MgB_2 – One Year Later

Wire Development Already Well Underway!

Paul M. Grant
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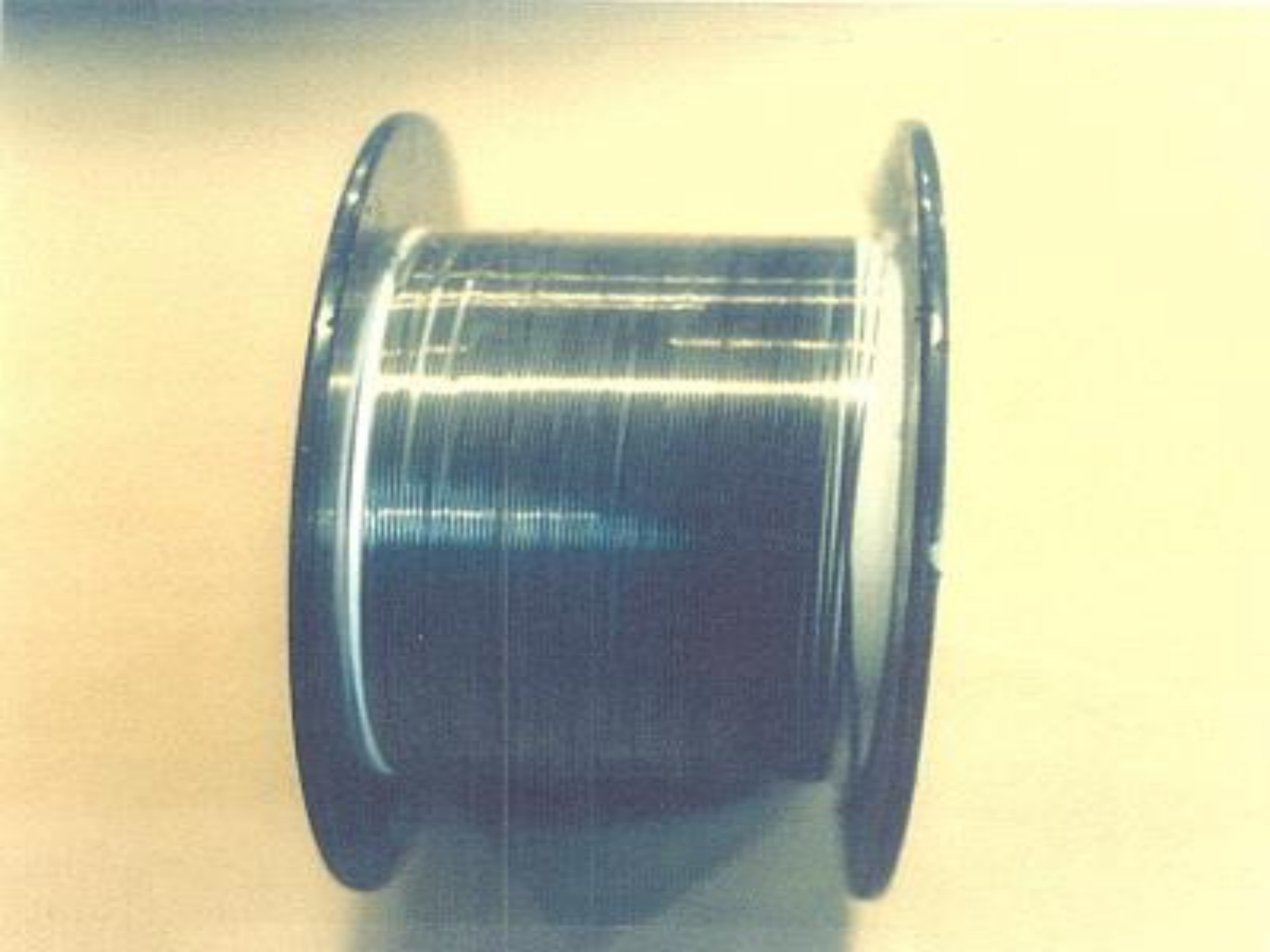
Electric Power Research Institute
Palo Alto, California USA



OPW's

- Tomsic (HyperTech)
- Sargent (Diboride)
- Grasso (INFM-Genova)
- Caplin (Imperial College)
- Larbalestier (UW/ASC)
- Christen (ORNL)
- Suenaga (BNL)
- Canfield (Ames)

U.S. Department of Energy
Superconductivity for Electric Systems
2002 Wire Development Workshop
St. Petersburg 22-23 Jan 02

Nature, 1 March 2001

How was it ever missed!

Superconductivity at 39 K in magnesium diboride

Jun Nagamatsu*, Norimasa Nakagawa*, Takahiro Muranaka*, Yuji Zenitani* & Jun Akimitsu*†

** Department of Physics, Aoyama-Gakuin University, Chitosedai, Setagaya-ku, Tokyo 157-8572, Japan*
† CREST, Japan Science and Technology Corporation, Kawaguchi, Saitama 332-0012, Japan

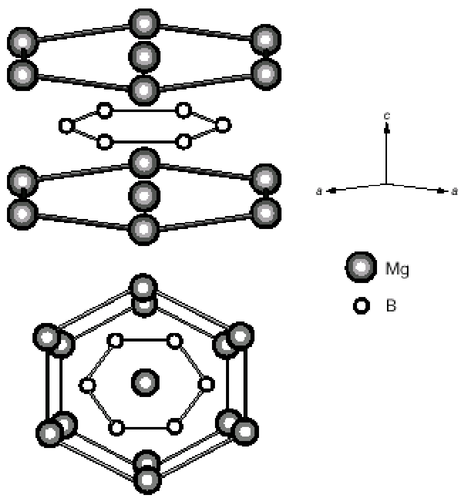


Figure 2 Crystal structure of MgB_2.

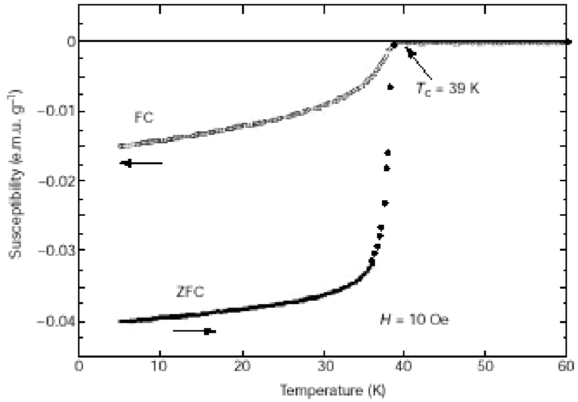


Figure 3 Magnetic susceptibility χ of MgB_2 as a function of temperature. Data are shown for measurements under conditions of zero field cooling (ZFC) and field cooling (FC) at 10 Oe.

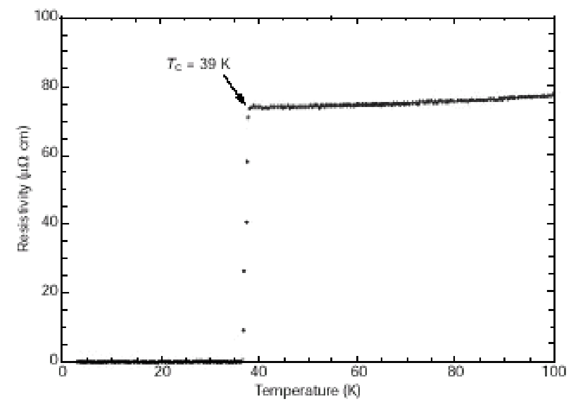


Figure 4 Temperature dependence of the resistivity of MgB_2 under zero magnetic field.

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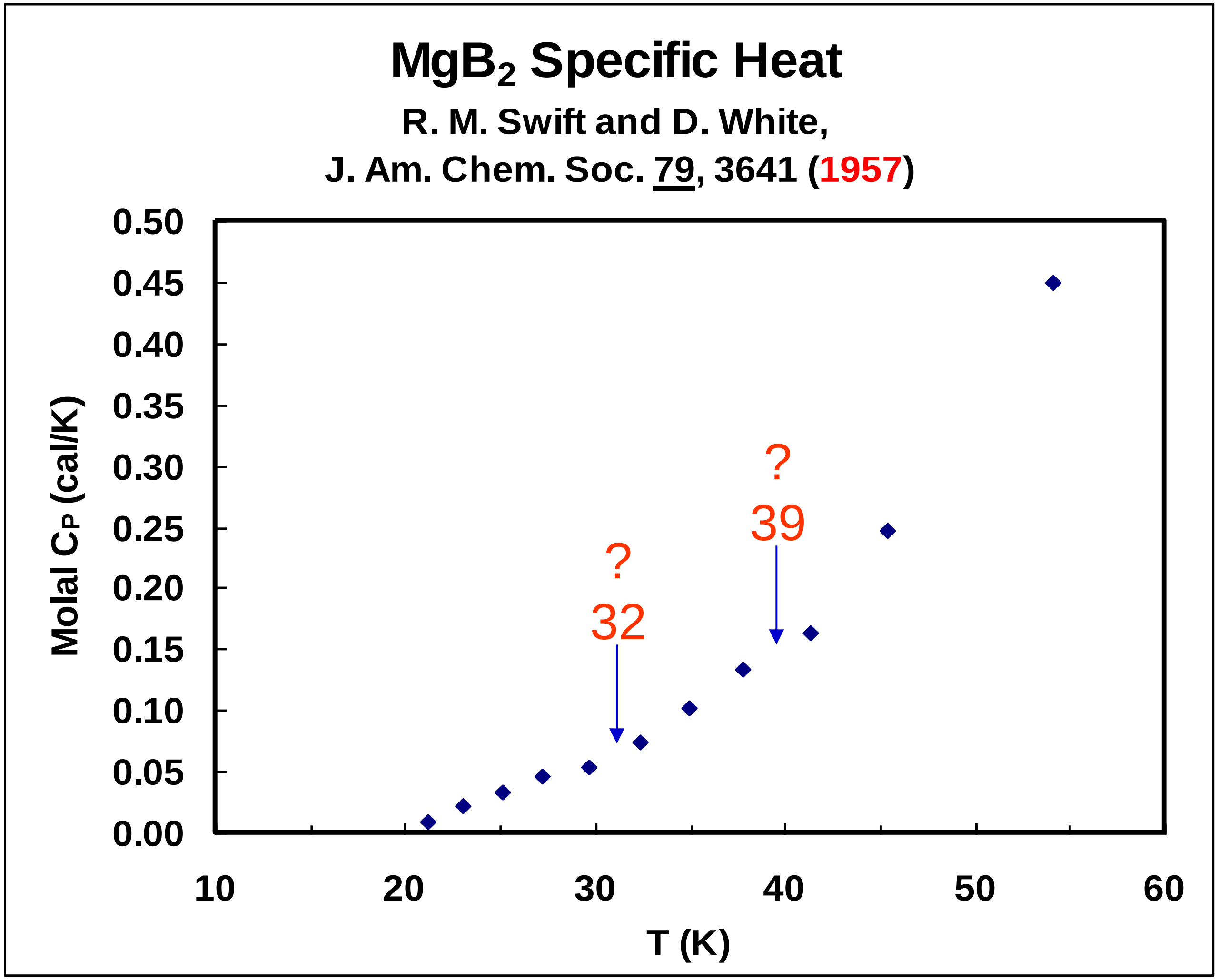
Maybe It Wasn't Missed!



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Wither Beyond MgB_2?

- MgB_2 appears to be the quintessential electron-phonon coupling superconductor
- A "tepid temperature" compound
- So far, one of a kind…end of the road?

Nature, 31 May 2001

Superconductivity

Rehearsals for prime time

Paul Grant

Superconductivity seems to have been forever waiting in the wings. Although superconducting power cables are about to go live, will the newest material, magnesium diboride, become the class act of the future?

High critical currents in iron-clad superconducting MgB_2 wires

S. Jin, H. Mavoori, C. Bower & R. B. van Dover

Agere Systems/Lucent Technologies, Murray Hill, New Jersey 07974, USA

	4.2 K	25 K
J_C @ 1 T (A/cm^2)	150,000	35,000

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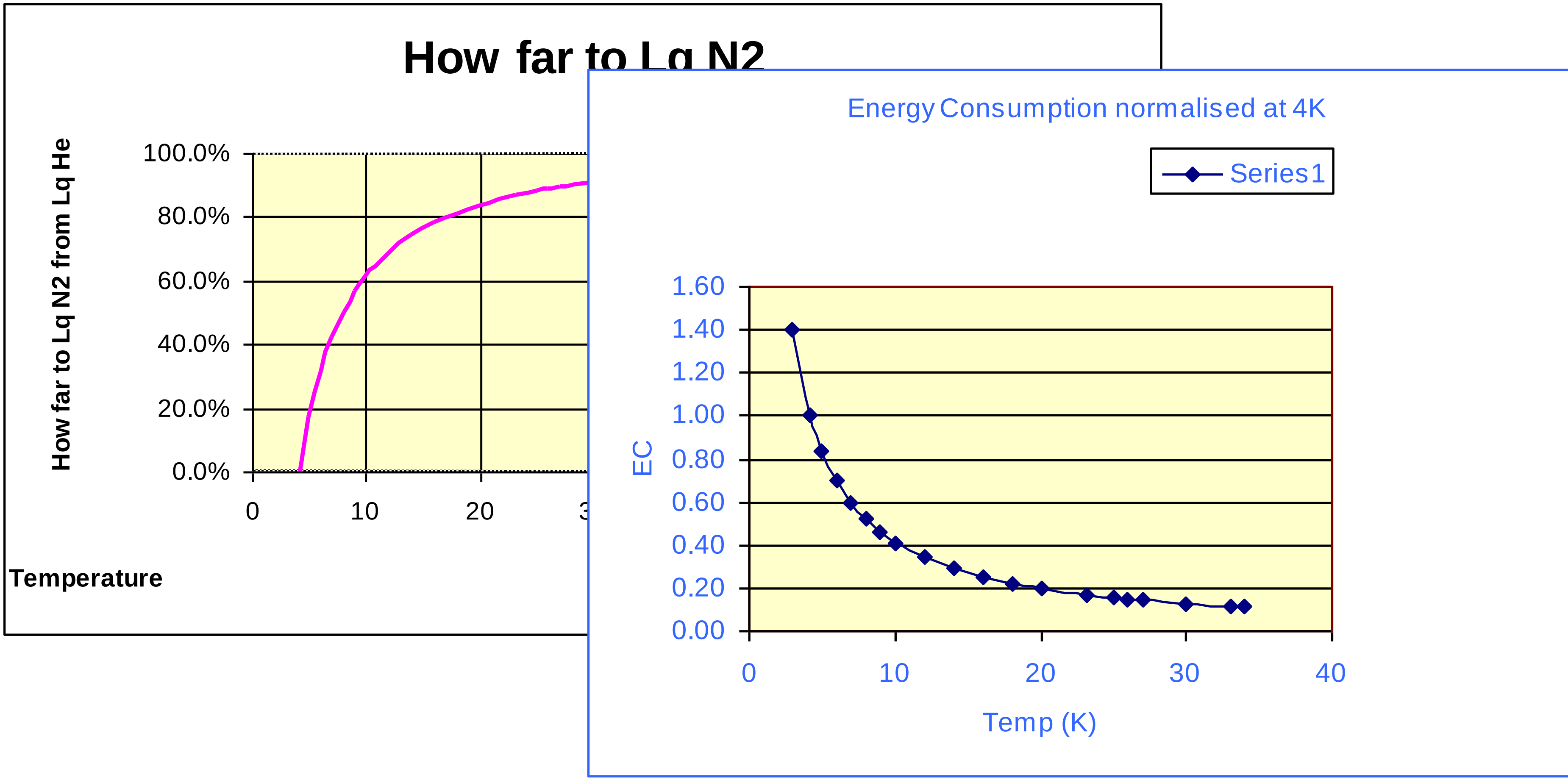
Power Device Req'mts

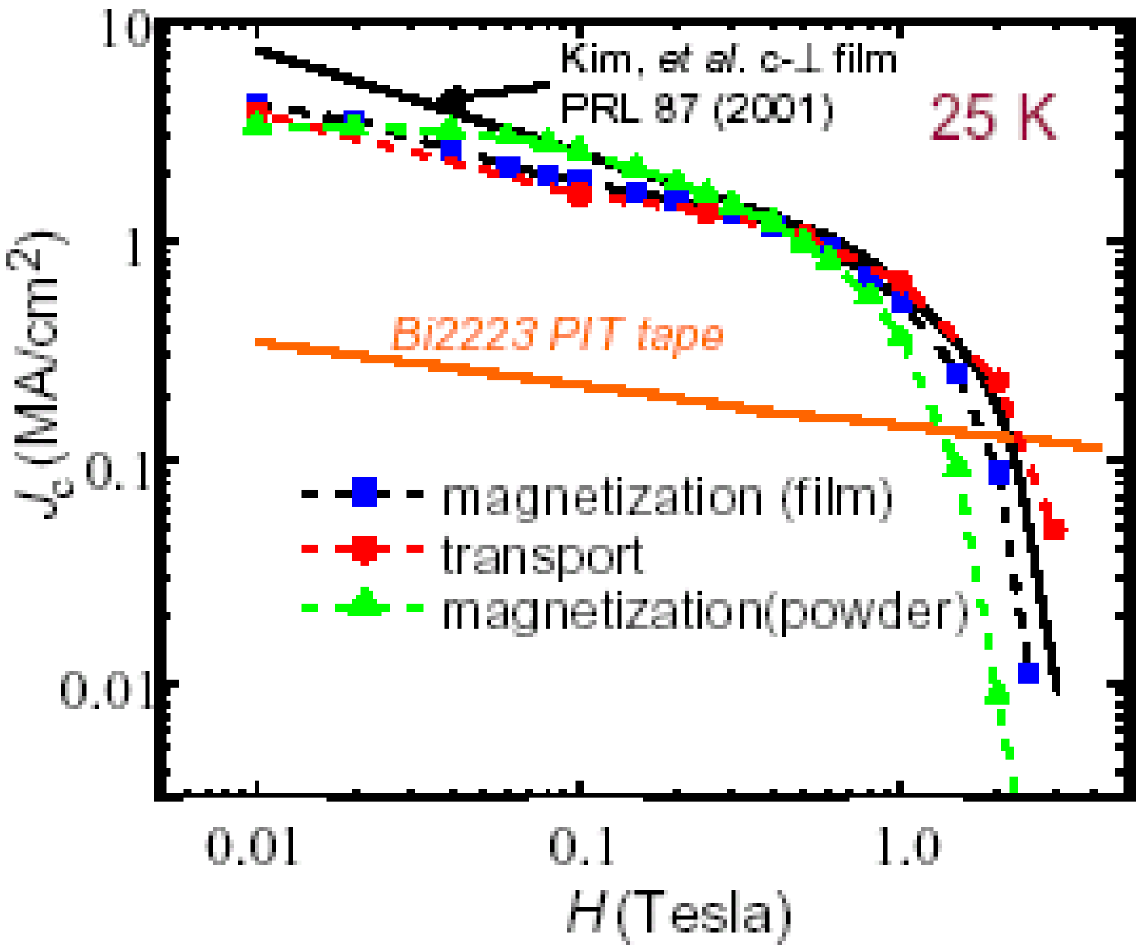
	T (K)	H (T)	J_c (A/cm^2)
Motors/ Generators	30	4	100,000
Transformers	30	2	80,000
Current Limiters	30	2	80,000
Cables	77	0.5	70,000

Dick Blaugher, NREL

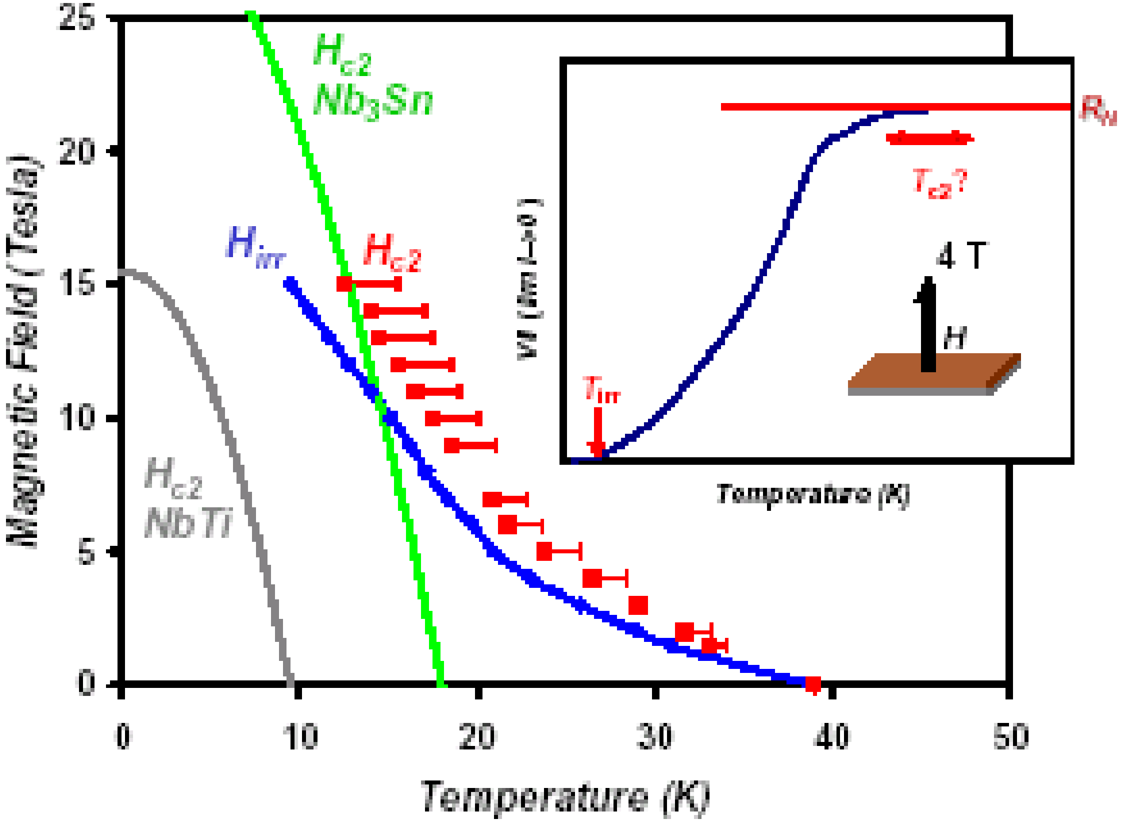
Is LN_2 Necessary?



ORNL: J_c vs H


Kim, et al. c-⊥ film
PRL 87 (2001)
25 K
Bi2223 PIT tape
magnetization (film)
transport
magnetization(powder)
10
1
0.1
0.01
J_c (MA/cm^2)
0.01
0.1
1.0
H (Tesla)

ORNL: H vs T


25
20
15
10
5
0
Magnetic Field (Tesla)
0
10
20
30
40
50
Temperature (K)
H_{c2} Nb_3Sn
H_{irr}
H_{c2}
H_{c2} NbTi
R_N
T_{c2}?
4 T
H
T_{irr}
Temperature (K)

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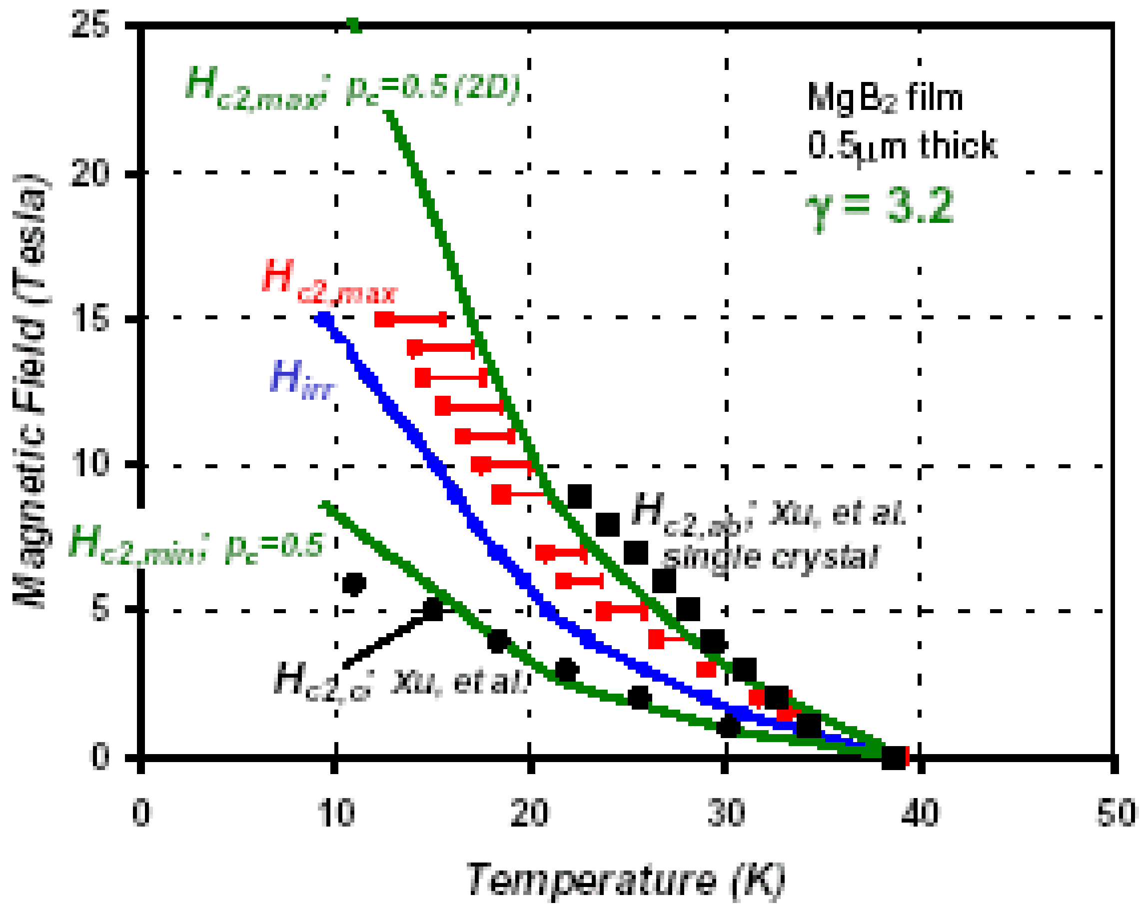
ORNL: Anisotropy in H_{C2}



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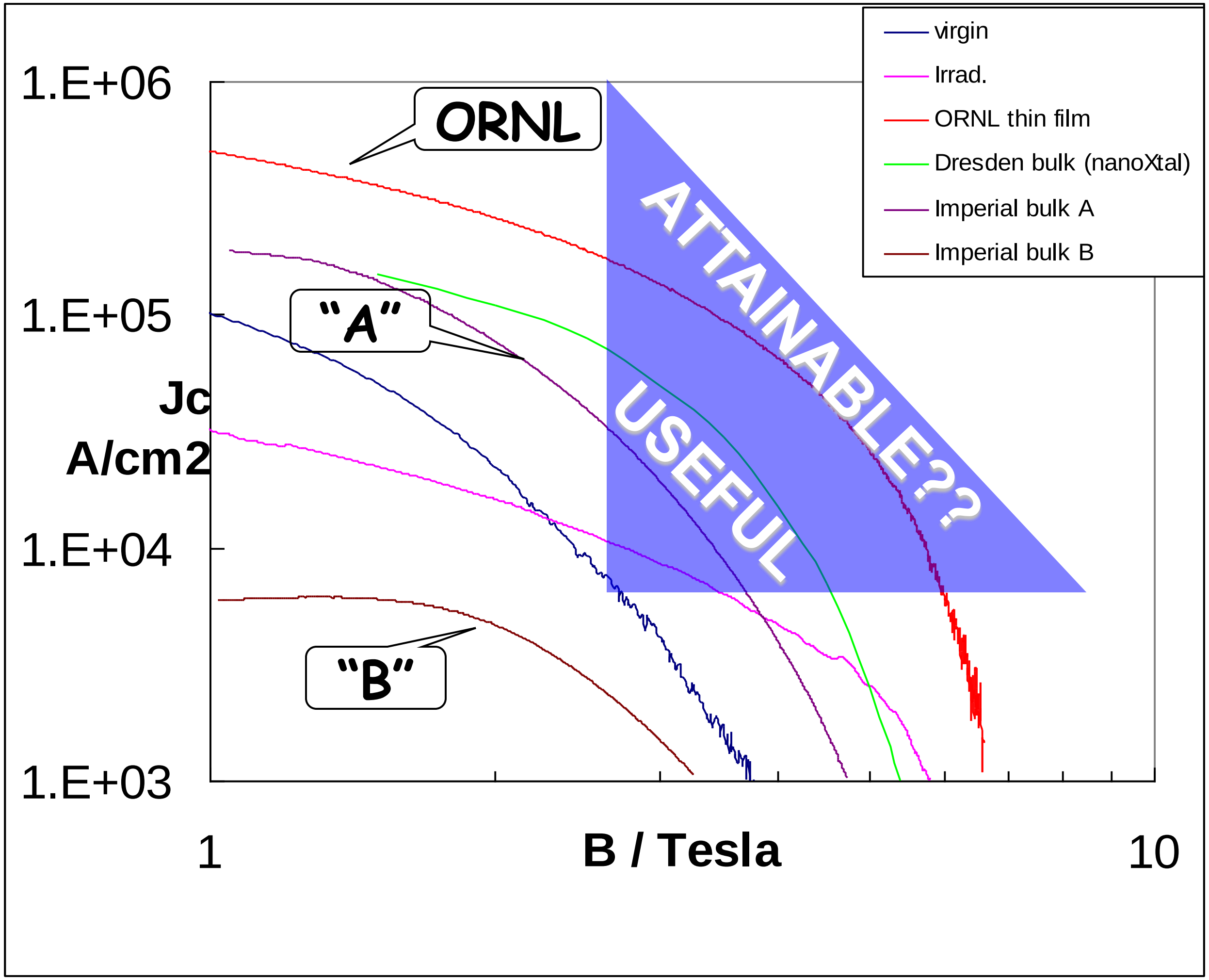
MgB_2 – One Year Later

MgB_2: J_c at 20K



Imperial College MgB_2 progress

- Additive A (by scaleable route) enhances J_c to levels comparable with micro-crystalline samples, and **that are useful for applications at 20K**.

- Additive B (by scaleable route) improves field dependence of $J_c(B)$. **NB, because of sample porosity, only a lower bound for magnitude of J_c.**

Wire Actors

- Institutions
  - INFM-Genova
  - UniGe
  - Ames
  - IRL (NZ)
  - NIMS (Japan)
- Companies
  - HyperTech (USA)
  - Diboride Conductors (UK)
  - Pirelli (?)
  - AMSC (?)
  - IGC-SP (????)
  - Japan (?)

No HTS wire Companies presently Have "visible" MgB_2 Development programs Underway

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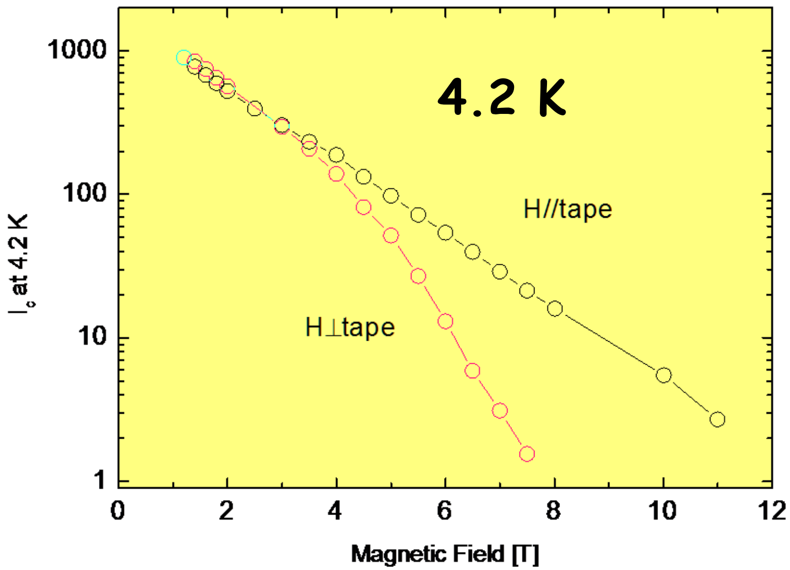
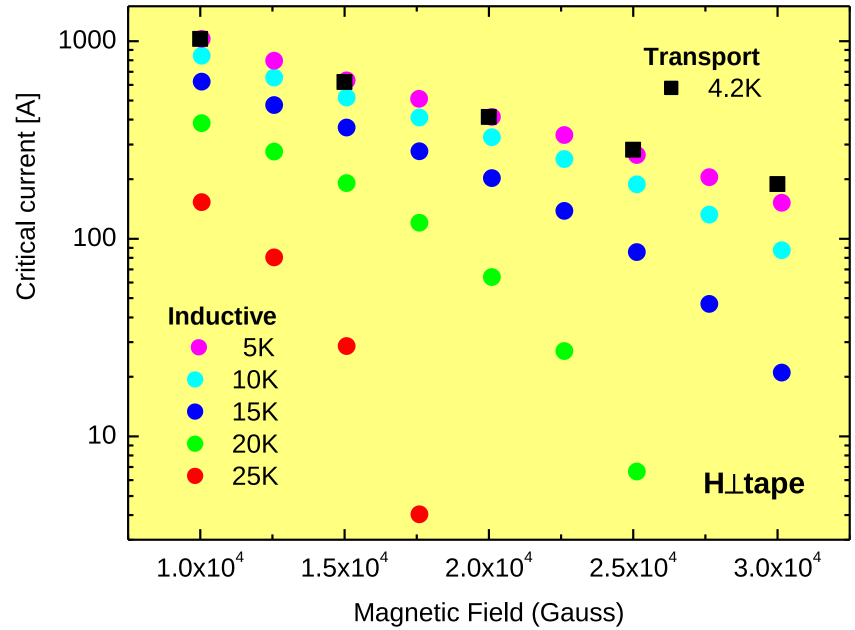
INFM-Genova
Ni-Sheathed MgB_2 Tape



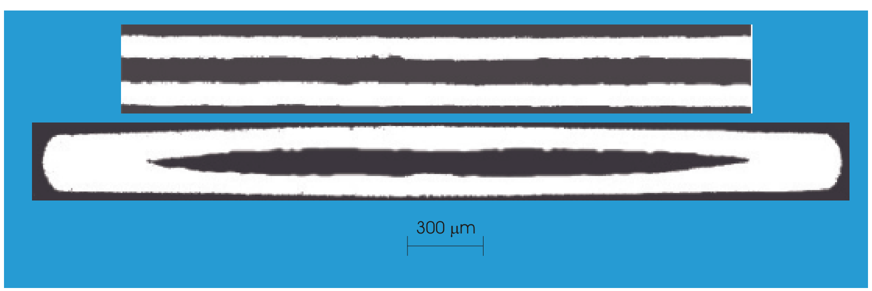


4×10^5

A/cm^2

4×10^4

4×10^3



Ex-Situ Sintered

Tape dimensions: 3.5 mm x 0.35 mm

Filling factor 20% $A_{sc} = 2.5\times10^{-3}\ cm^2$

Treated at 900°C for 2 hours in Ar

INFM-Genova, G. Grasso, A. Malagoli, V. Braccini, S. Roncallo, and A.S. Siri, Italy

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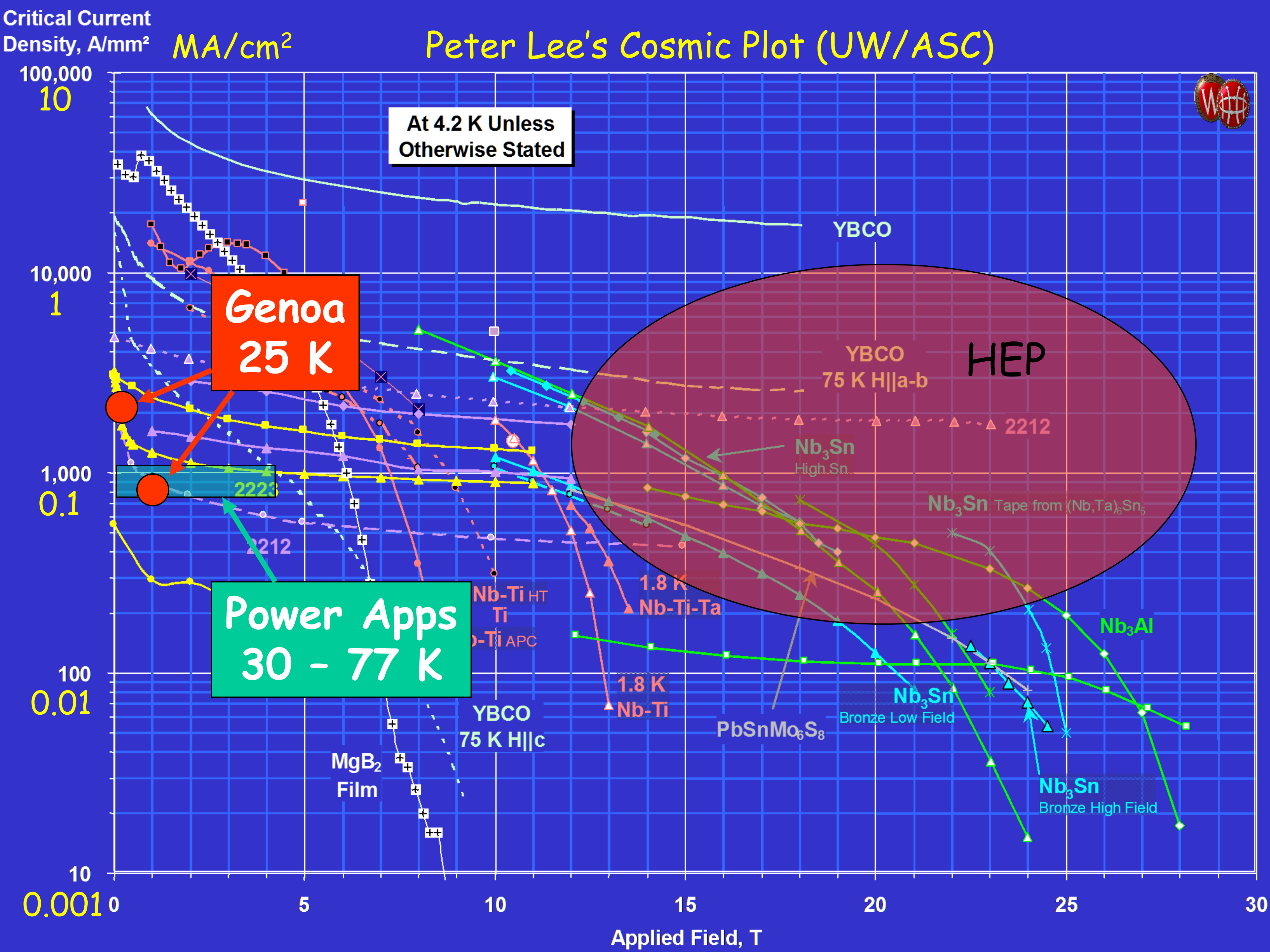
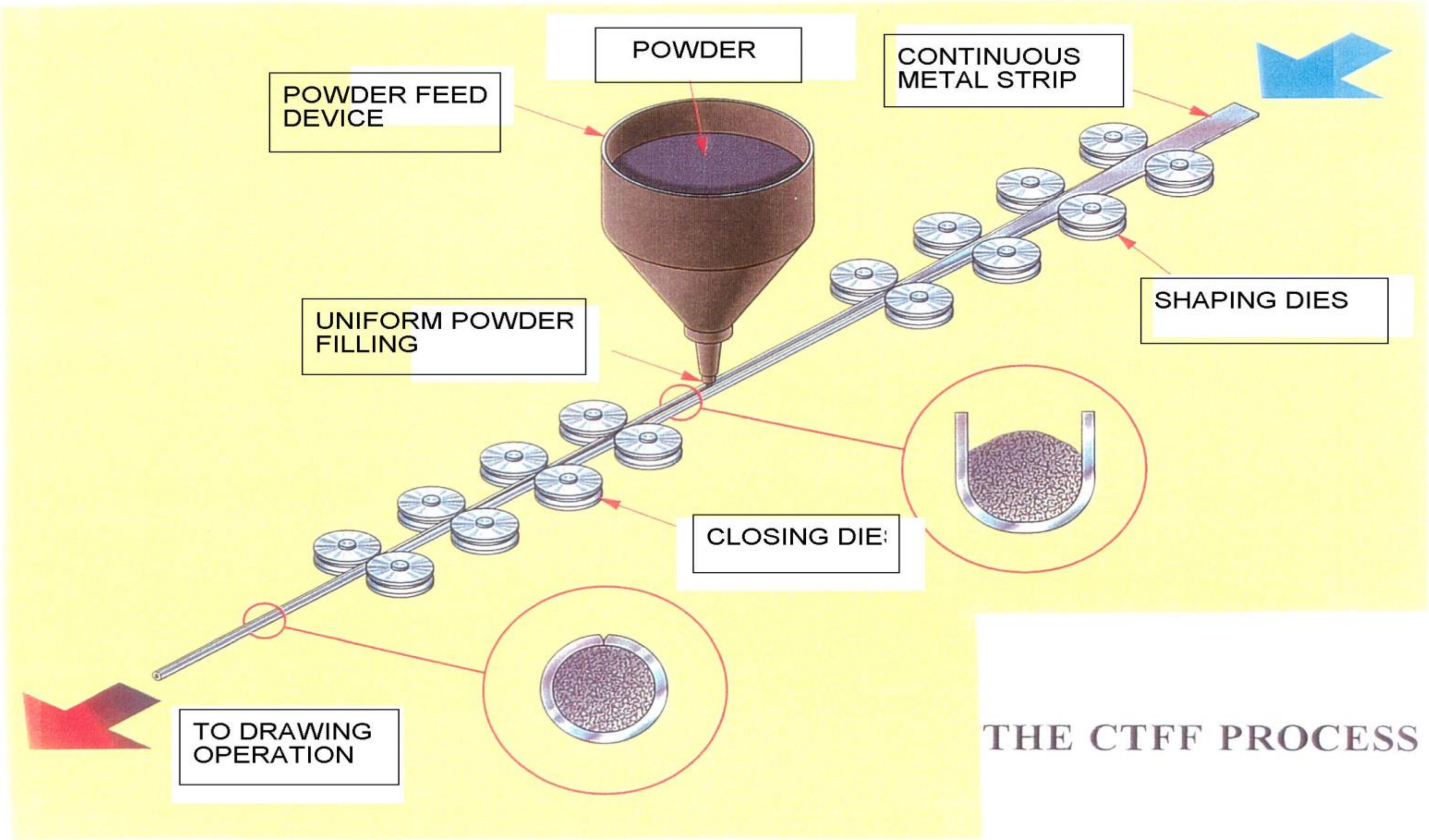
Peter Lee's Cosmic Plot (UW/ASC)



HyperTech CTFF for MgB_2

CONTINUOUS TUBE FORMING AND FILLING (CTFF)



THE CTFF PROCESS

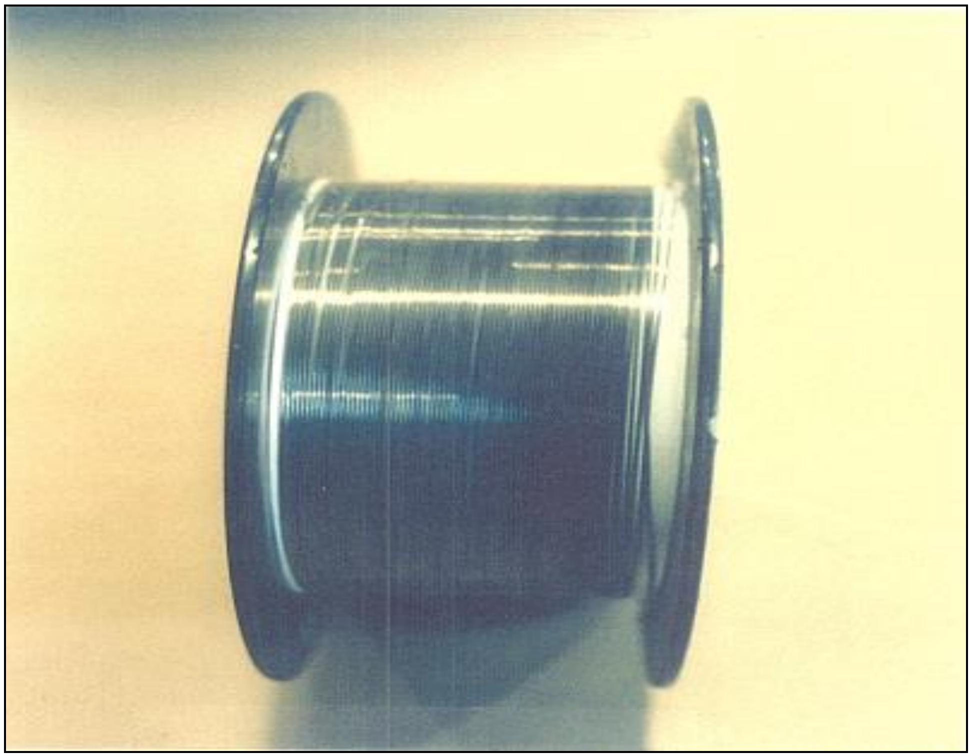
HyperTech Representative J_C's

Temperature, K	4K	4K	4K
Field, T	0-0.2	1	3
Jc -kA/mm^2	7.5*	3*	0.2
A/cm^2	**750,000**	**300,000**	**20,000**
Temperature, K	30K	30K	
Field, T	0-0.2	1	
Jc -kA/mm^2	0.32	0.1	
	(over 300 amps)	(over 100 amps)	
A/cm^2	**32,000**	**10,000**	

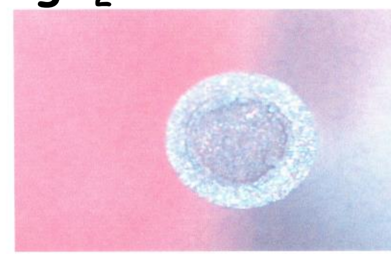
* by extrapolation due to flux jump and lack of stabilization

HyperTech MgB_2 Wire

60 meters, 1.2 mm Mono

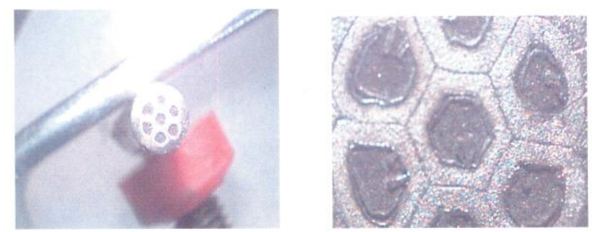


MgB_2 CTFF Iron in Monel



Multi-filament

MgB_2, 7 filament multifilament, iron CTFF in Monel



Wire Cost Issues

Merit Factor for Superconducting Wire:
C/P = $/kAmp × meters

Wire	C/P	Cost Driver
NbTi (4.2 K, 2 T)	0.90	Materials (Nb)
Nb_3Sn (4.2 K, 10 T)	10	Materials (Nb)
Bi-2223 (25 K, 1 T)	20	Materials (Ag)
Y-123 (25 K, 1 T)	4	Capital Plant

MgB_2 Wire C/P

Assumptions/Givens:

- J_C = 100,000 A/cm^2
- I_C = 2000 A/wire (Area = 2 mm^2)
- Non-Materials C/P = 0.11 \$/kA•m (NbTi)

Alfa Aesar MgB_2 Price Quote (10 kg)

- 750 \$/kg (0.75 \$/gm)

MgB_2 Wire C/P

- 2.03 \$/kA•m @ 25 K, 1 T

Critical Wire Issues

20 - 30 K 1 - 3 T	J_c, H_{irr}	Length
BSCCO/OPIT	++++	++++
YBCO CC	++++++	
MgB_2	++++ ac Losses ?	++++++

MgB_2 Opportunities

20 – 30 K, 0 – 3 T

- Transformers
- Rotating Machinery
- Cables (?)

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1967 SC Cable !

Superconducting Lines for the Transmission of Large Amounts of Electrical Power over Great Distances

R. L. GARWIN AND J. MATISOO

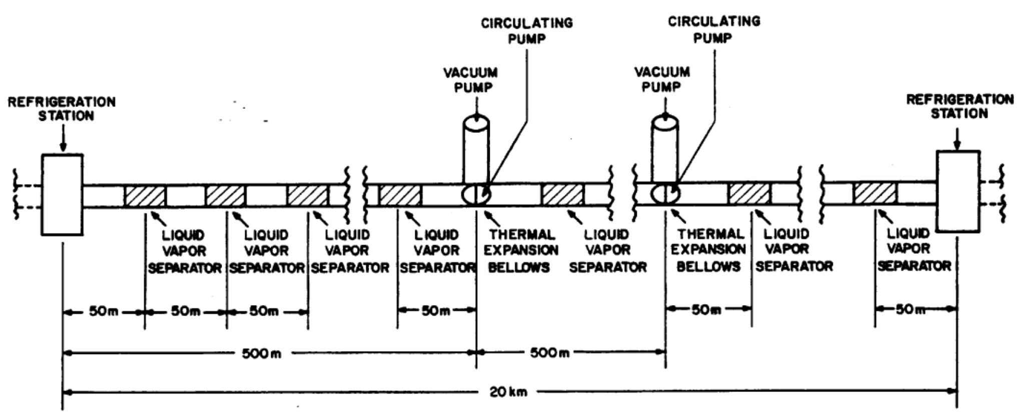

Fig. 2. A 20-km module of the 1000-km, 100-GW line.

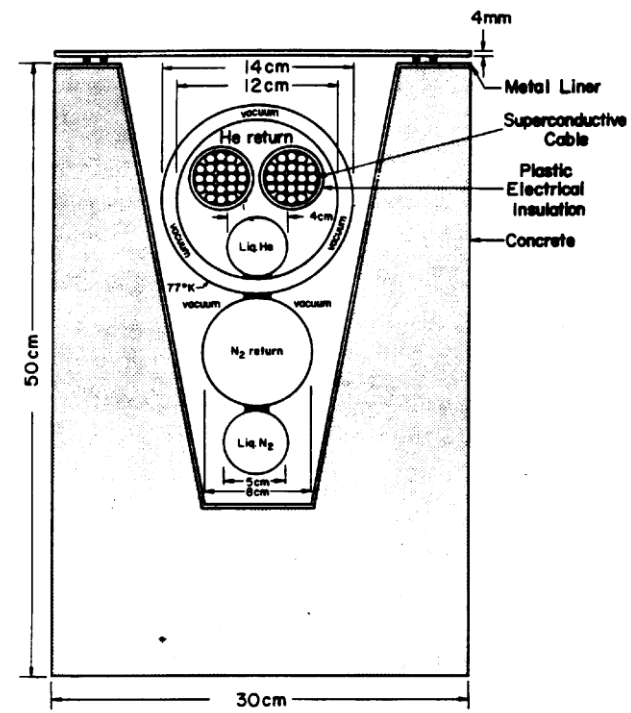

Fig. 1. Cross section of the 100-GW line.

100 GW dc, 1000 km !

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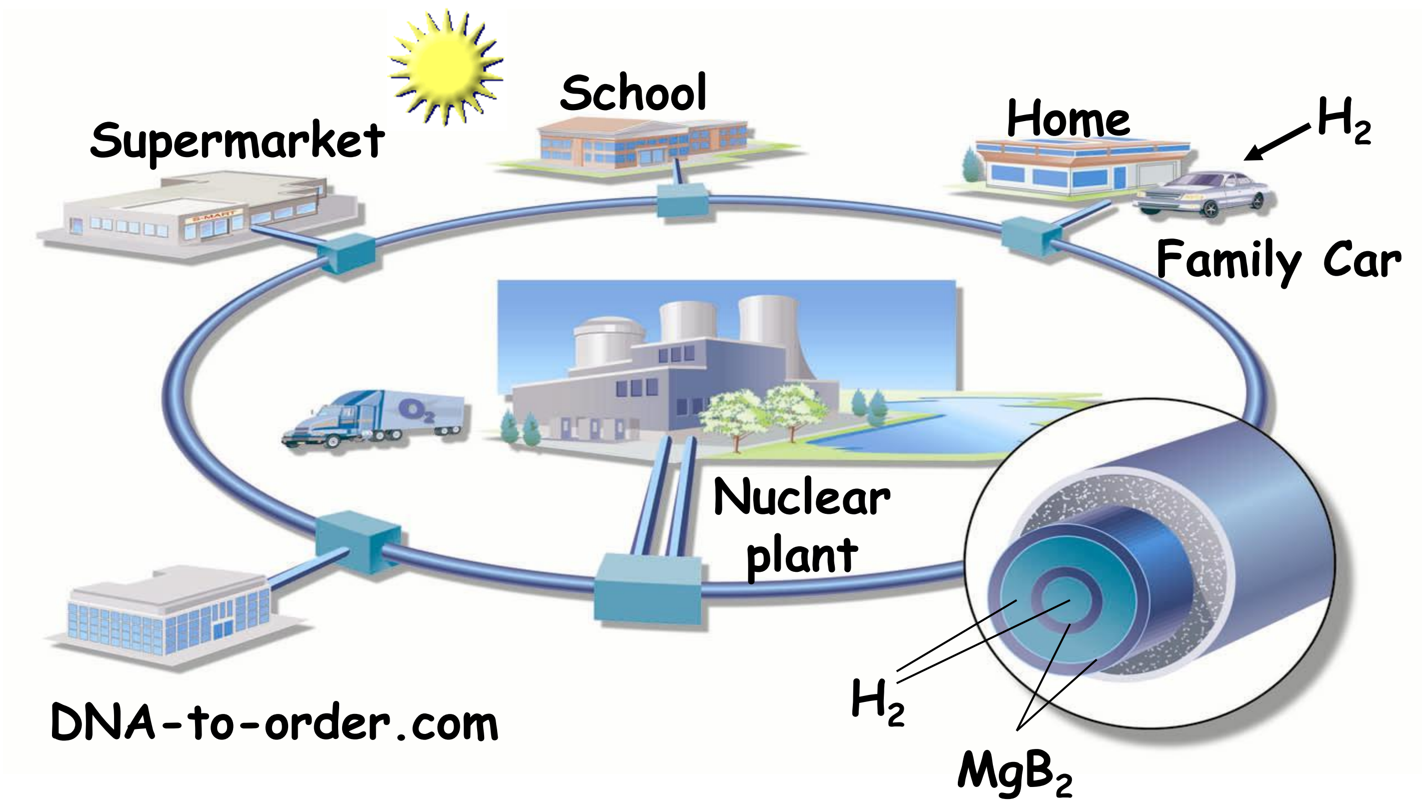
"SuperCity"



P.M. Grant, The Industrial Physicist, Feb/March Issue, 2002
ftp://ftpuser:ftpuser1@ftp.epri.com/outgoing/pgrant/SuperCity