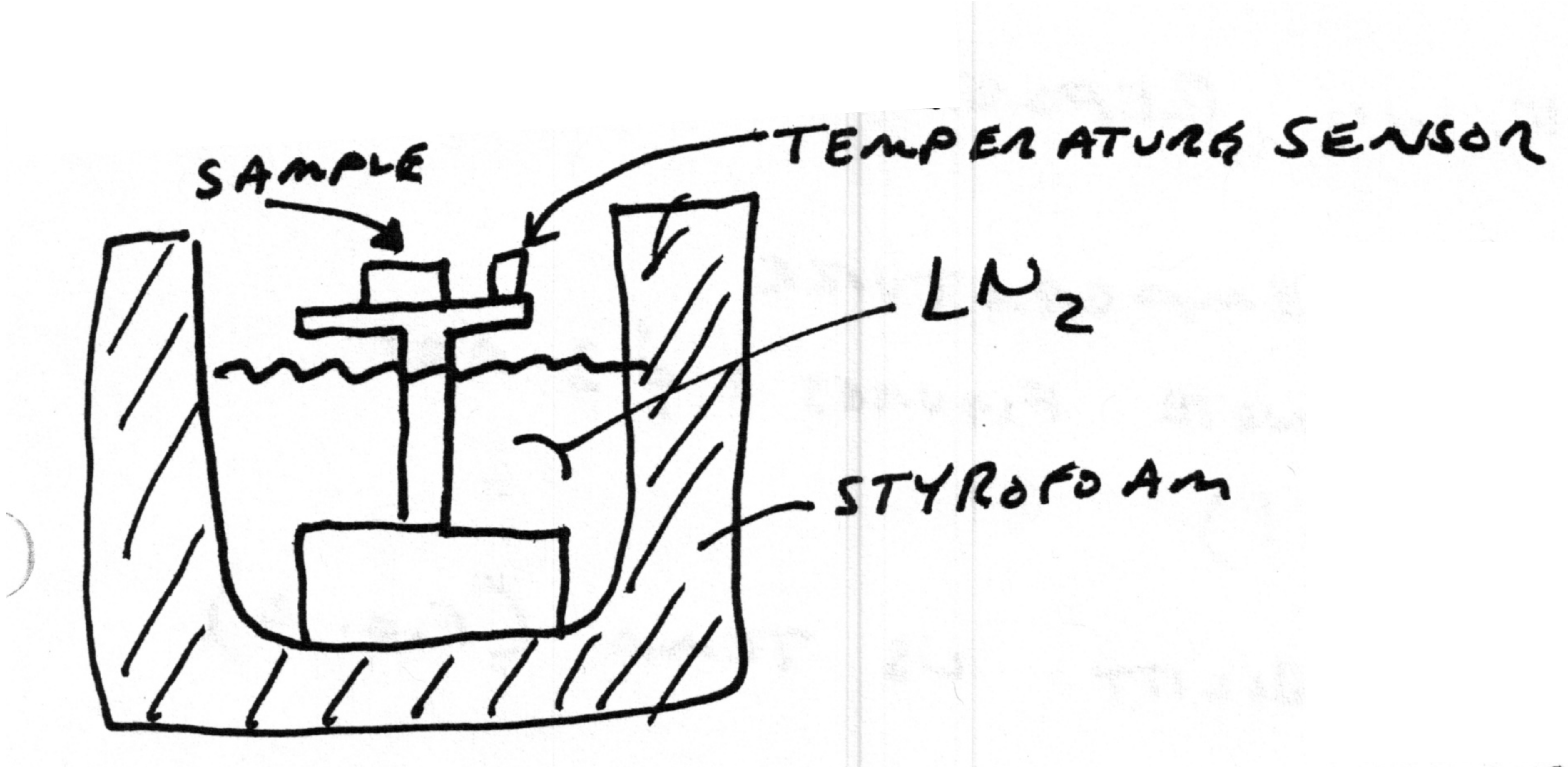
Yttrium Barium Copper Oxide
(YBCO or Rare-Earth Barium Oxide)

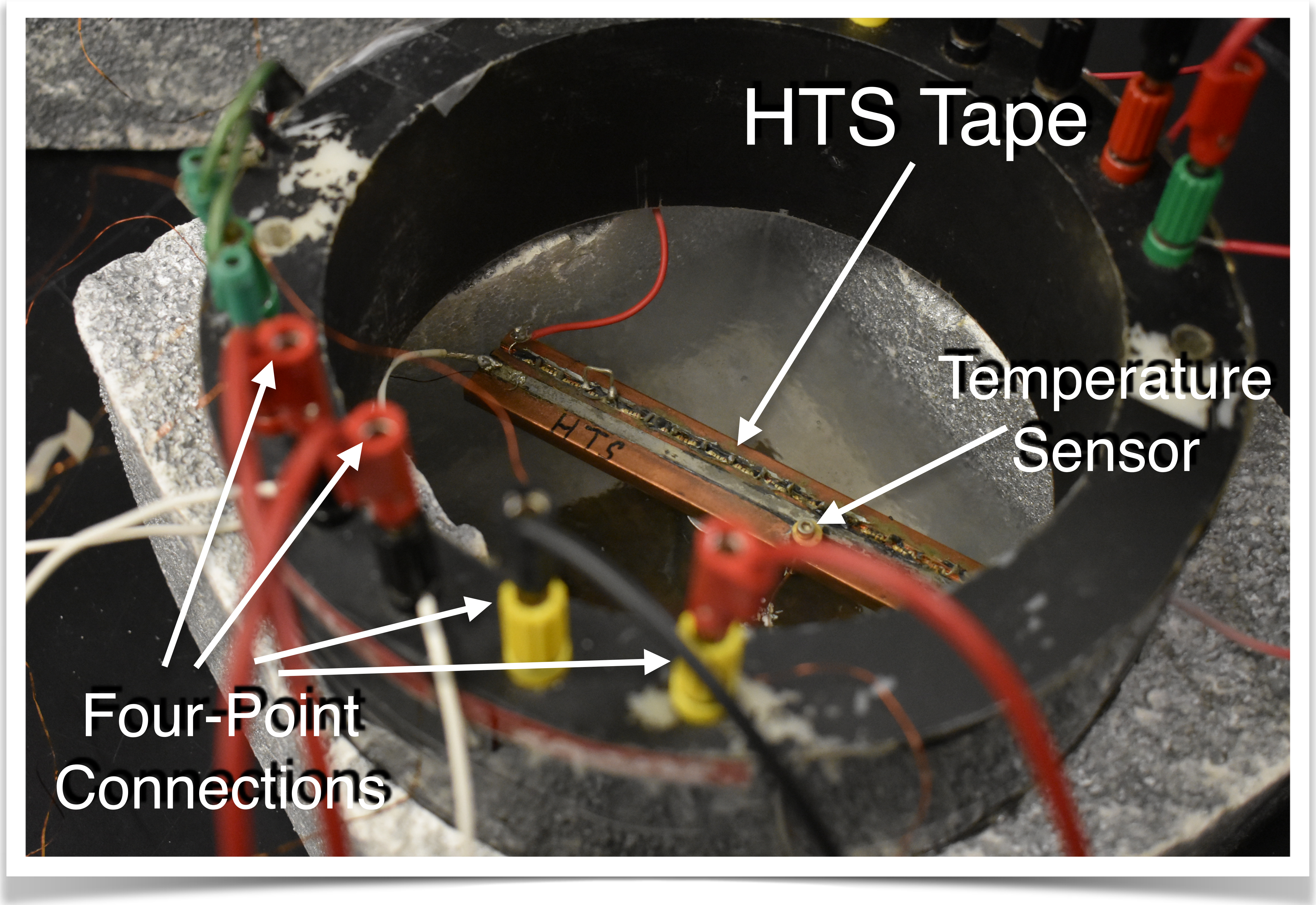


1 Inside a superconducting wire The cross-sections of high-temperature superconducting wires. Top, a Bi-2223 tape with dimensions of 4.1 mm x 0.2 mm. Middle, a Y-123 tape comprising 36,000 wire filaments that was made using a metal-alloy processing technique. The tape measures 3 mm x 0.6 mm. Bottom, a magnified view of the left-most bundle of filaments. The tapes were manufactured by American Superconductor Corporation.

bismuth strontium calcium copper oxide
$Bi_2Sr_2Ca_2Cu_3O_{10}$

Styrofoam Dewar





Recipe: YBCO tape, thin films are deposited onto a silver/copper/steel tape.

Four-Point Measurement of Resistance

(or how does one measure “zero” resistance?)

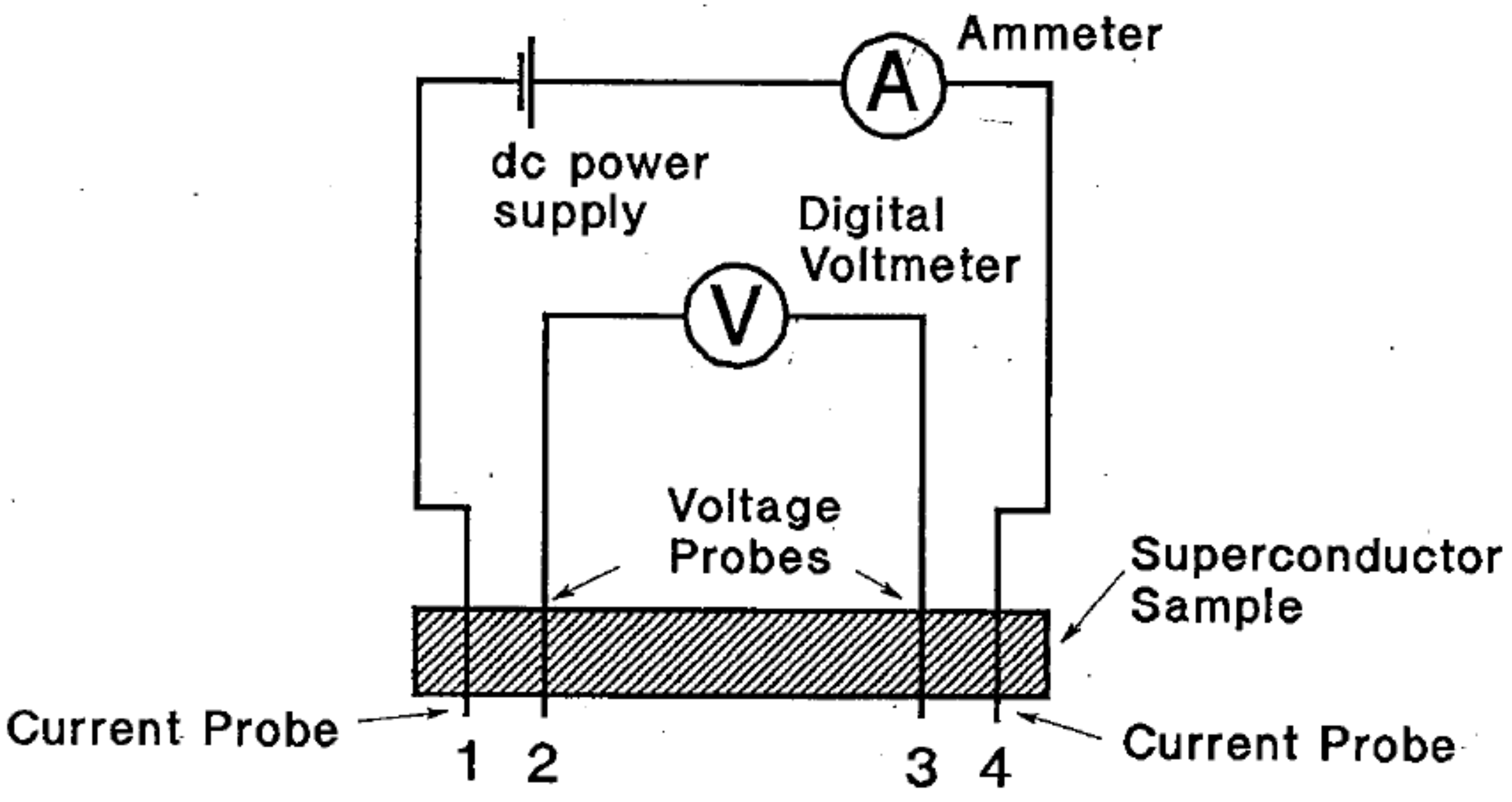
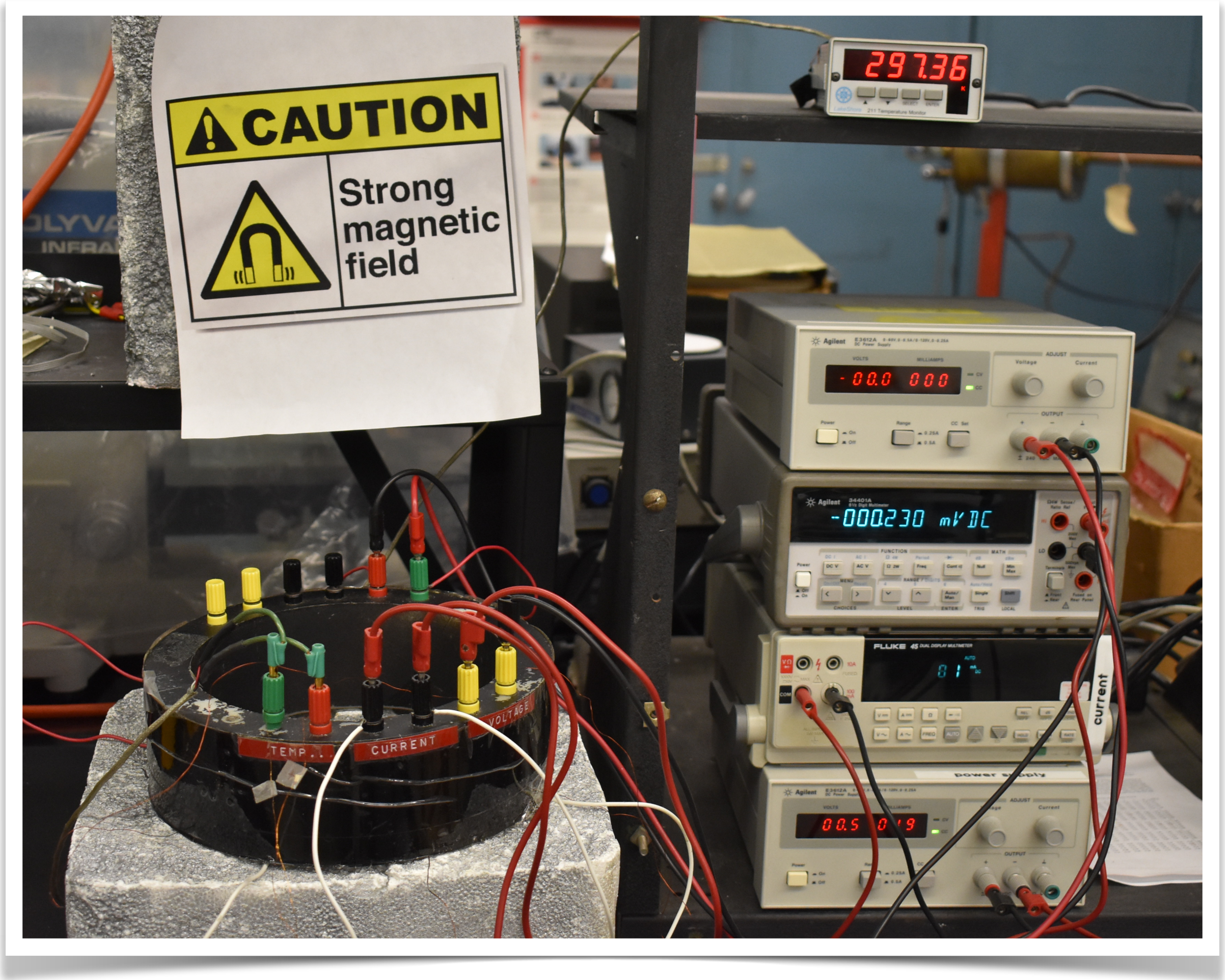
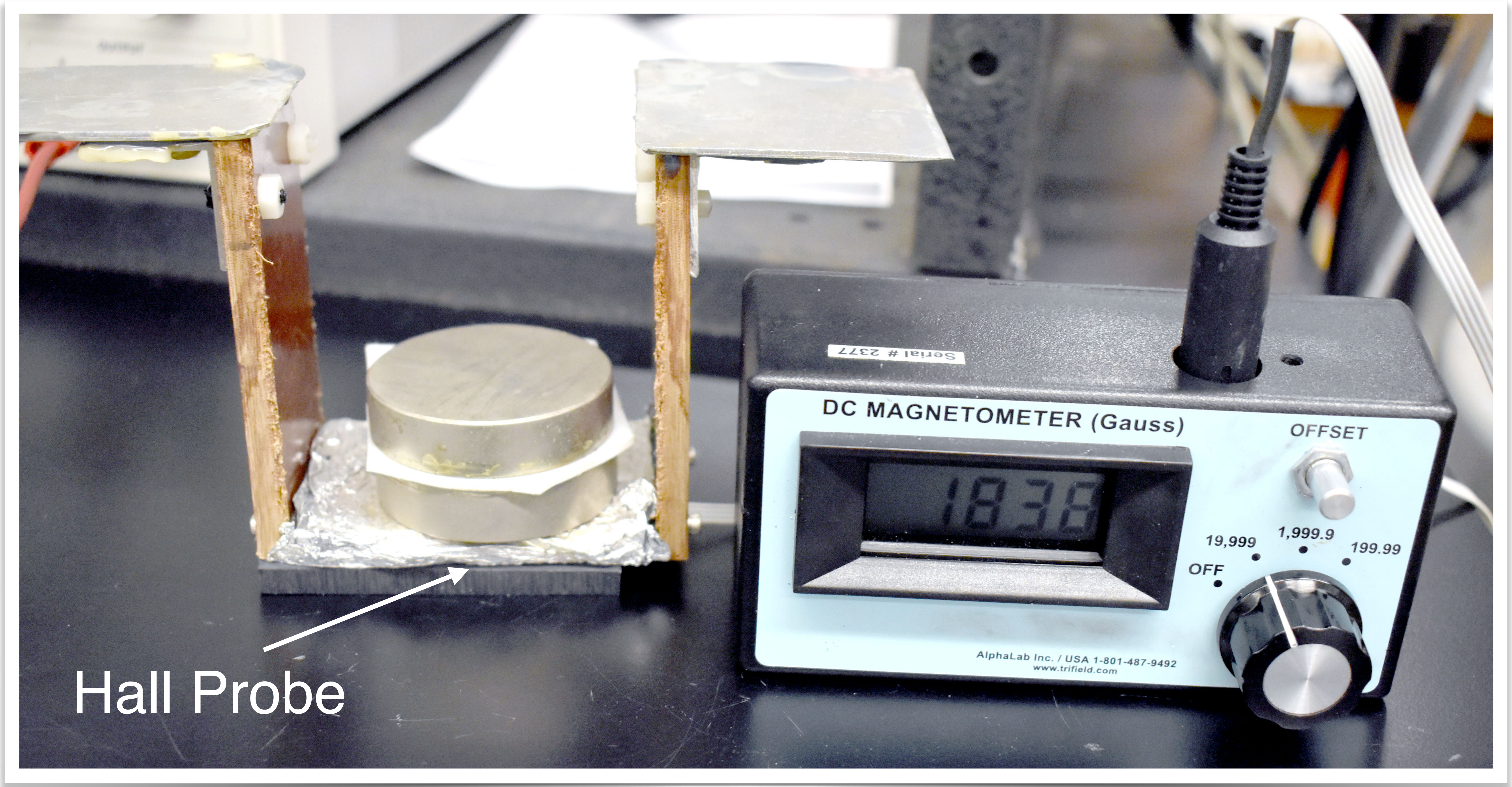


Figure 2: Schematic of Four Point Probe



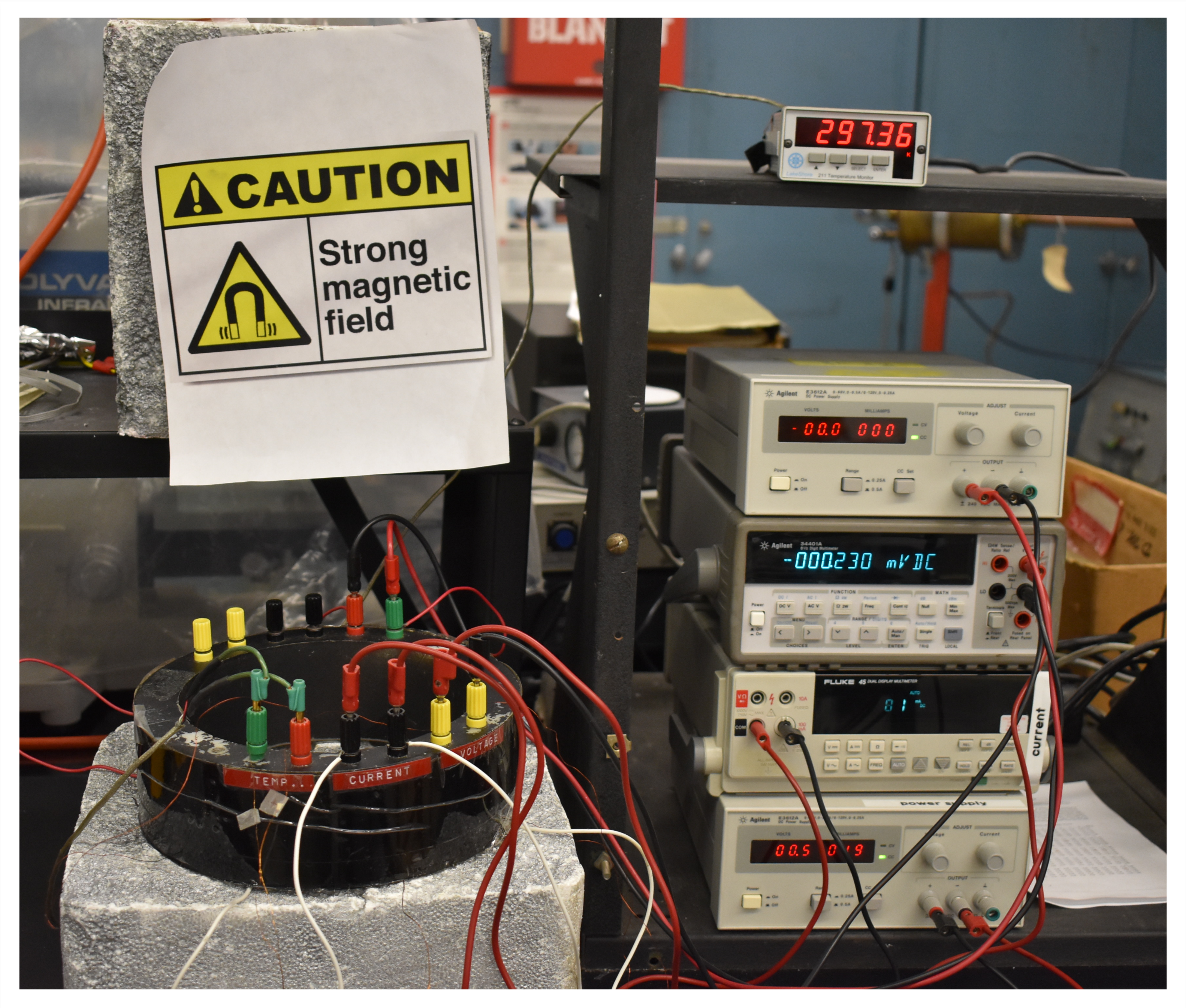
Applying a Magnetic Field



0.18 T

What is Contained in Data Files?

- Bi-2223 (bismuth strontium calcium copper oxide):
  - `Bi-2223-No-B.mov`
  - `Bi-2223-With-B.mov`
- YBCO (yttrium barium copper oxide):
  - `YBCO-No-B.mov`
  - `YBCO-With-B.mov`



Bi-2223 at Room Temperature

Summary: Week 2

- Using a four-point measurement technique, measure the resistance of superconducting tape (Bi-2223 and YBCO) as a function of temperature, and
- as a function of magnetic field.