Cost/Performance Update on HTS Wires & Tapes

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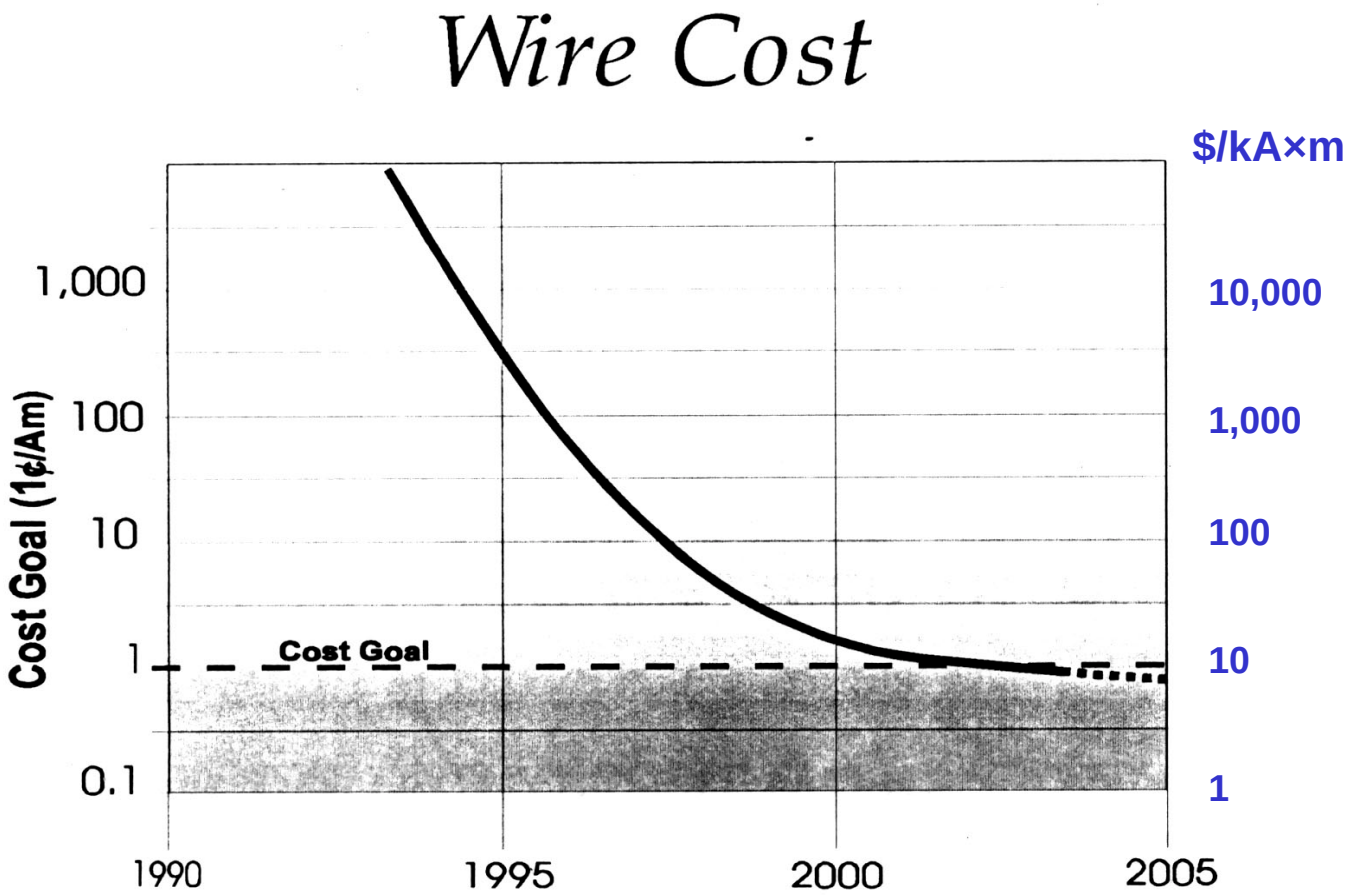
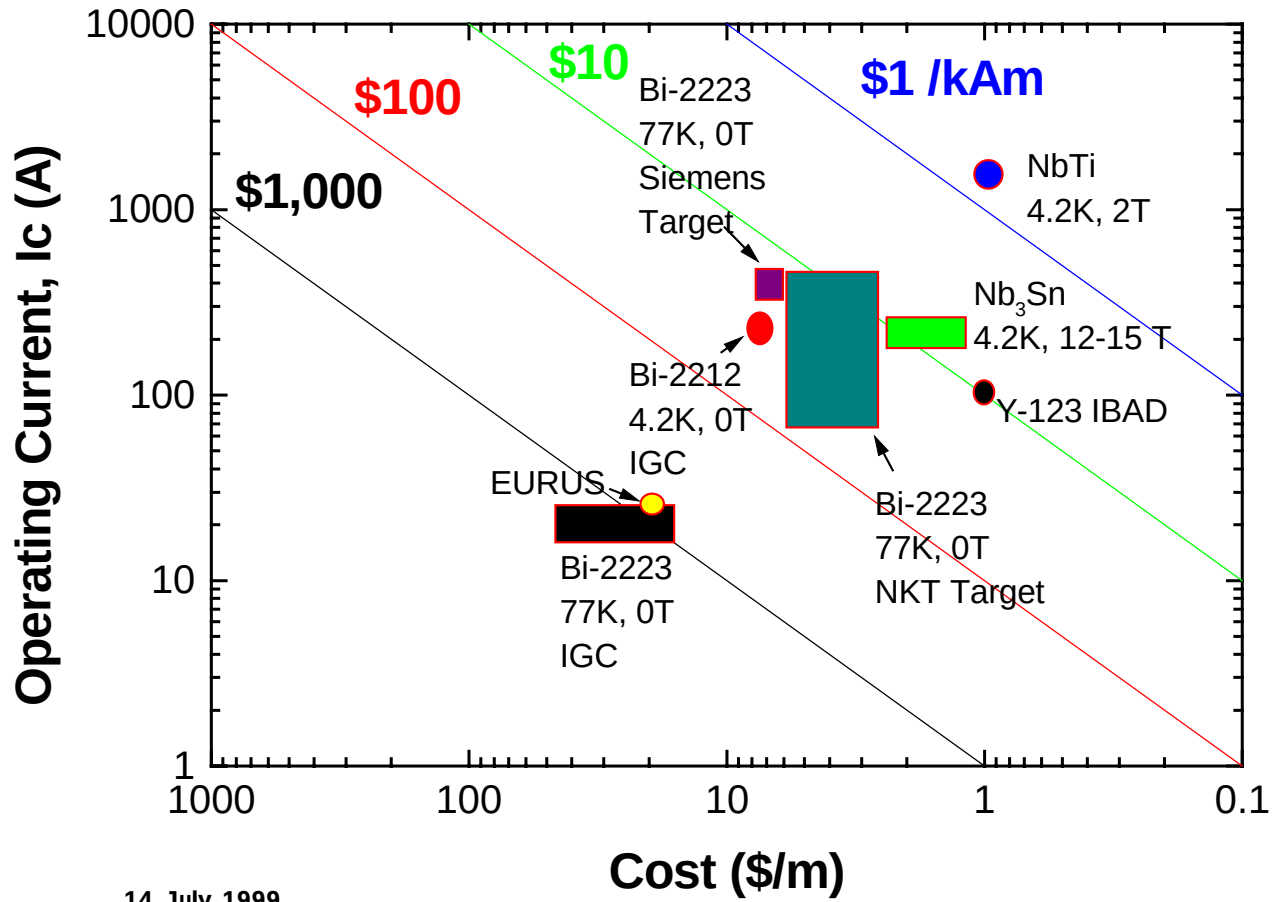
3/98 DOE Handout



"The SokPlot"

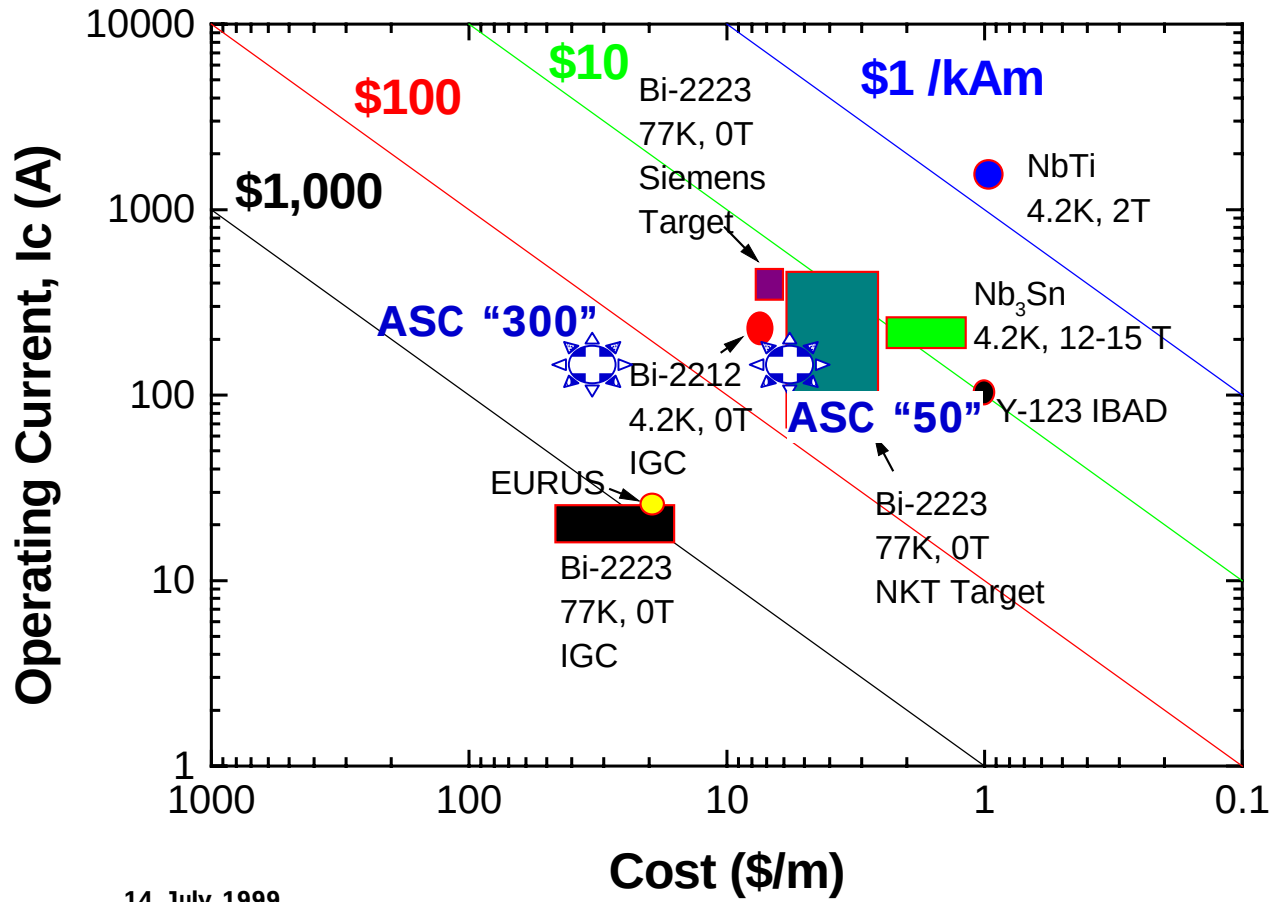
"Sokolowski Plot" of HTSC Wire Performance and Cost



"Le SokPlot"

Le Quatorze Juillet 1999

"Sokolowski Plot" of HTSC Wire Performance and Cost



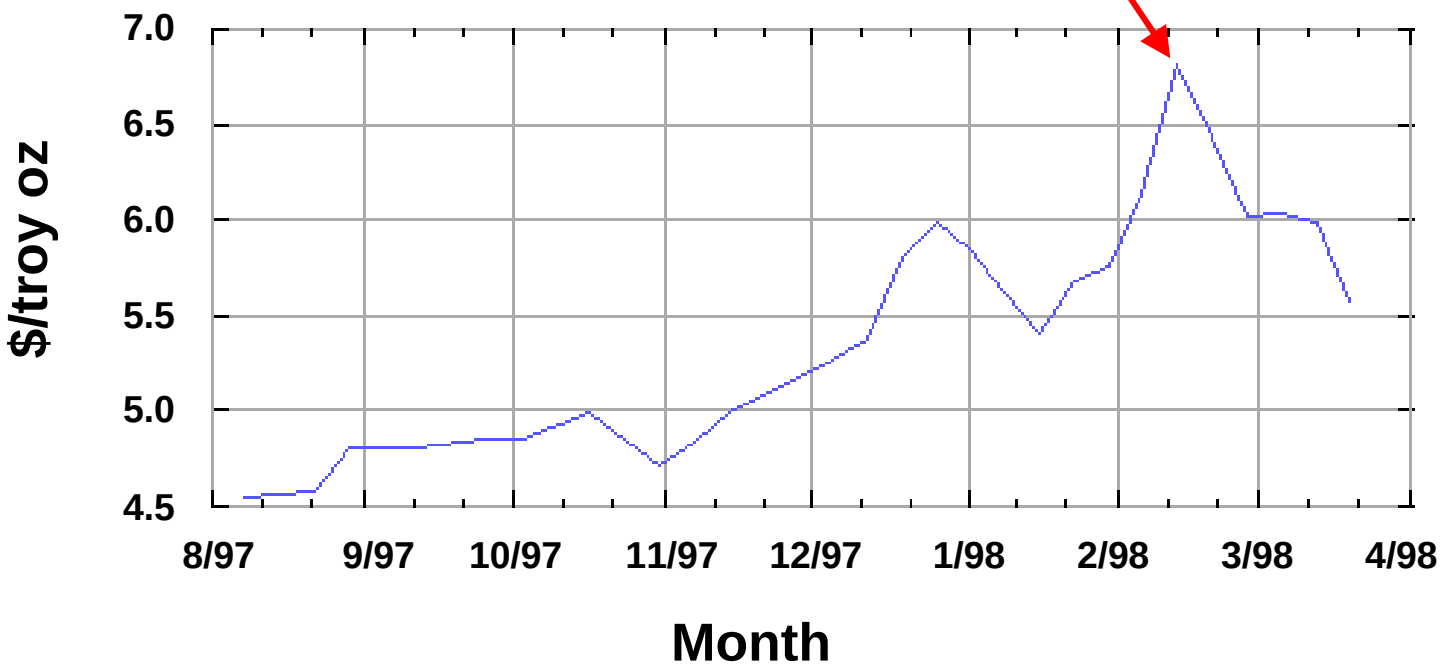
BSCCO OPIT/Ag : C/P; Materials + L&O

- Assumptions/Costs
  - Tape Area: 3 mm^2
  - 30% HTSC Fill Factor
  - I_C = 200 A
  - Ag Cost = \$0.161/gm (\$5.00/troy oz); Ag C/P = \$16.88/kA×m
  - BSCCO Cost = \$0.86/cc; BSCCO C/P = \$4.28/kA×m
  - L&O Cost = \$3.00/m; L&O C/P = \$15.00/kA×m
- Overall "Laboratory" C/P ~ \$36/kA×m !

Warren Buffet Effect

May '98 Silver Futures

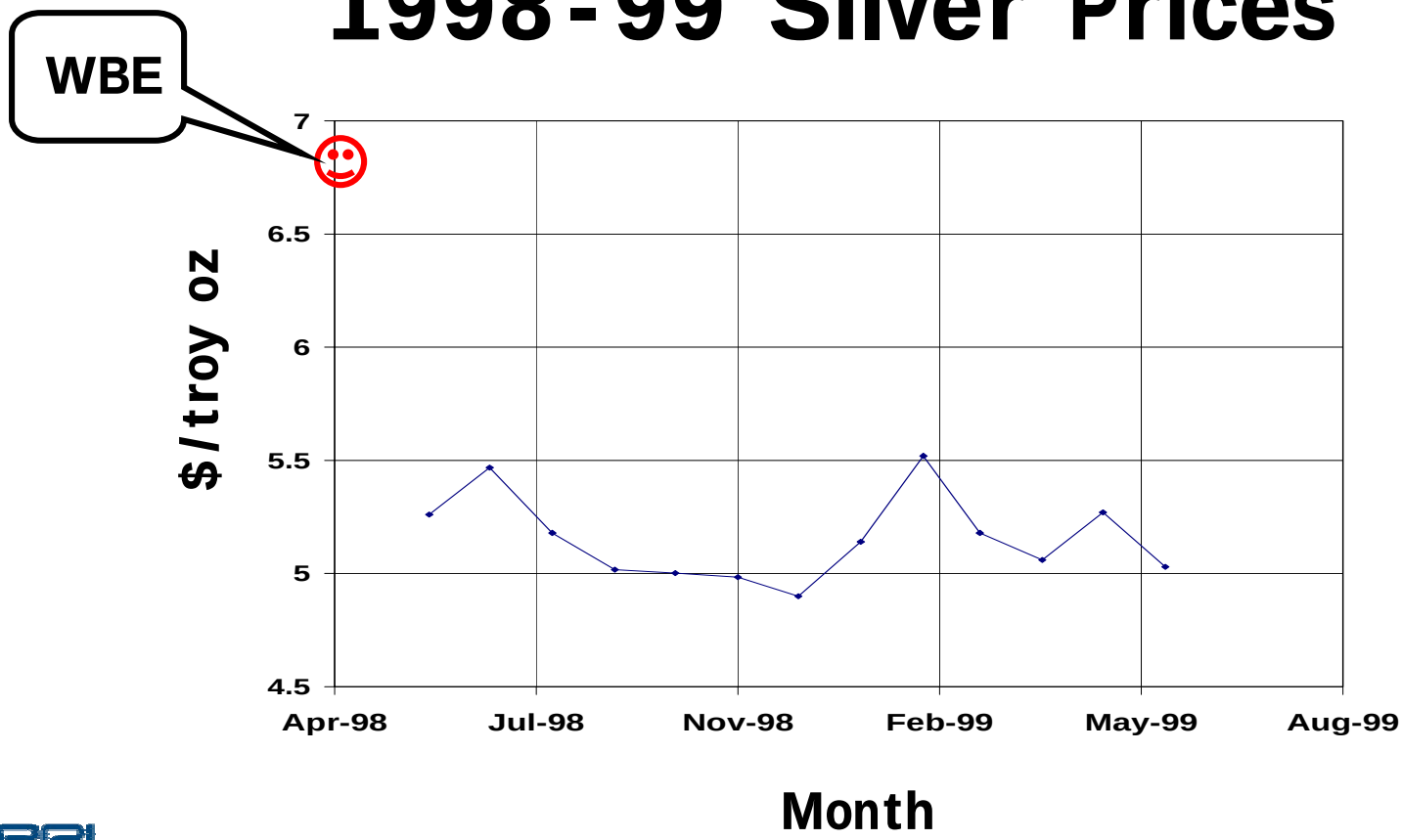
Past 8 Months



www.silverinstitute.org

Current Ag Prices

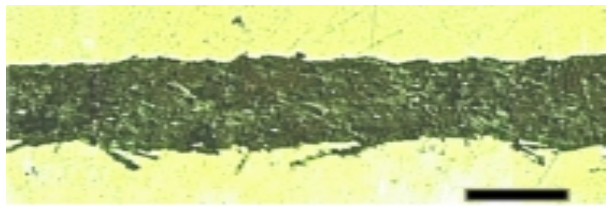
1998-99 Silver Prices



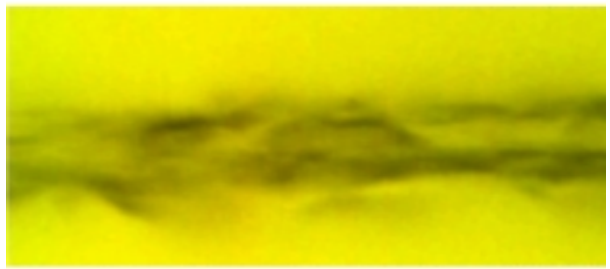
Silver Futures

- Demand exceeded supply for last nine years, in 1997 by 20%
- High grade ore mostly exhausted, today recovered from base metals and low grade ore
- Photographic uses increasing 3-6%/yr. 50,000 km/yr BSCCO/OPIT would take all photo-recycling of 1.4 million kg/yr, or 6% of total demand

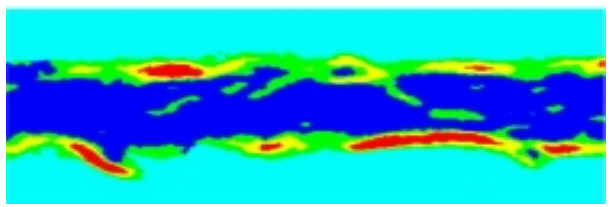
J_C Paths in BSCCO OPIT/Ag (UW-ASC)



Polarized Micrograph



Magneto-Optic Image



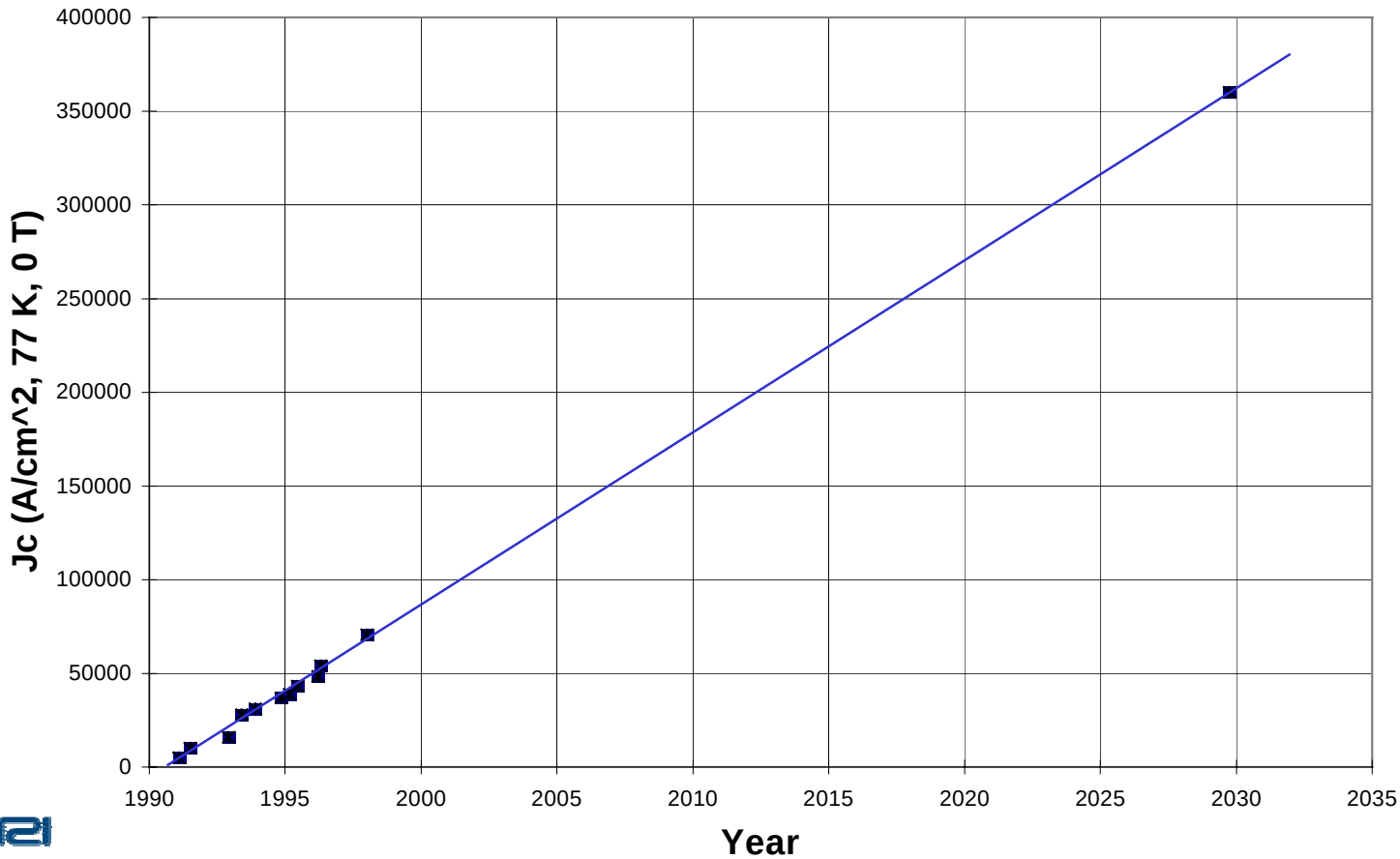
J_C Paths @ 12 K

- $> 3.6 \times 10^5$ A/cm^2
- $> 2.6 \times 10^5$ A/cm^2
- $> 1.6 \times 10^5$ A/cm^2
- ≈ 0 A/cm^2

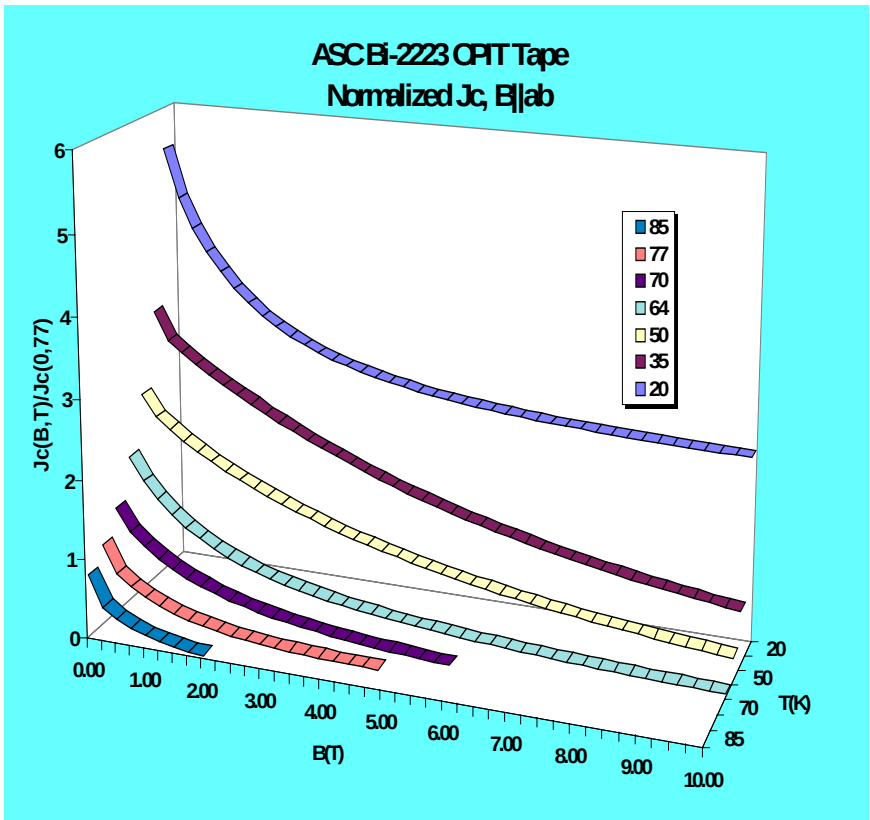
As Good As It Gets

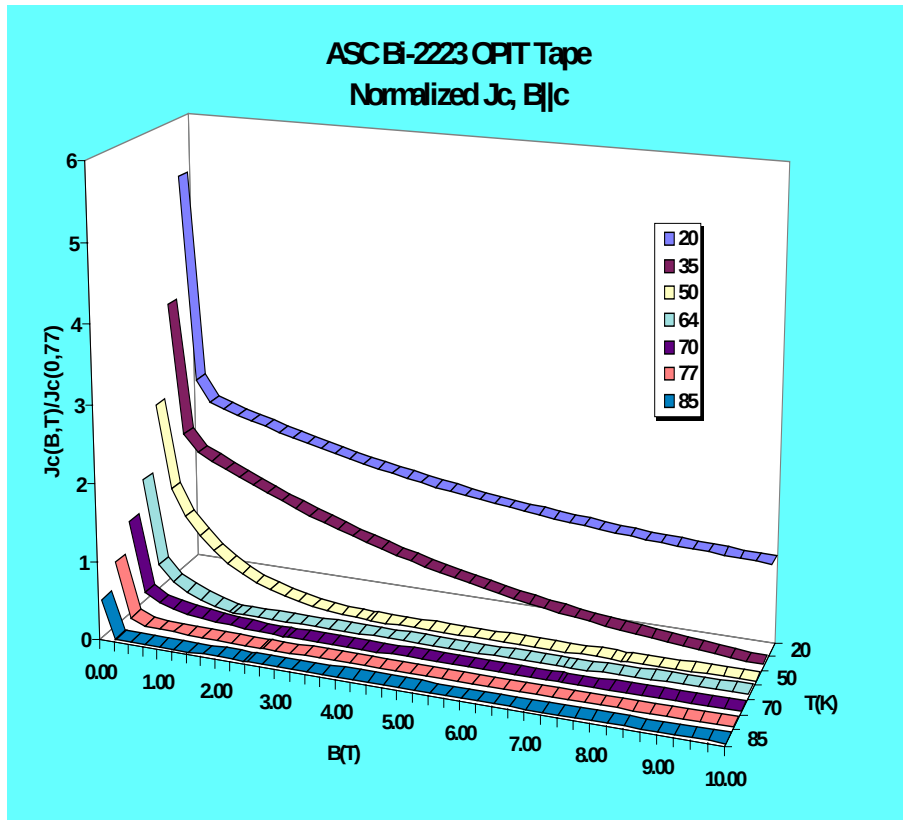
ASC Short Rolled Multifilament
(Bi,Pb)-2223/Ag

Slope = 9211 A/cm^2/yr



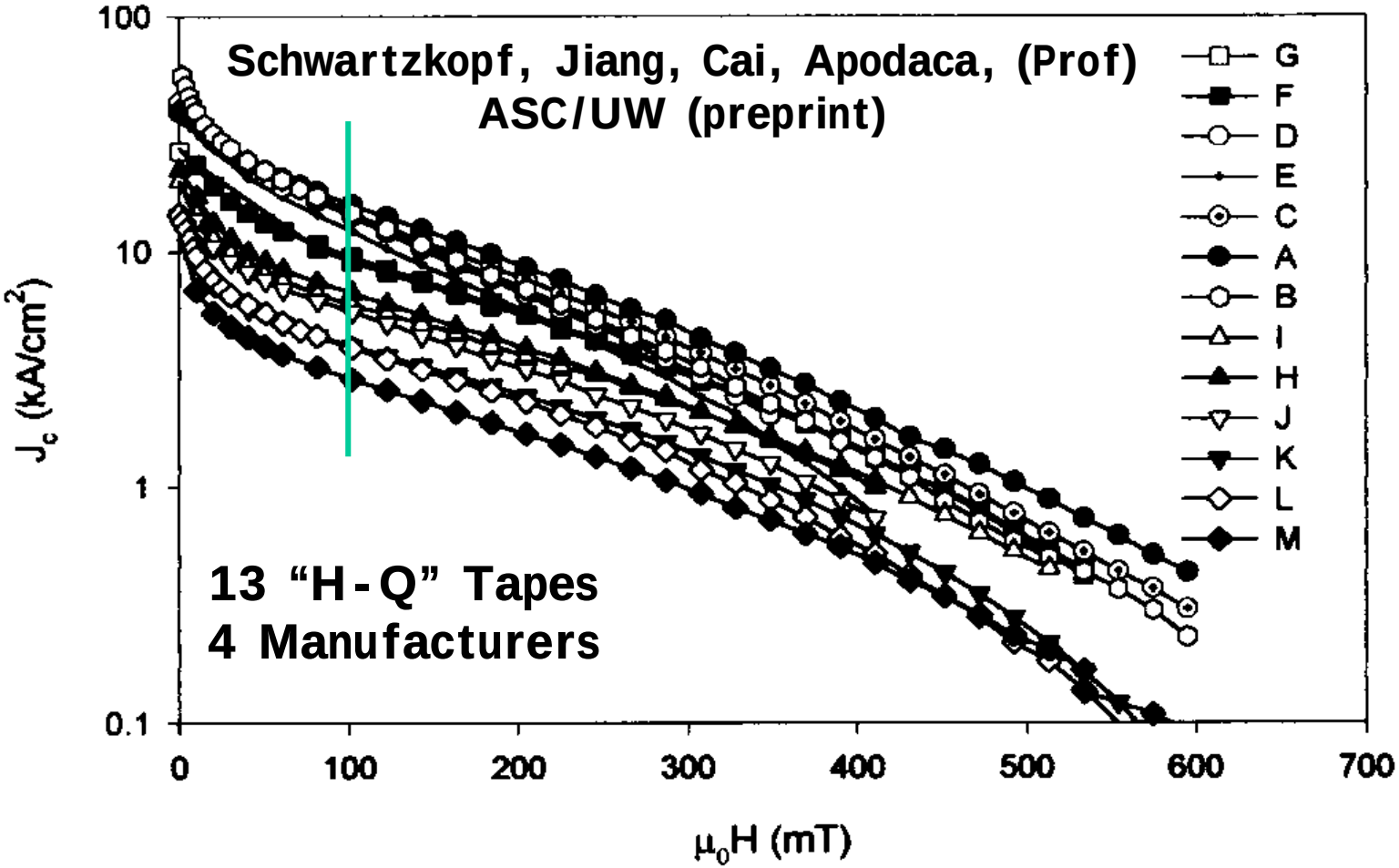
$J_C(B,T)$ for BSCCO



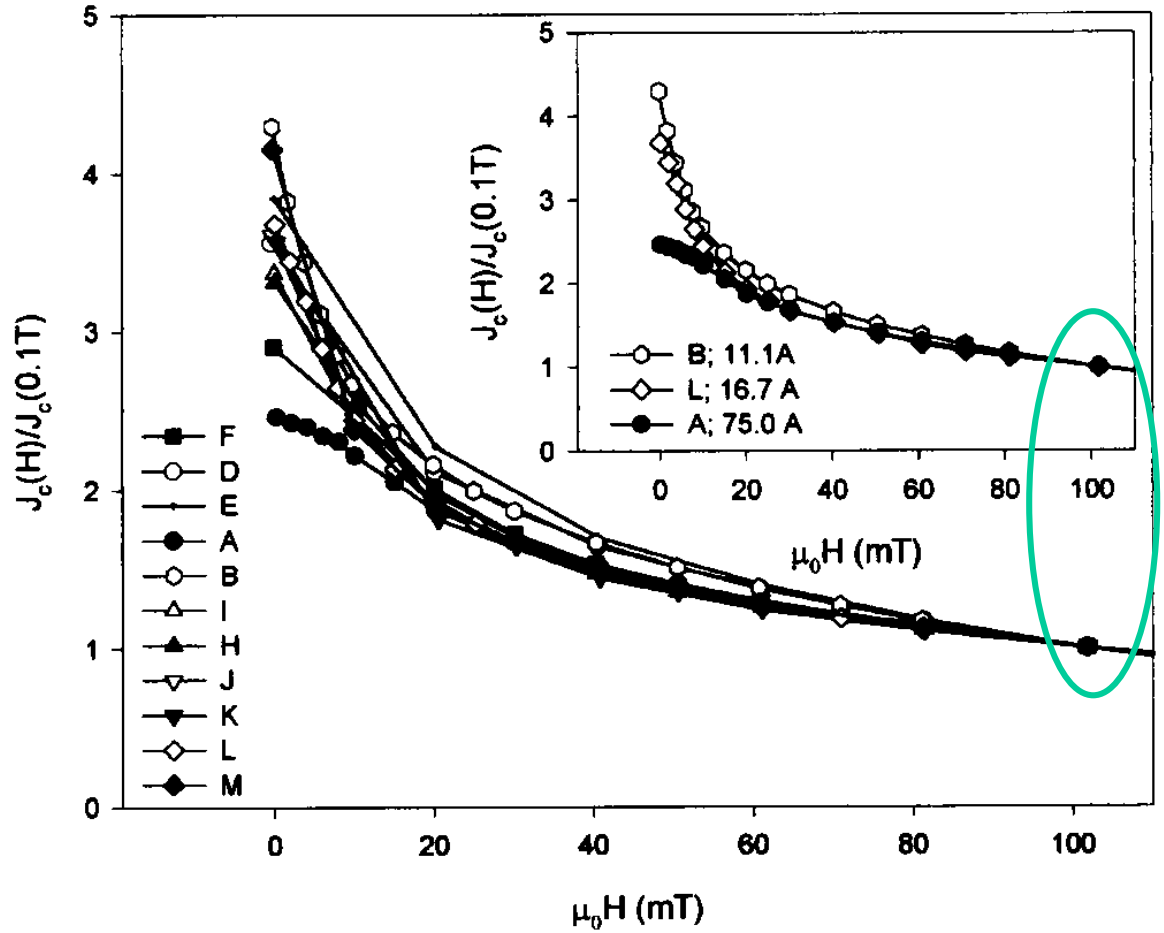



Montreal
CEC
ICMC
'99

$J_c(77, B)$


Schwartzkopf, Jiang, Cai, Apodaca, (Prof)
ASC/UW (preprint)
13 "H-Q" Tapes
4 Manufacturers
G
F
D
E
C
A
B
I
H
J
K
L
M
100
10
1
0.1
0
100
200
300
400
500
600
700
J_c (kA/cm^2)
$\mu_0 H$ (mT)

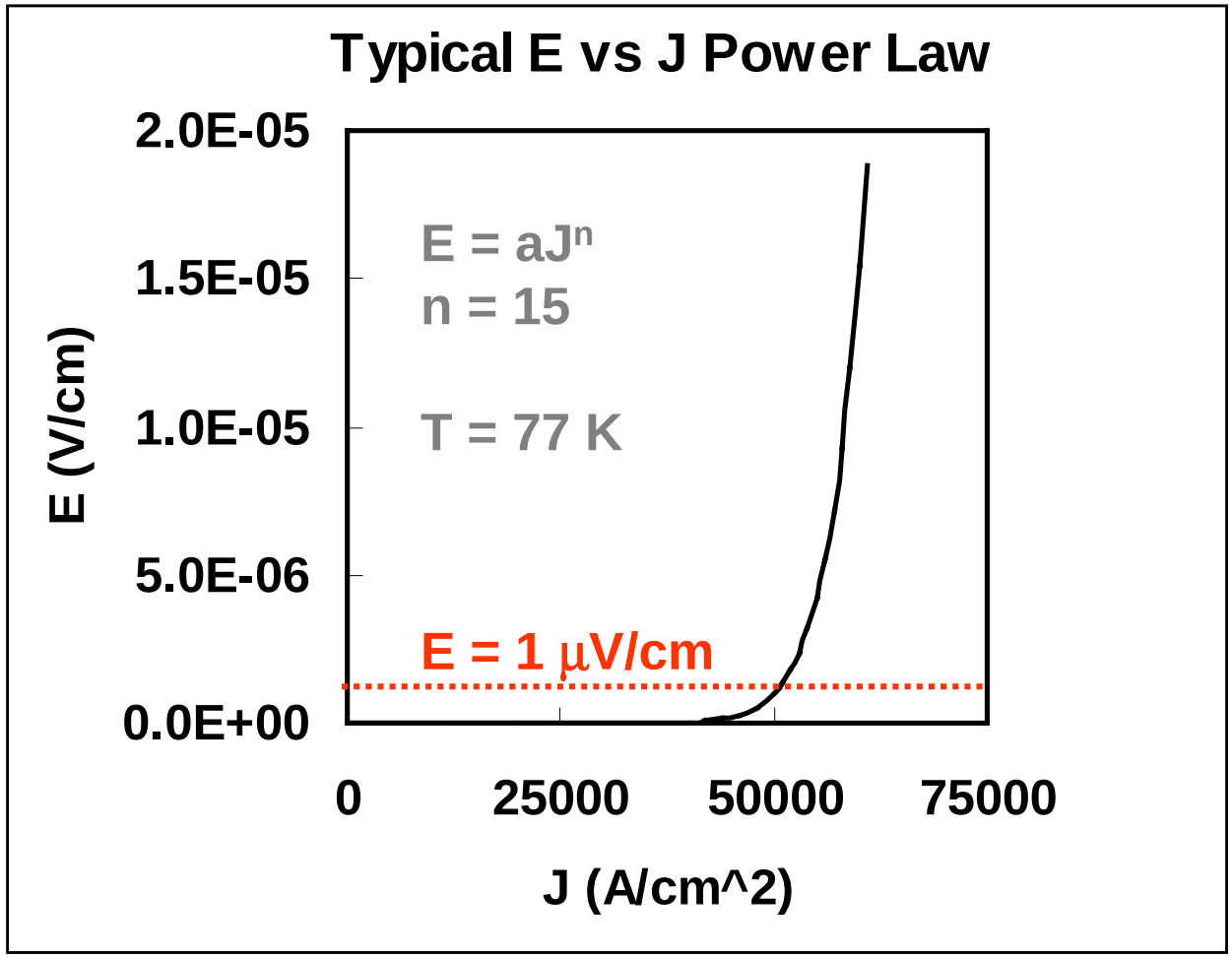
$J_c(77, B) / J_c(77, 0.1)$



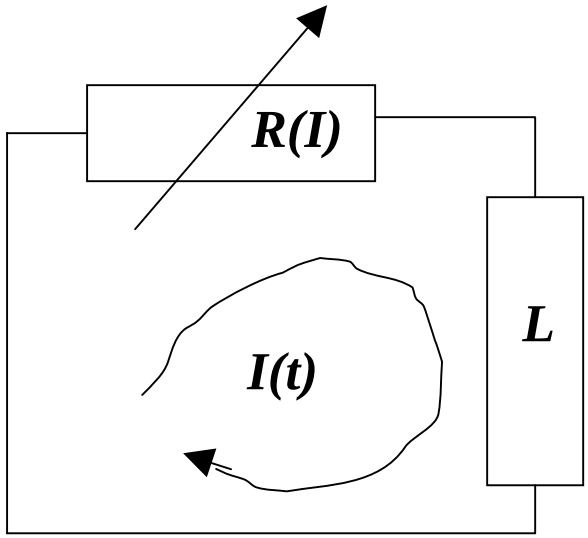
Homework Problem

- MRI/μSMES Proto-Solenoid
  - Diameter = 1m; Length = 5m
  - Wire Diameter = 1mm; # Turns = 5000
  - Wire Length = 15.7km; Inductance = 4.95H
- Operation Parameters
  - I = 392.5A (J = 50,000A/cm^2); ΔV = 1.57V
  - "R" = 0.004Ω (J = 50,000A/cm^2, E = 1μV/cm)
  - **E** = 0.38MJ; B = 0.49T; P = 616W

BSCCO OPIT/Ag E-J Characteristic



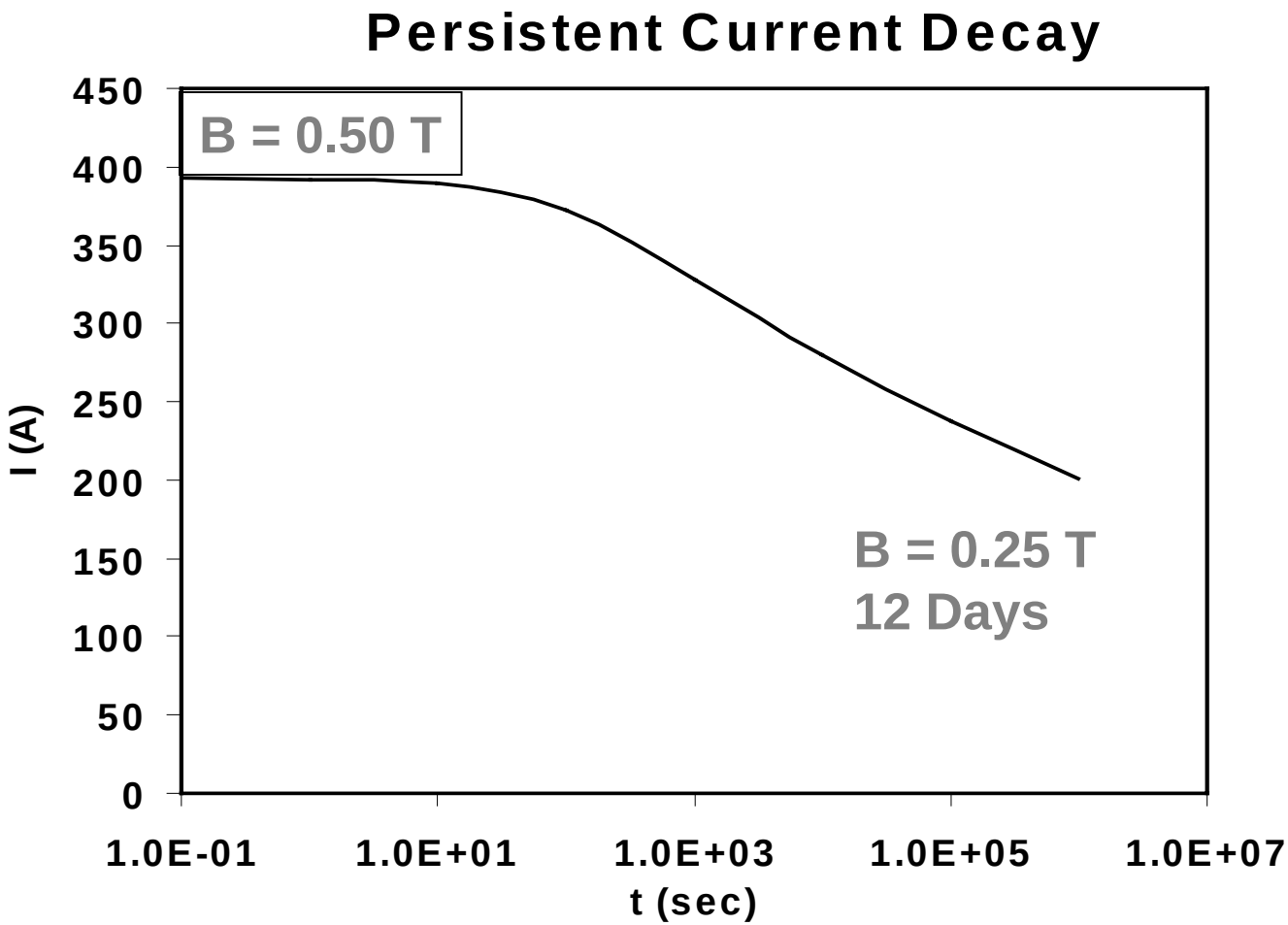
Solenoid Loop Current: $t > t_0$



$$bI^n + L\frac{dI}{dt} = 0$$

$$I(t) = \left| \frac{b(n-1)}{L}(t - t_0) + I_0^{1-n} \right|^{\frac{1}{1-n}}$$

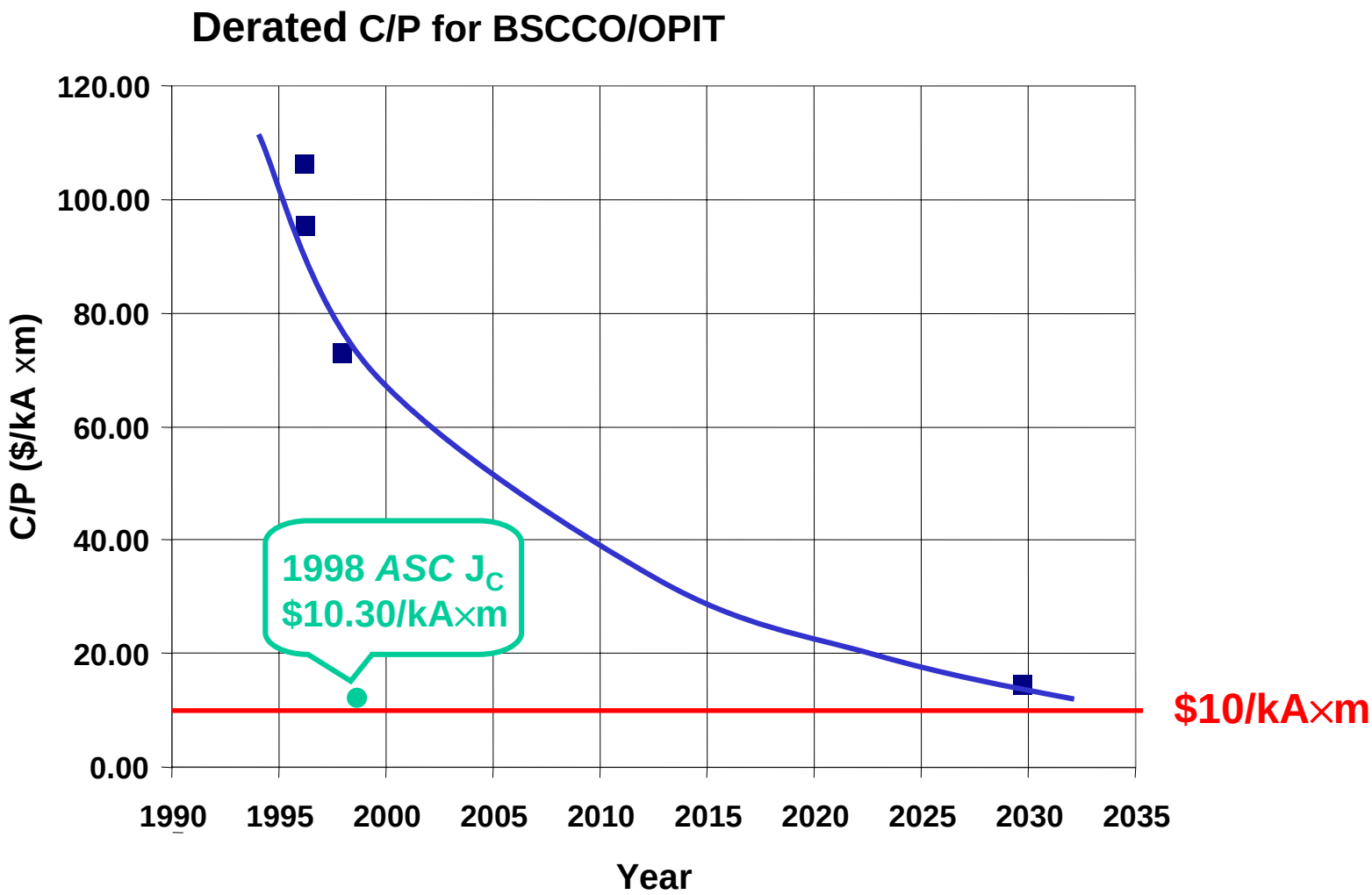
"Persistent" Current Decay



Derating Factors: C/P Multipliers

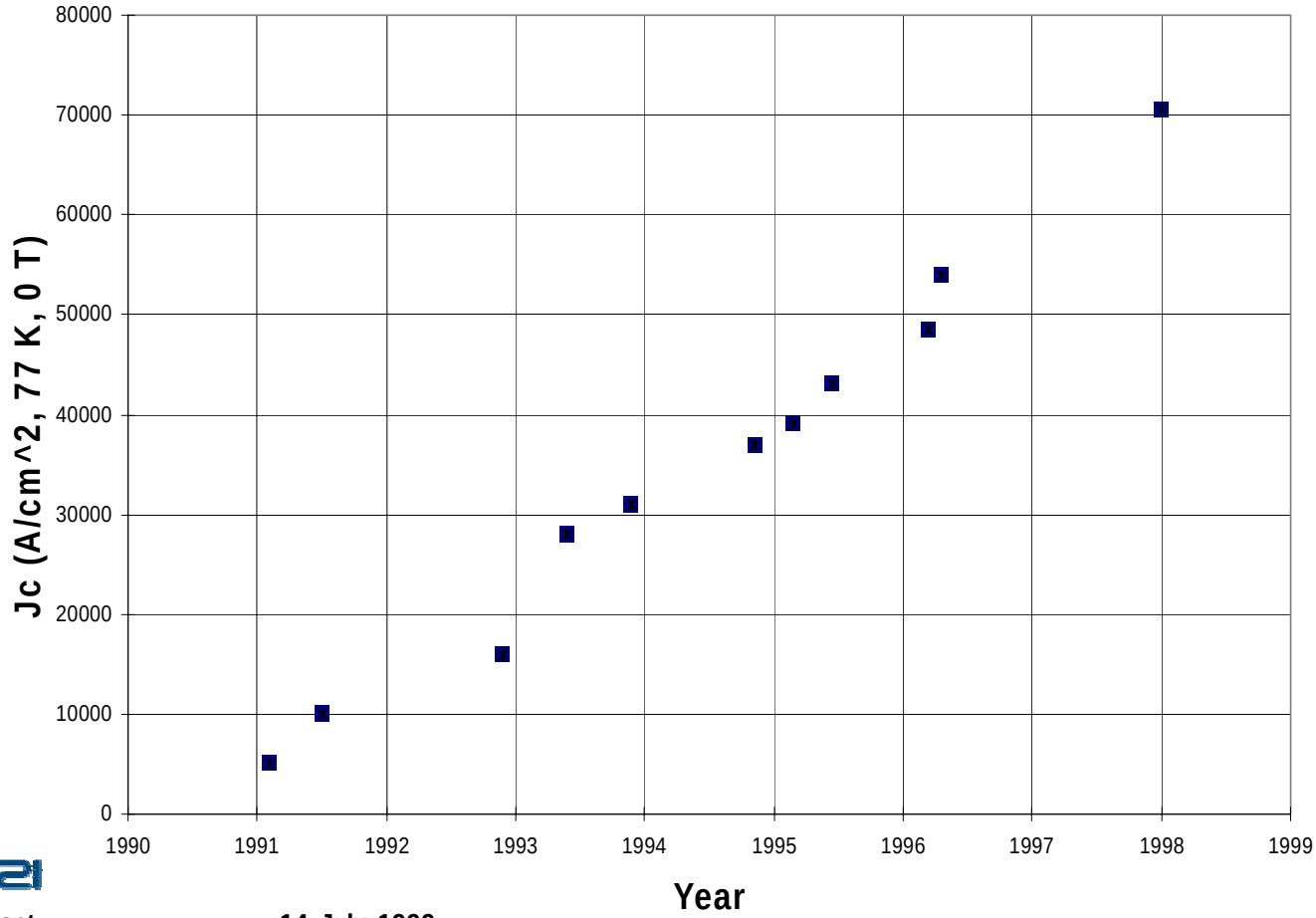
		(ASC)
• 1.0 → 0.1 μV/cm @ 77 K	1.2	
• Ag Treatment	1.5	
• 0.1 T Field	1.8	1.15 (B ab)
• 1 km Length	3.0	1.05
• ac Operation	2.5	
• Profit (???)	1.3	
Accumulated Multiplier	31.6 !	7.1

The Future of BSCCO/OPIT



Malozemoff's Law

ASC Short Rolled Multifilament
(Bi,Pb)-2223/Ag

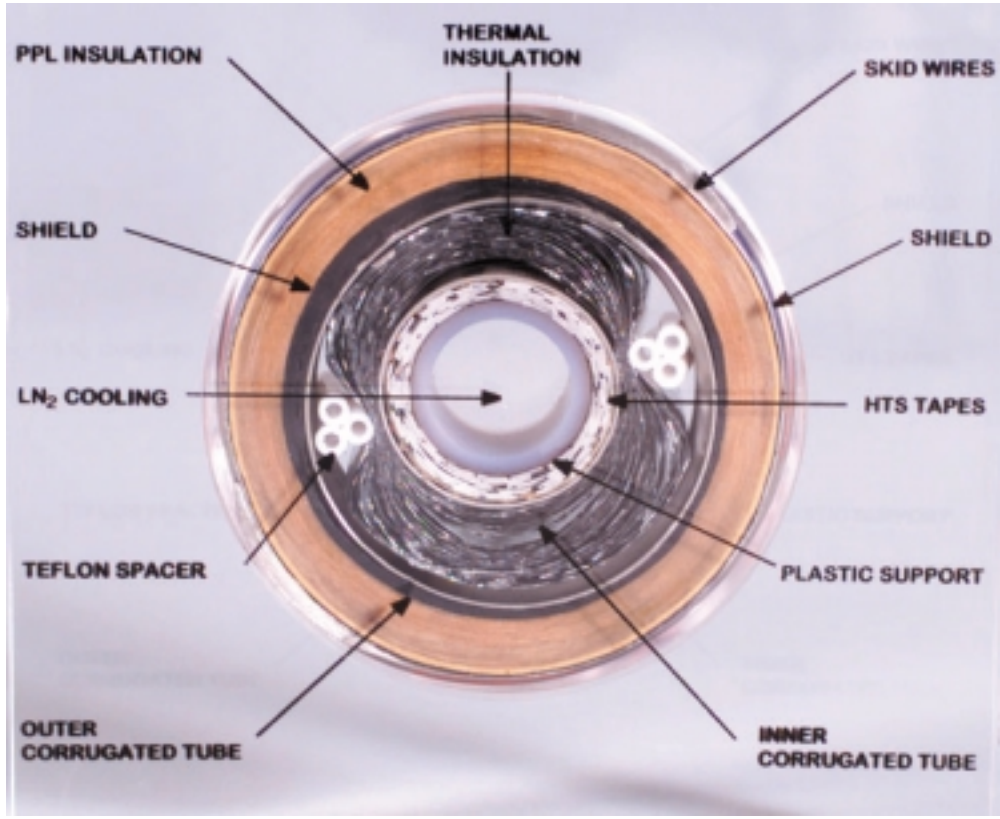


ASC
"long lengths"
77 K, sf

"le cidre et le vin"

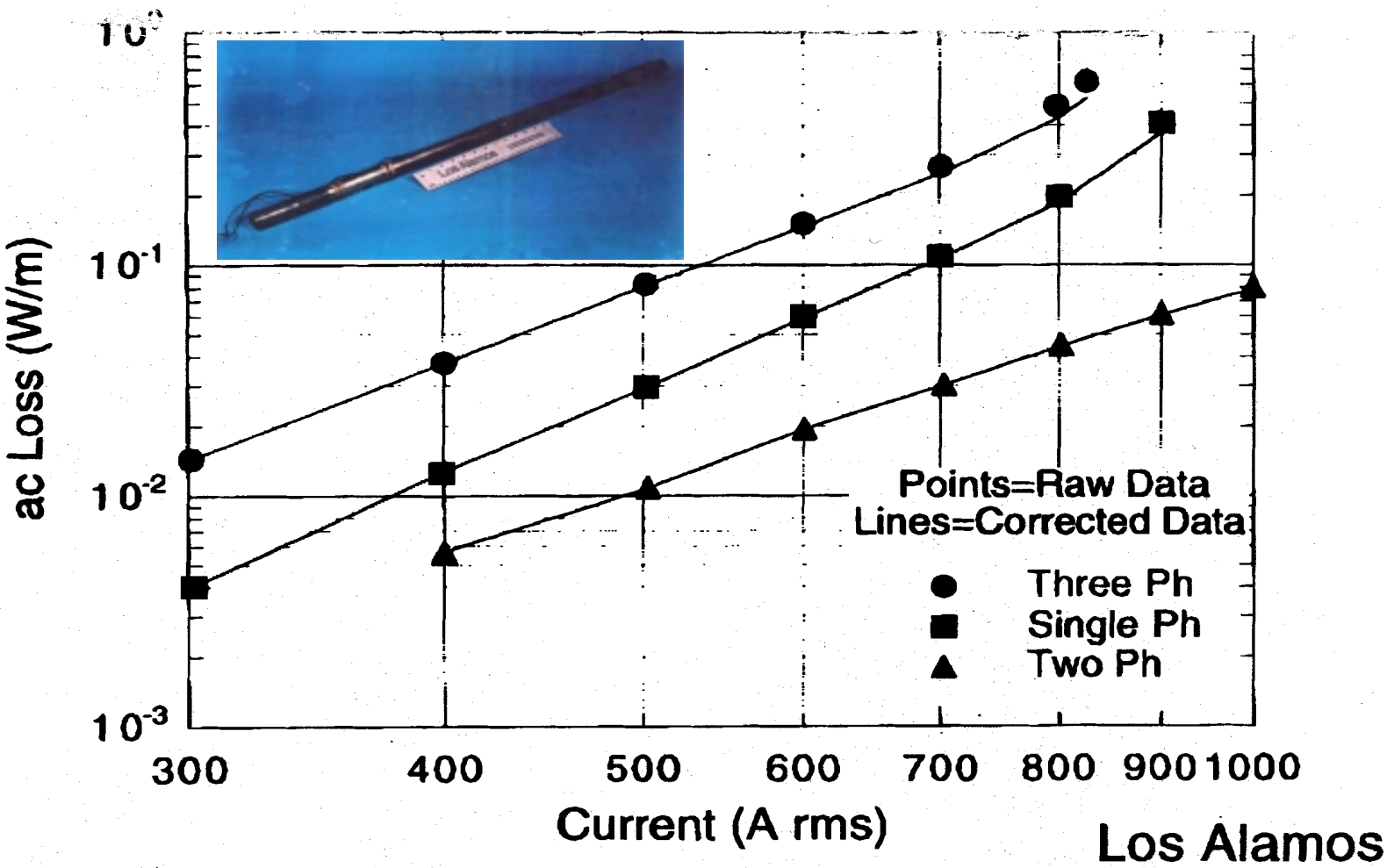
(apples & oranges)

1000 A_{rms}



3000 A_{rms}

Hysteretic ac Loss



Cu vs. BSSCO

6 cm dia. Copper

- Cost: $50/m
- Current: 1000 A
- I^2R Loss: 6 W/m

40 BSSCO Tapes

- Cost $200/m
- Current: 4000 A
- Losses:
  - ac 4 W/m
  - cryo/other 2 W/m

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  6 W/m

Cost Recovery

Financial Assumptions

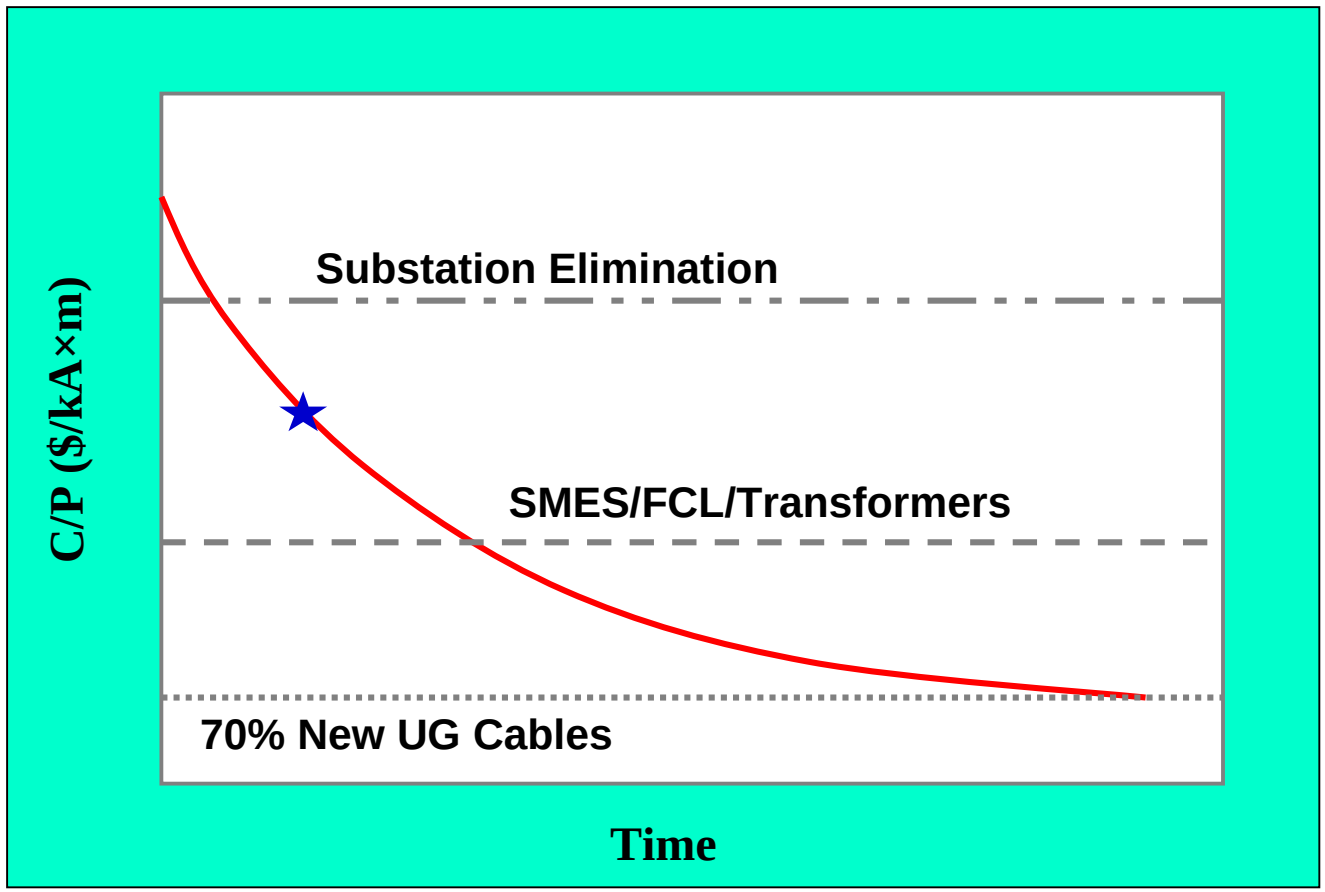
- **COF 10%**
- **Life 20 yrs**
- **Power 0.12 $/kWh**

W/m	KWh/yr	$/yr	EOL
1	8.76	1.05	60
4	35.04	4.21	240

Trenching Costs

- Urban/Suburban $500/m
- Rural $225/m

Wire C/P Market Entry Thresholds



What's Needed?

A Spec Sheet for HTS Wire!

$$V = f(I,T,B,\theta,\omega,A,l,\sigma,\varepsilon),$$

where V = voltage drop per unit length,
I = current,
T = temperature,
B = magnetic field,
θ = crystallographic orientation,
ω = frequency,
A = cross-sectional area,
l = wire length,
σ = stress,
ε = strain.

$$C/P \equiv \$/I\times l = g\,(V,T,B,\theta,\omega,A,l,\sigma,\varepsilon).$$

Electricity: A Life Necessity

California, Summer 1996

Sunday, August 11, 1996

Millions lose power

Half of PG&E's customers in Northern California affected; blackouts in 9 states

THE POWER PROBLEM

PG&E Firms wonder: Is this the future?

U.S. says power will be bolstered

Substation explosion cuts PG&E service in South San Jose

Outage raises serious worries

Investigations planned after power grid falters

More Outages Expected for Power Network

Increased demand strains regional transmission lines

ELECTRICITY USERS FEELING POWERLESS

Shutoffs fray nerves in South San Jose

Quebec, Winter 1997

“You don’t always get what you want…”

"...you get what you need!"