The American Physical Society
3-7 March 2002
Austin, TX
R1 – Poster Session III

Magnesium diboride wire application to high power superconducting dc cables

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R1.039: 13.30 5 March 2003

Abstract

In 1967, R. L. Garwin and J. Matisoo considered the possibility of constructing a 100 GW, 1000 km, dc superconducting transmission line based on the then newly discovered type II material, Nb_3Sn, refrigerated by liquid helium at 4.2 K.[1]

In this poster we will rescale their study for MgB2 cooled by liquid hydrogen to 20 K, which will be used as an additional energy delivery agent as well as a cryogen.

[1]R. L. Garwin and J. Matisoo, Proc. IEEE **55**, 538 (1967).

Garwin-Matisoo

100 GW dc, 1000 km !

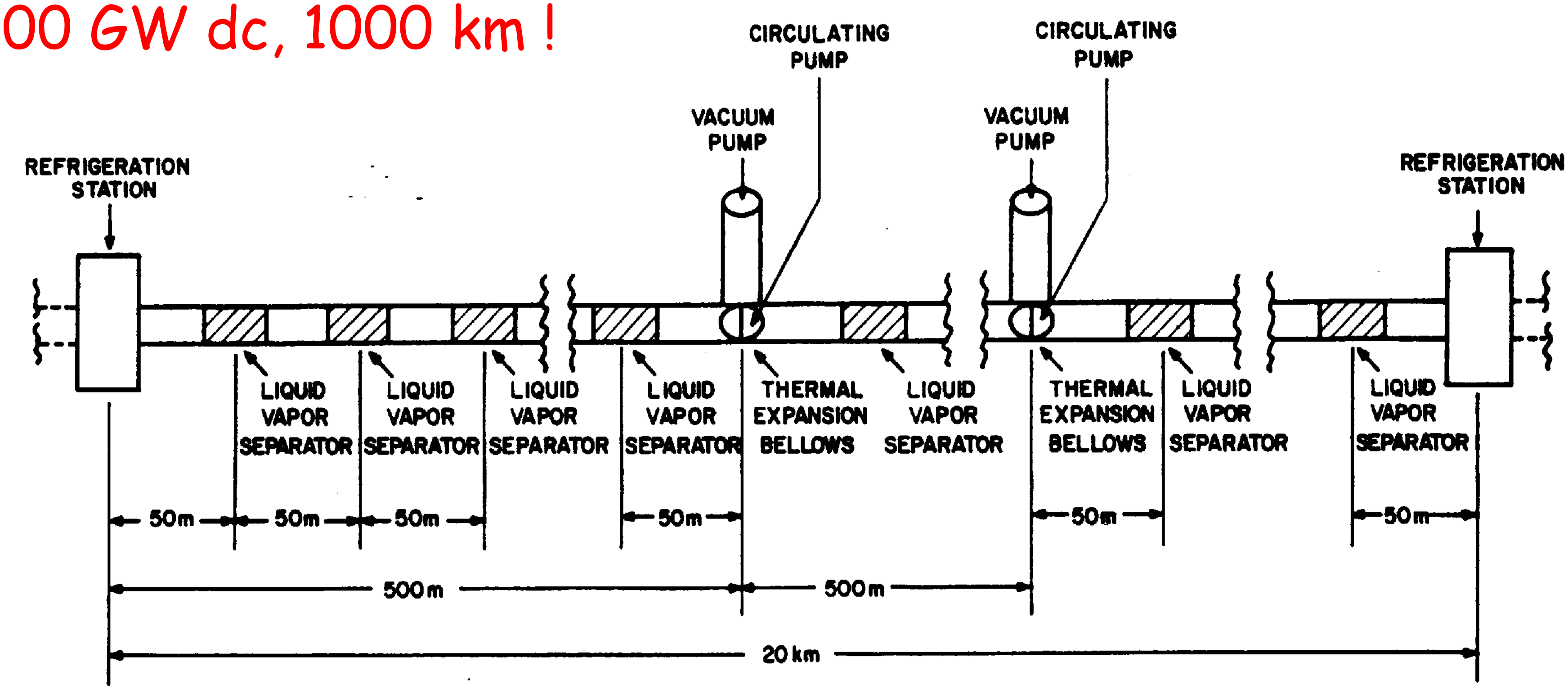


Fig. 2. A 20-km module of the 1000-km, 100-GW line.

Superconducting Lines for the Transmission of Large Amounts of Electric Power over Great Distances,
R. L. Garwin and J. Matisoo, Proceedings of the IEEE **55**, 538 (1967)

Garwin-Matisoo

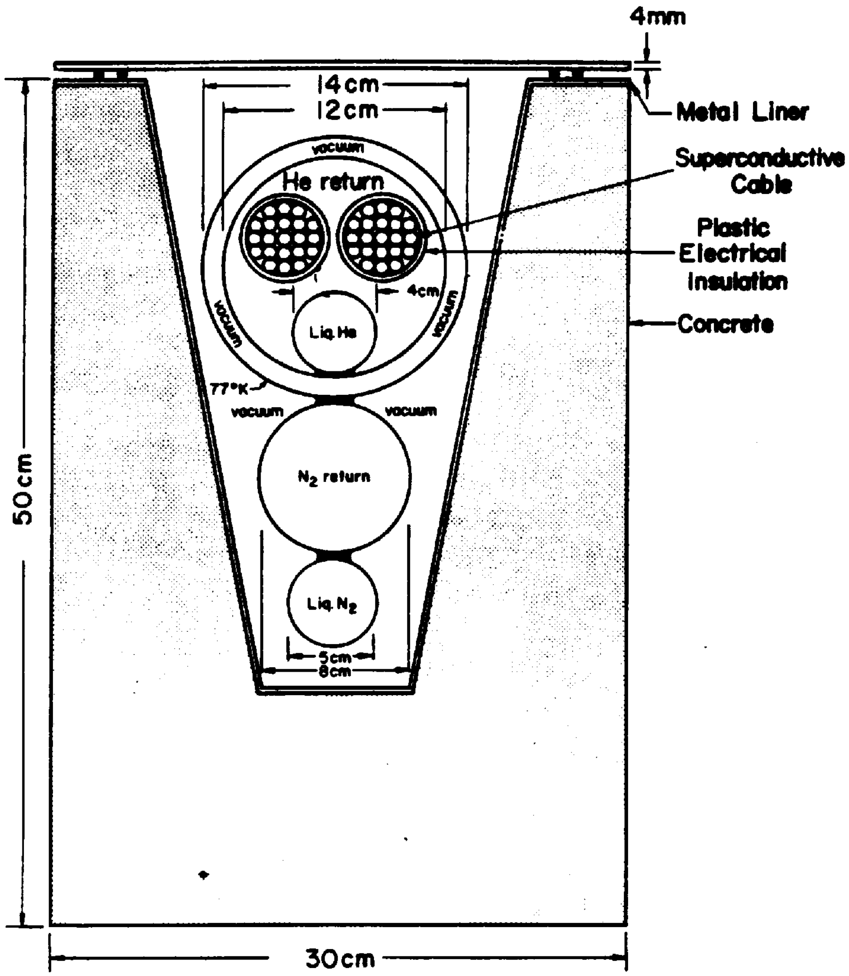
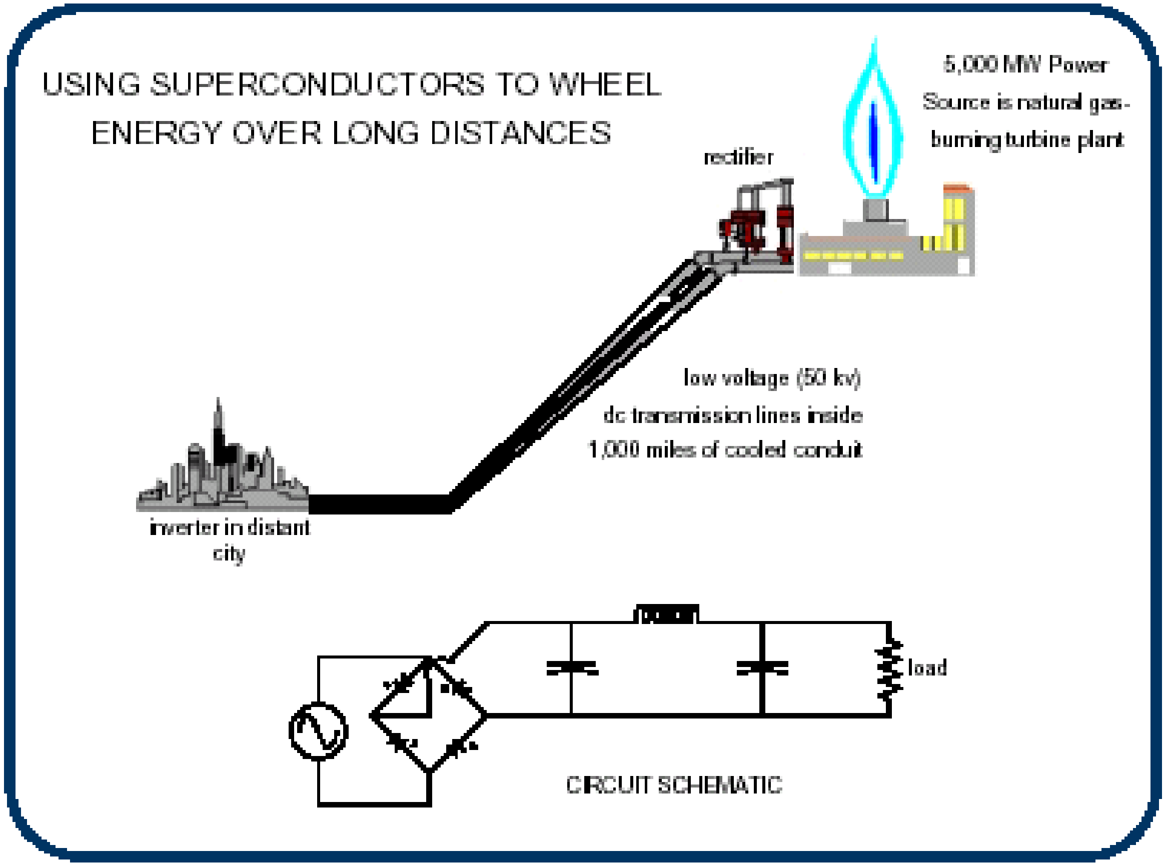


Fig. 1. Cross section of the 100-GW line.

- Nb_3Sn Wire
- T_C = 9 K
- LHe liquid-vapor cooled
- LN_2 heat shield

Electricity Pipe



Initial EPRI study on long distance (1000 km) HTSC dc cable cooled by liquid nitrogen
-- 1997 --

P.M. Grant, S. Schoenung, W. Hassenzahl, EPRI Report 8065-12, 1997

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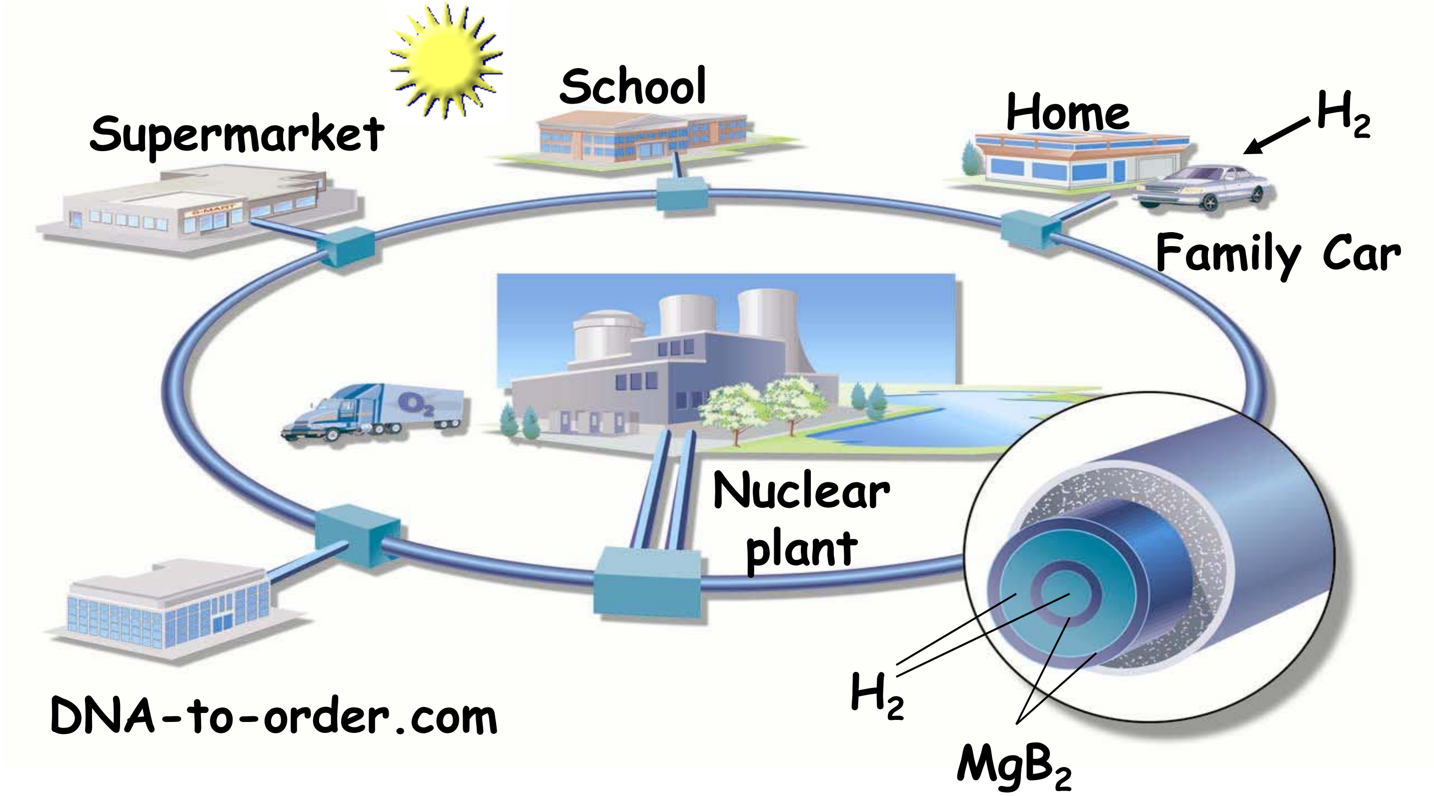
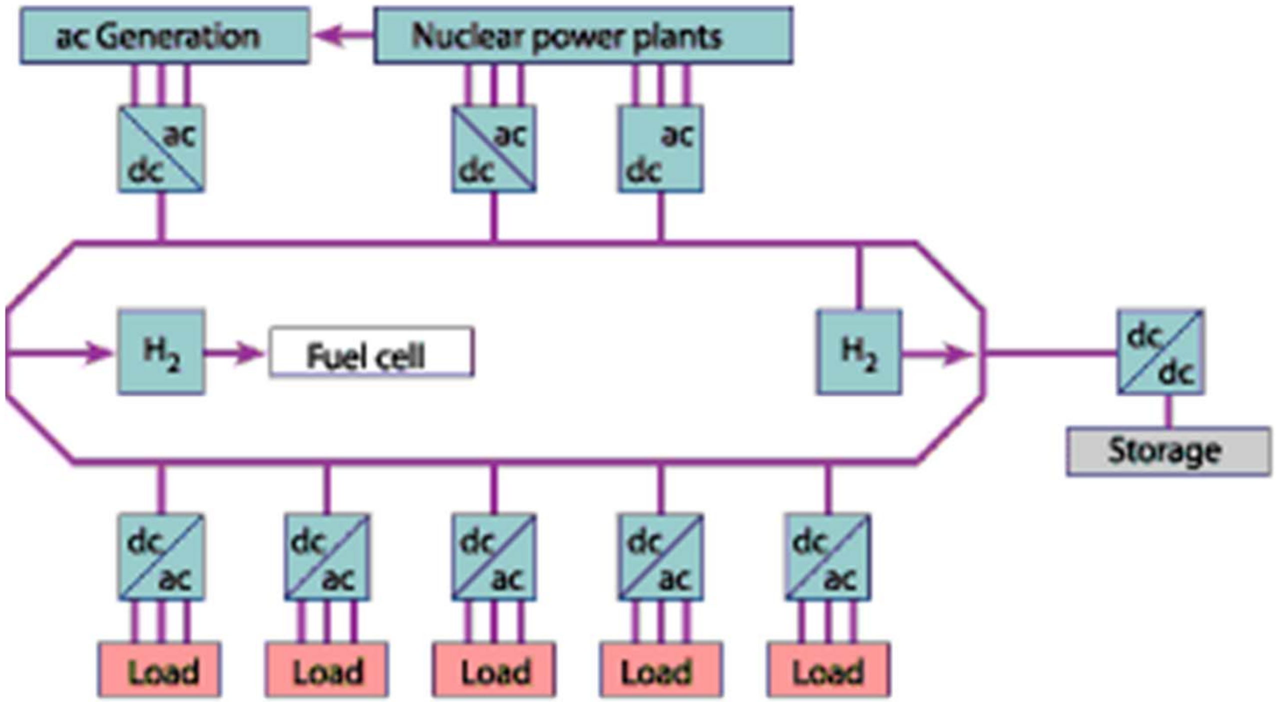
SuperCity



P.M. Grant, The Industrial Physicist, Feb/March Issue, 2002

http://www.aip.org/tip/INPHFA/vol-8/iss-1/p22.pdf

SuperGrid

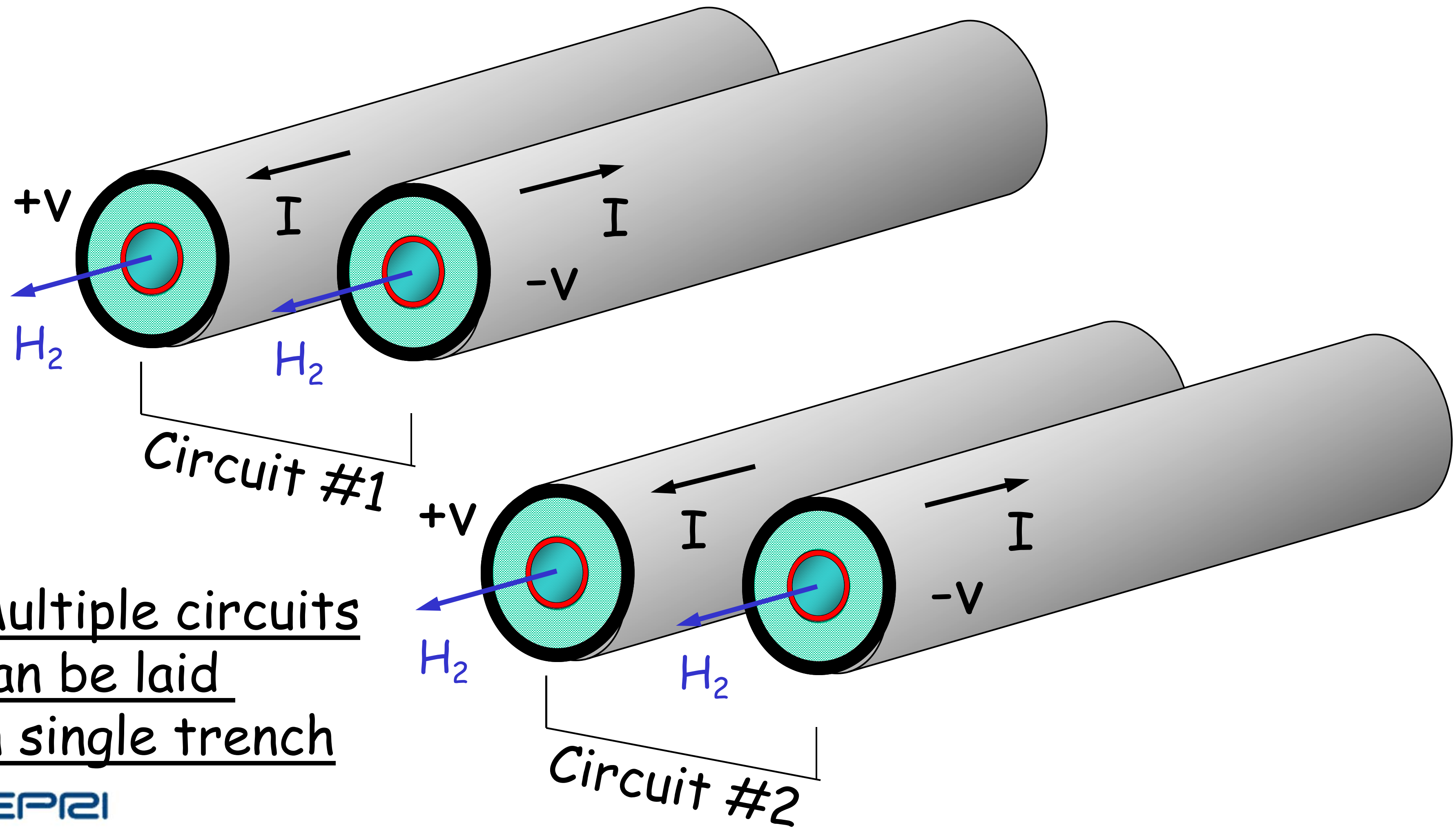


Continental SuperGrid

"Continential SuperGrid Workshop," UIUC/Rockefeller U., Palo Alto, Nov. 2002

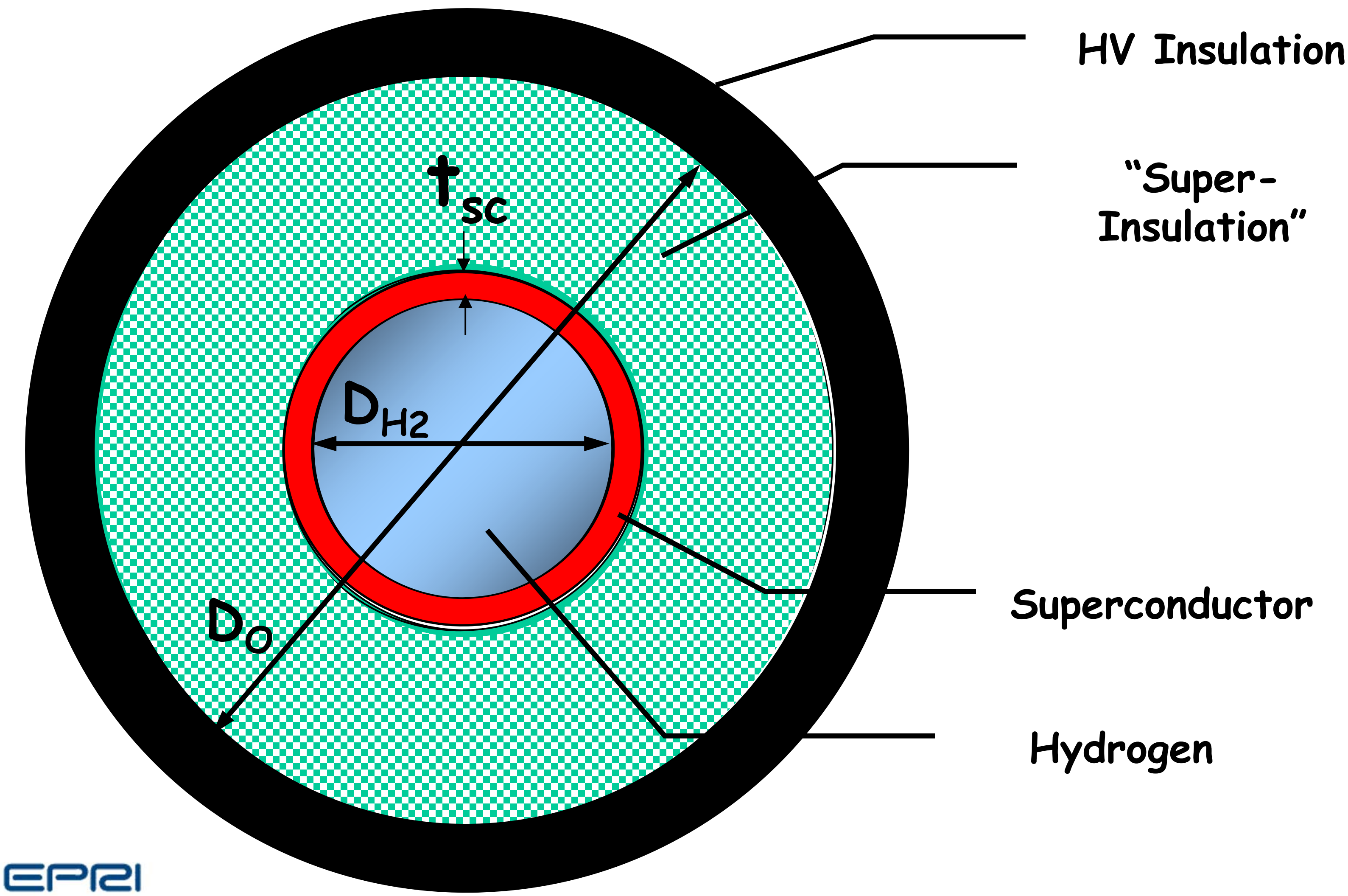
http://www.epri.com/journal/details.asp?doctype=features&id=511

SuperCables



Multiple circuits can be laid in single trench

SuperCable


HV Insulation
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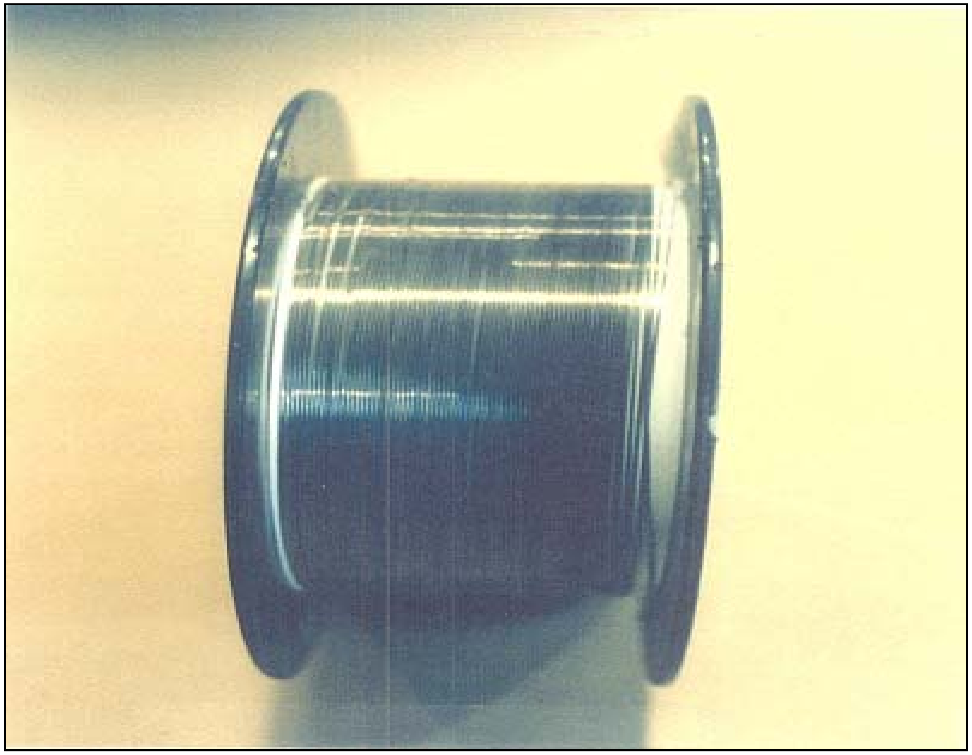
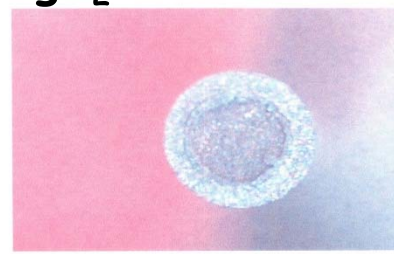
HyperTech MgB_2 Wire

60 meters, 1.2 mm Mono

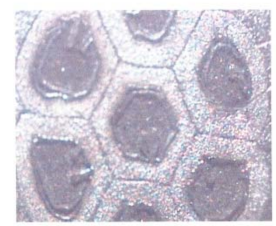


MgB_2 CTFF Iron in Monel



Multi-filament

MgB_2, 7 filament multifilament, iron CTFF in Monel



J_e = 25,000 A/cm^2 @ 20 K

EPRI

MgB_2 wire application to high power superconducting dc cables

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Power Flows

Hydrogen

$P_{H2} = 2(Q\rho vA)_{H2}$, where

P_{H2} = Chemical power flow
Q = Gibbs H_2 oxidation energy (2.46 eV per mol H_2)
ρ = H_2 Density
v = H_2 Flow Rate
A = Cross-sectional area of H_2 cryotube

Electricity

$P_{SC} = 2|V|IA_{SC}$, where

P_{SC} = Electric power flow
V = Voltage to neutral (ground)
I = Supercurrent
A_{SC} = Cross-sectional area of superconducting annulus

Electric & H_2 Power

Electricity

Power (MW)	Voltage (V)	Current (A)	Critical Current Density (A/cm^2)	Annular Wall Thickness (cm)
1000	+/- 5000	100,000	25,000	0.125

Hydrogen (LH_2, 20 K)

Power (MW)	Inner Pipe Diameter, D_{H2} (cm)	H_2 Flow Rate (m/sec)	"Equivalent" Current Density (A/cm^2)
500	10	3.81	318

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Thermal Losses

Radiation Losses

$W_R = 0.5\varepsilon\sigma\,(T^4_{amb} - T^4_{SC})$, where

W_R = Power radiated in as watts/unit area
$\sigma = 5.67\times10^{-12}\ W/cm^2K^4$
T_{amb} = 300 K
T_{SC} = 20 K
ε = 0.05 per inner and outer tube surface
D_{SC} = 10 cm

W_R = 3.6 W/m

Superinsulation: $W_R^f = W_R/(n-1)$, where
n = number of layers

Target: W_R^f = 0.5 W/m requires ~10 layers

Other addenda (convection, conduction): W_A = 0.5 W/m

$W_T = W_R^f + W_A$ = 1.0 W/m

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Heat Removal

$dT/dx = W_T/(\rho v C_p A)_{H2}$, where

dT/dx = Temp rise along cable, K/m
W_T = Thermal in-leak per unit Length
ρ = H_2 Density
v = H_2 Flow Rate
C_p = H_2 Heat Capacity
A = Cross-sectional area of H_2 cryotube

Take W_T = 1.0 W/m, then $dT/dx = 1.89\times10^{-5}$ K/m,
Or, 0.2 K over a 10 km distance

Remaining Issues

- Current stabilization via voltage control
- Magnetic forces
- Hydrogen gas cooling and transport
- Pumping losses
- Hydrogen storage
- Costs