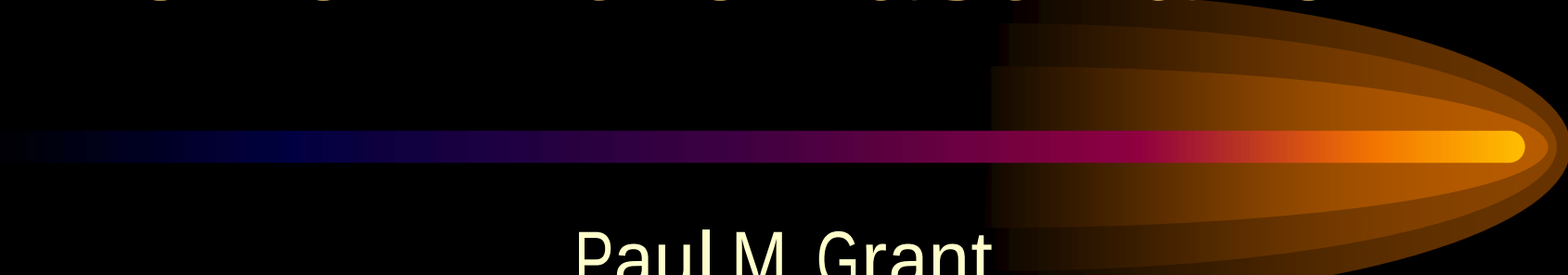


Superconductivity: Power in the Fast Lane



Paul M. Grant

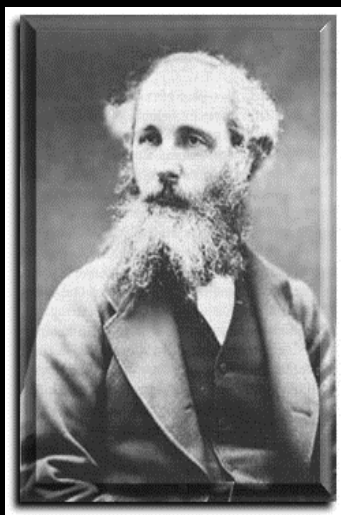
EPRI Lead, Tech Forecast

Strategic Science & Technology

IEEE Power Engineering Winter Meeting

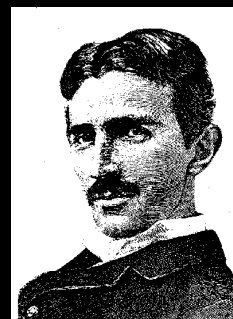
4 February 1998

Fathers of Electricity



Discoverers

Practitioners



Fathers of Cryogenics



Dewar

P.M. Grant
IEEE PE Mtg
Superconductivity
4 February 1998

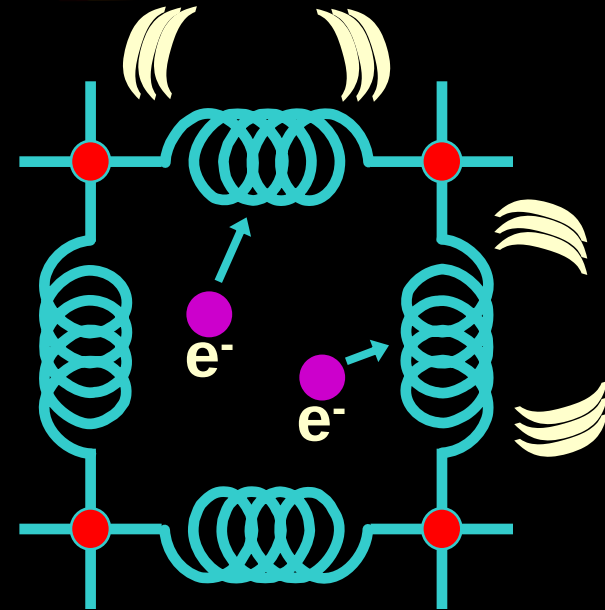
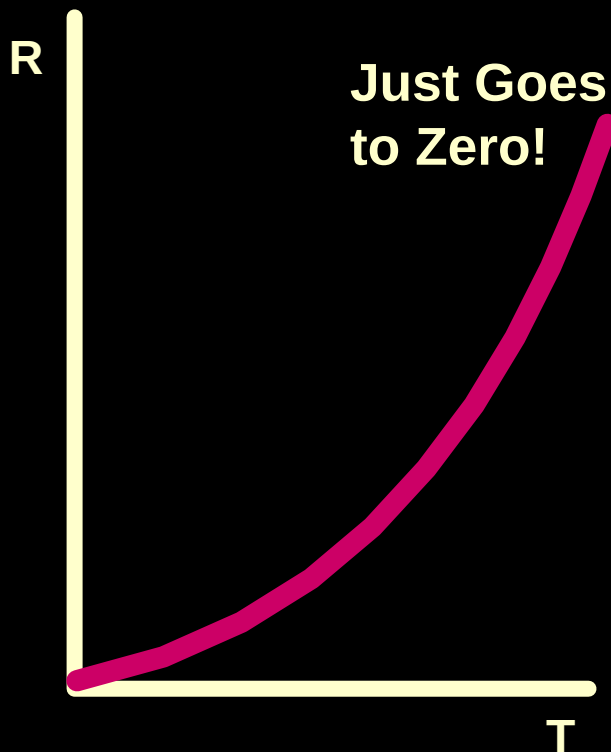
CH ₄	112 K
O	90
N ₂	77
Ne	27
H ₂	20
He	4.2



Kammerlingh-Onnes

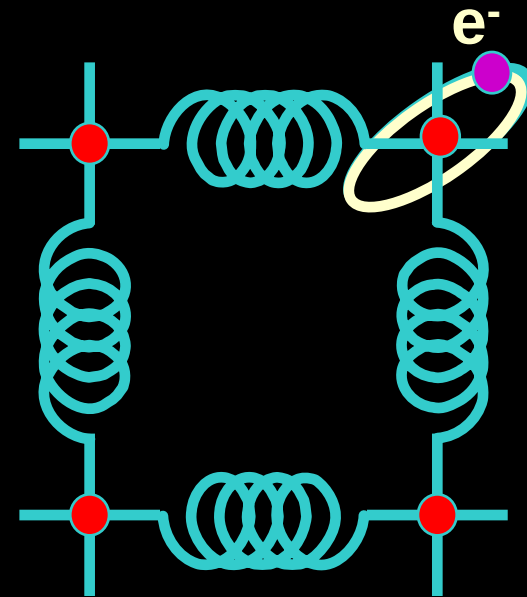
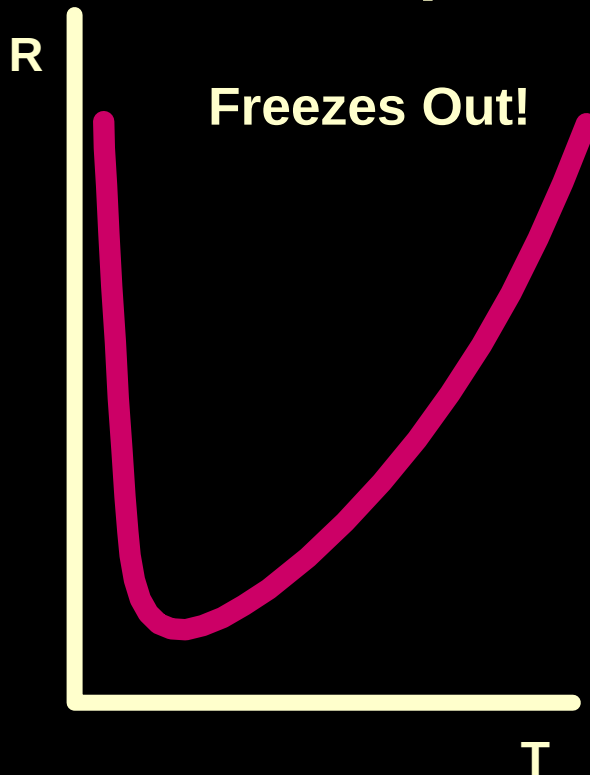
Models of Electrical Conductivity

The First Idea:



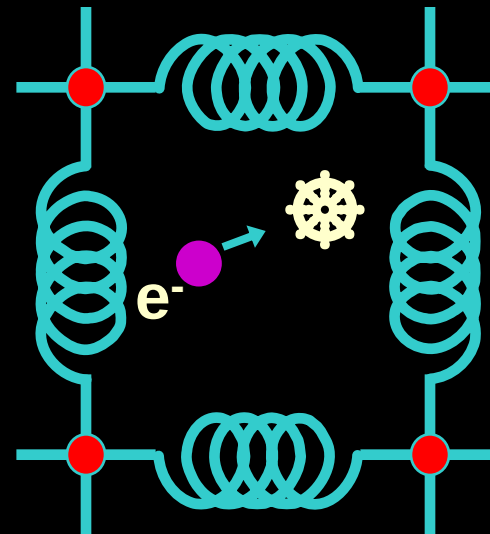
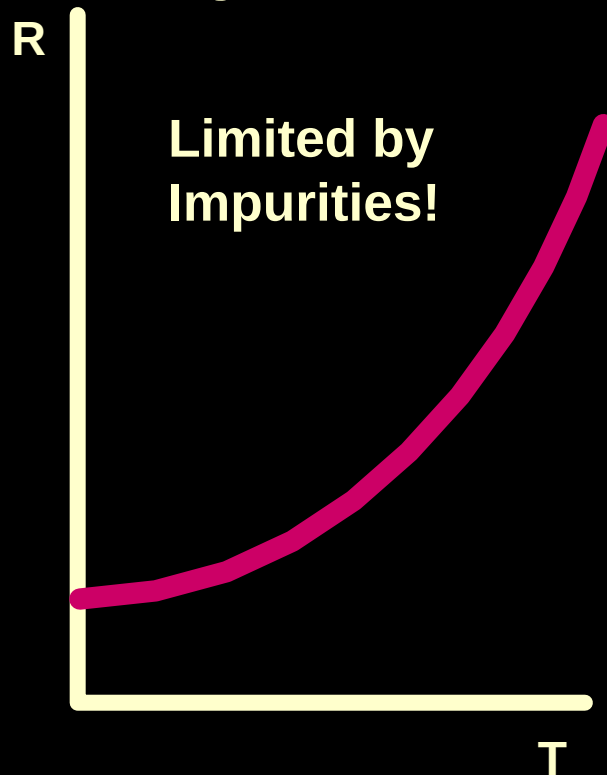
Models of Electrical Conductivity

The Most Popular:



Models of Electrical Conductivity

Reality:

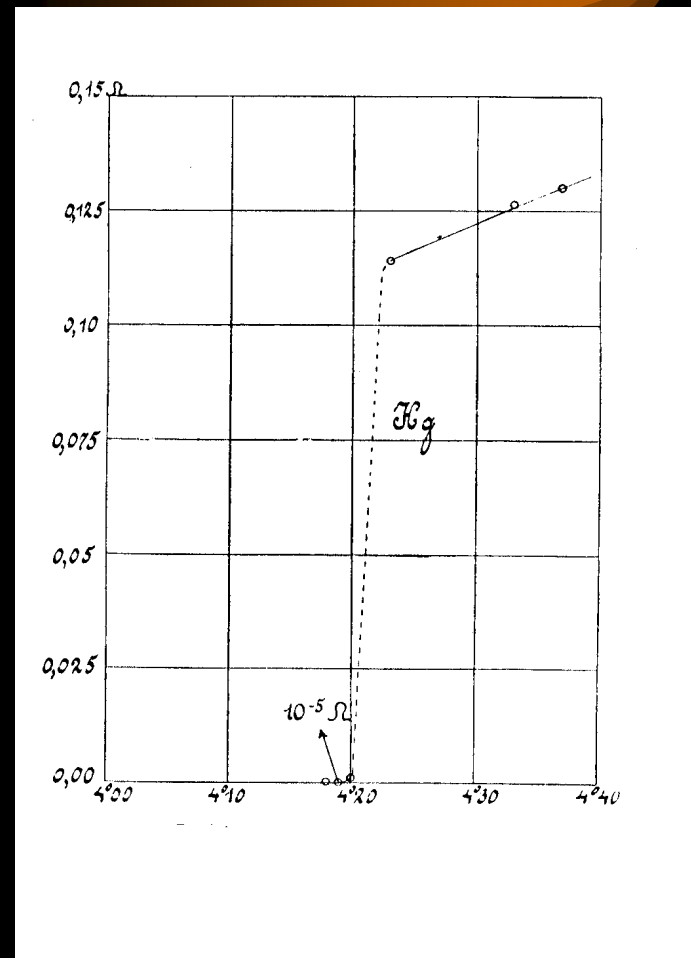


A Big Surprise!

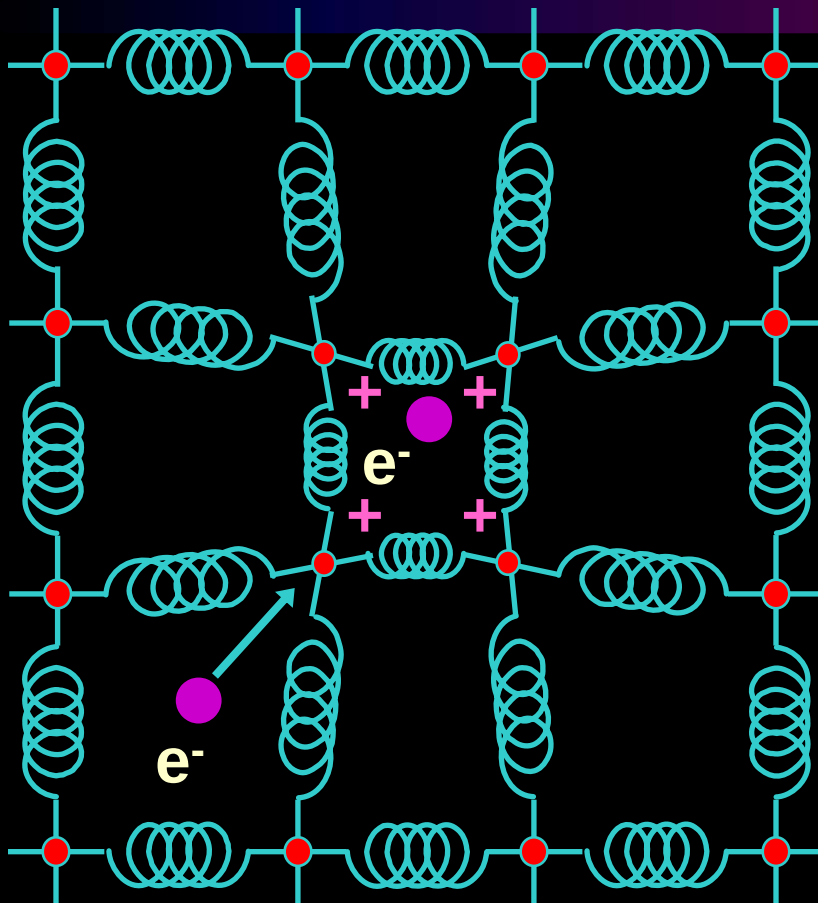


Thus the mercury at 4.2 K has entered a new state, which, owing to its particular electrical properties, can be called the state of *superconductivity*

H. Kamerlingh-Onnes (1911)



Physics of Superconductivity



Electrons Pair Off!

BCS Equation

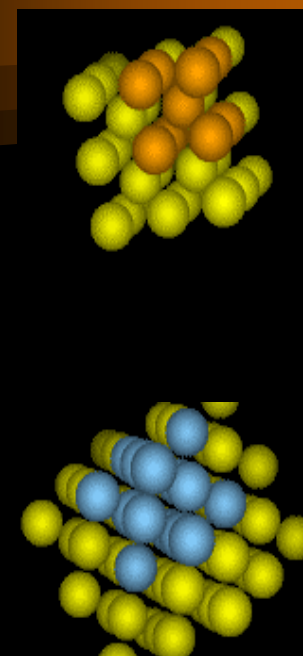
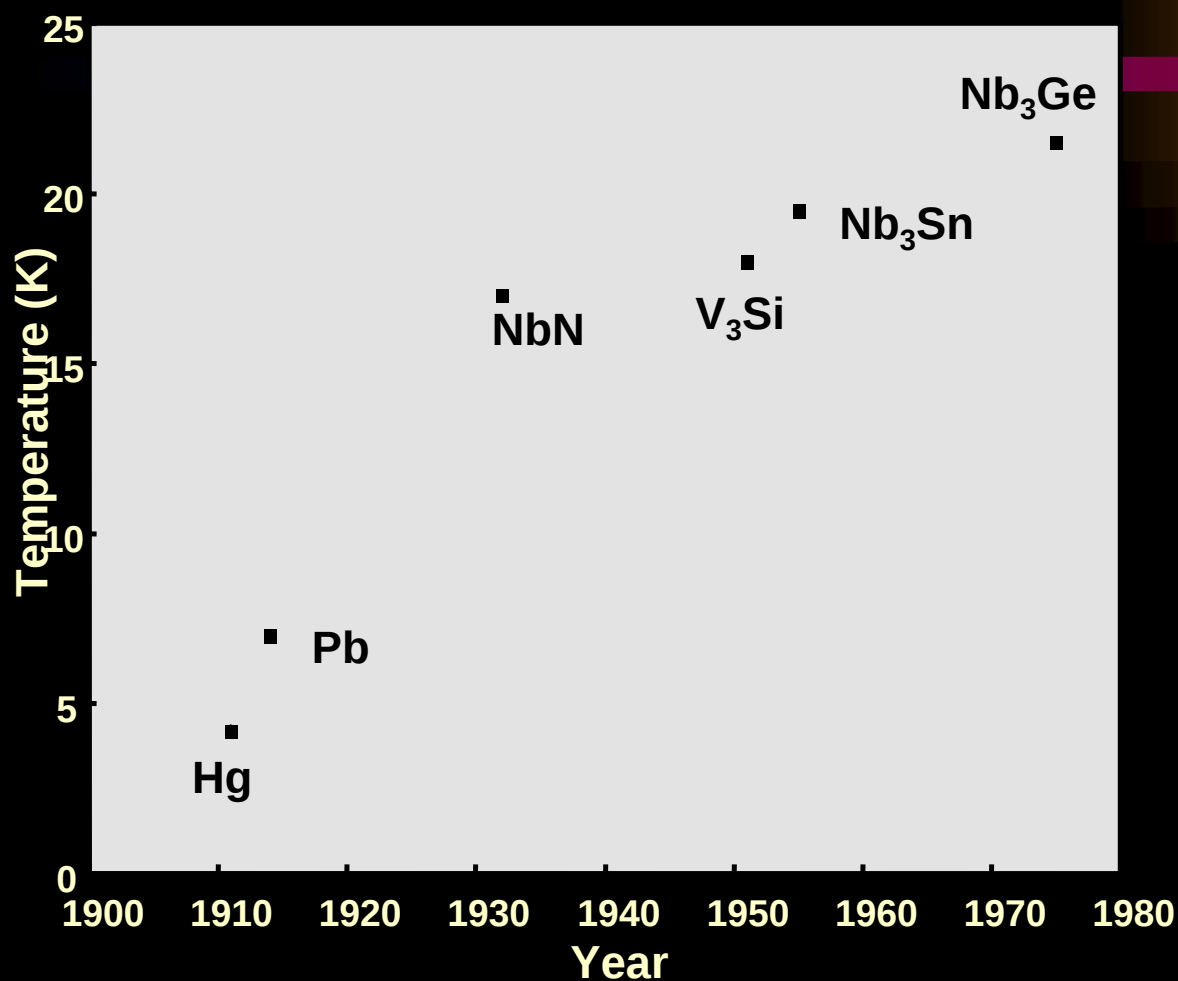
$$T_C = 1.14 \theta_D \exp(-1/\lambda)$$

$$\theta_D = 275 \text{ K},$$

$$\lambda = 0.28,$$

$$\therefore T_C = \underline{9.5 \text{ K}} \text{ (Niobium)}$$

T_c vs. Year: The Past

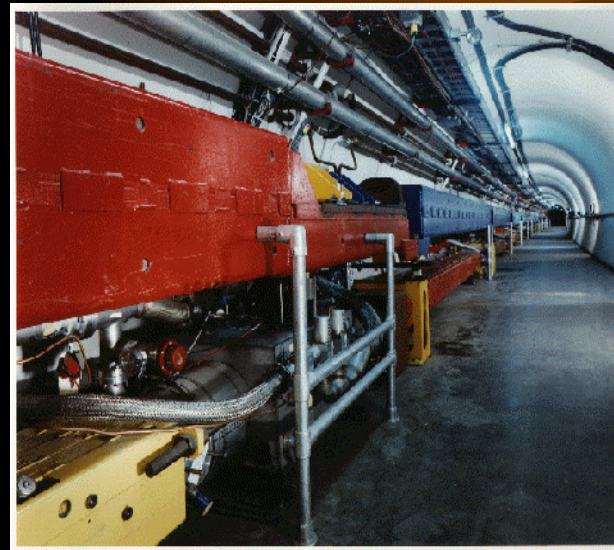


Cubic Metals

Superconductivity: *What's It Good For?*

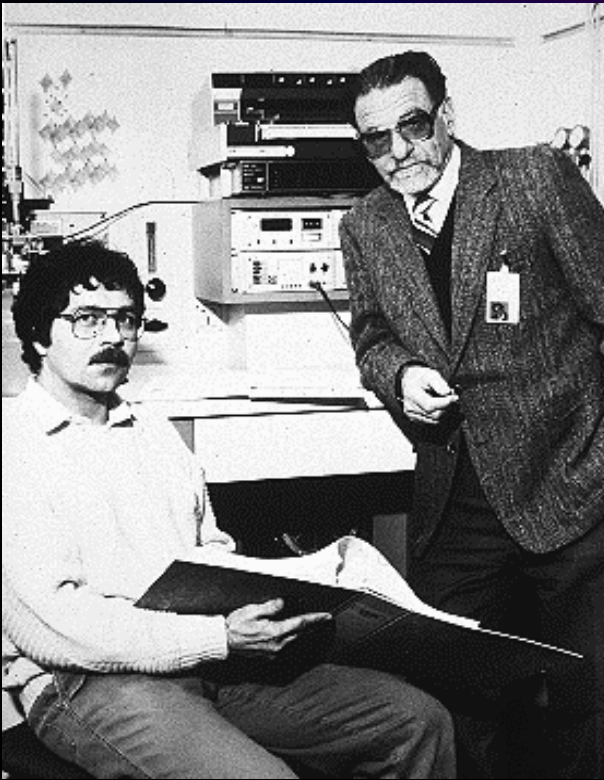


MRI Surgical Unit
General Electric

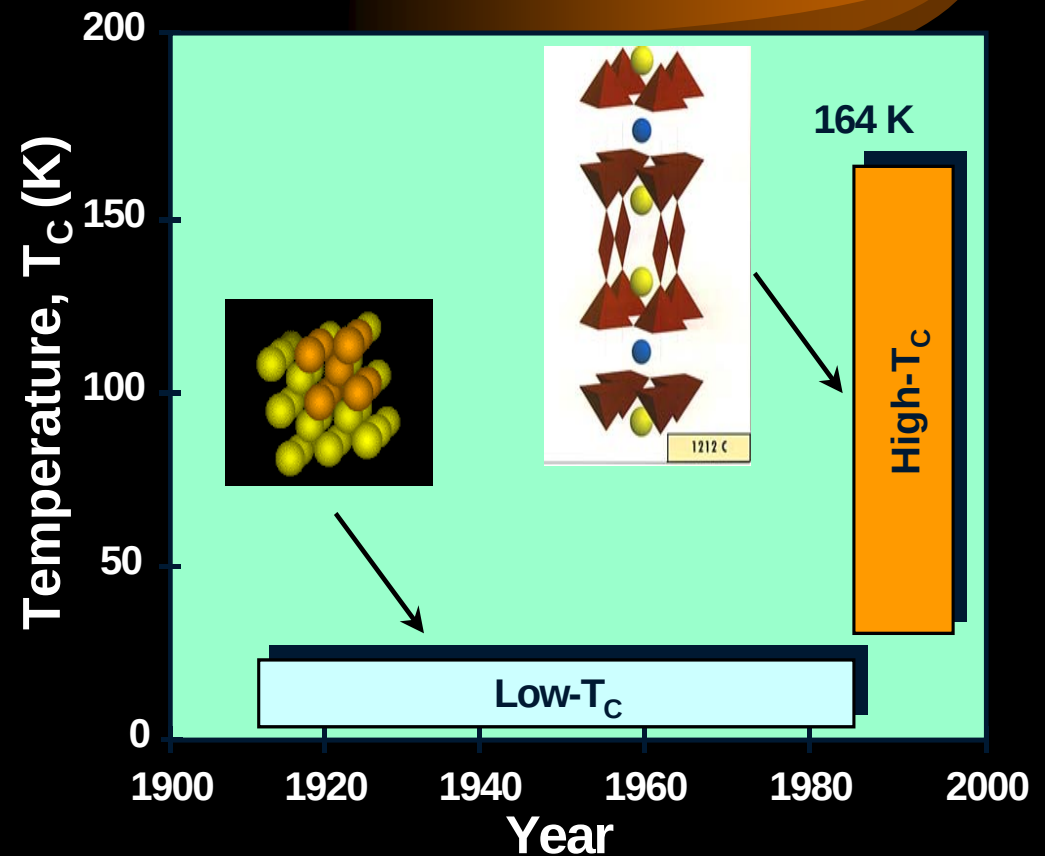


Tevatron
Fermi National Laboratory

Superconductivity: *High- T_c Surprise!*



Bednorz and Mueller
IBM Zuerich, 1986



1987: “The Prize!”

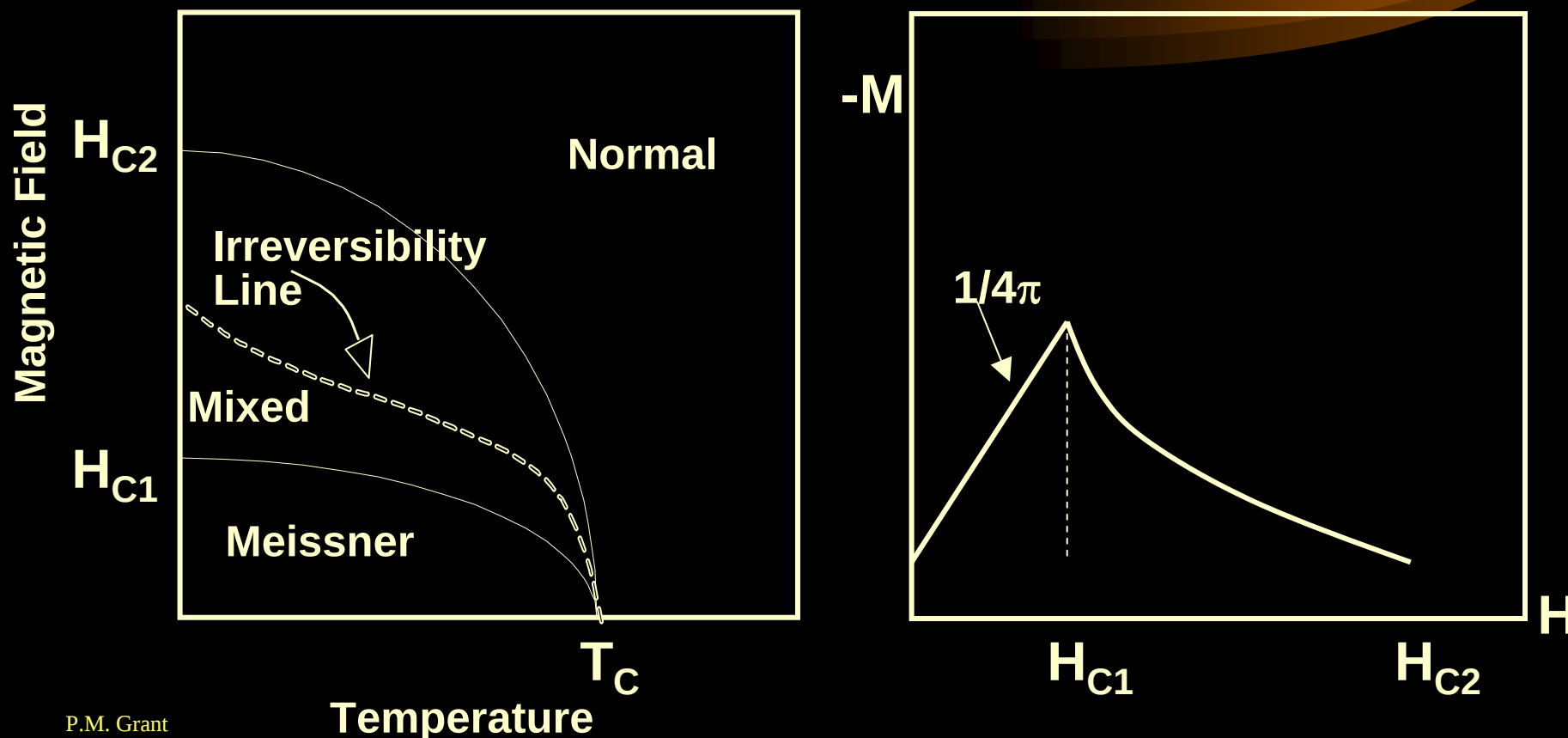


Associated Press

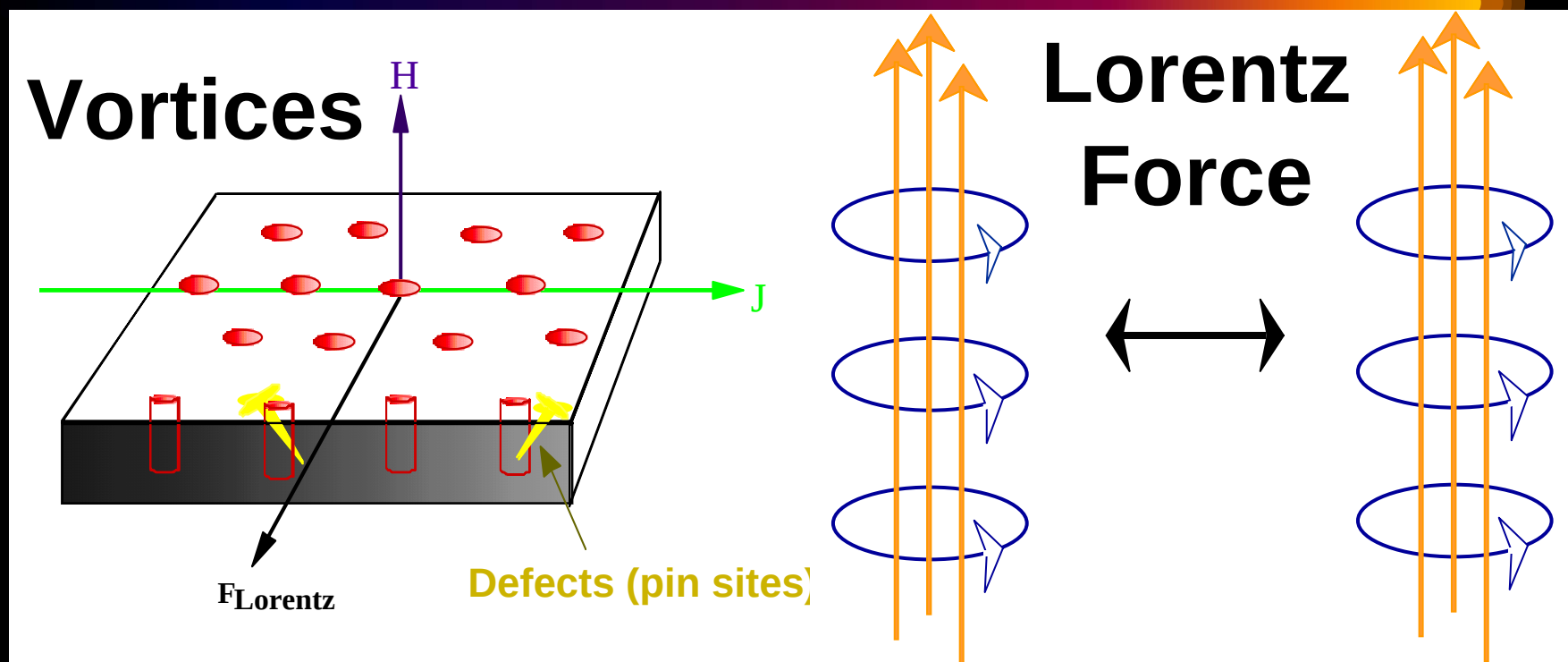
J. Georg Bednorz, left, and K. Alex Müller after learning they had won the Nobel Prize in physics.

2 Get Nobel for Unlocking Superconductor Secret

Type II Superconductivity

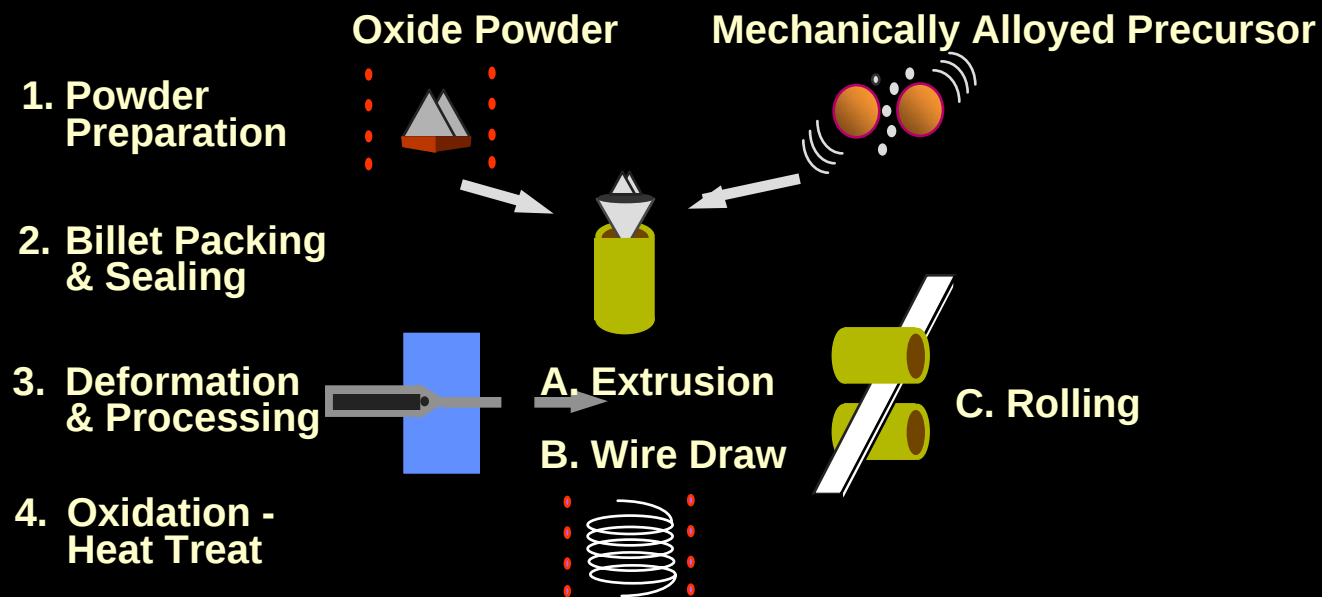


Abrikosov Vortex Lattice

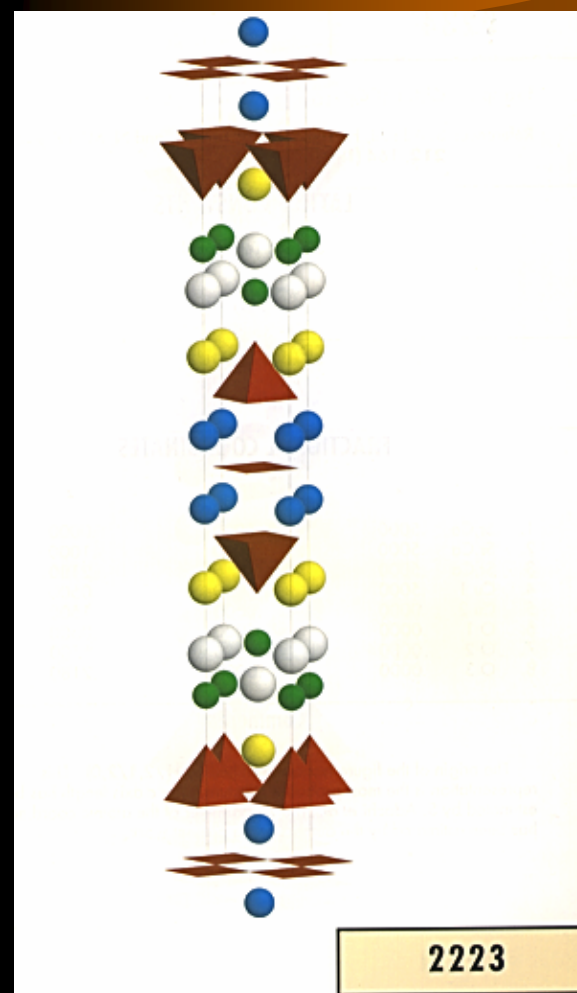
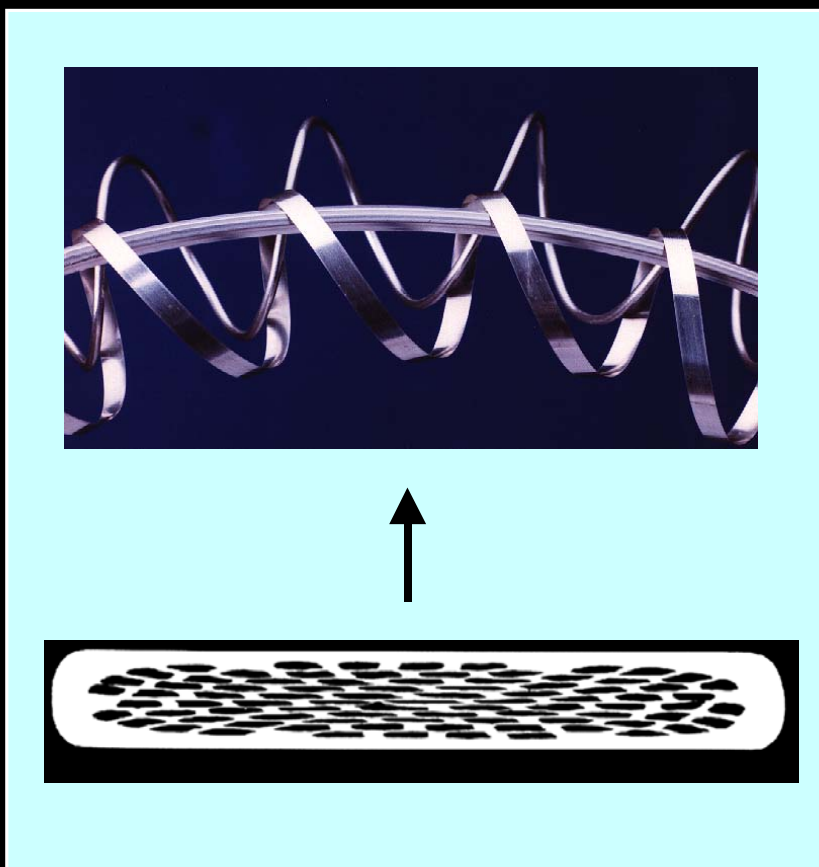


BSCCO OPIT/Ag Process

ASC Wire Forming Process

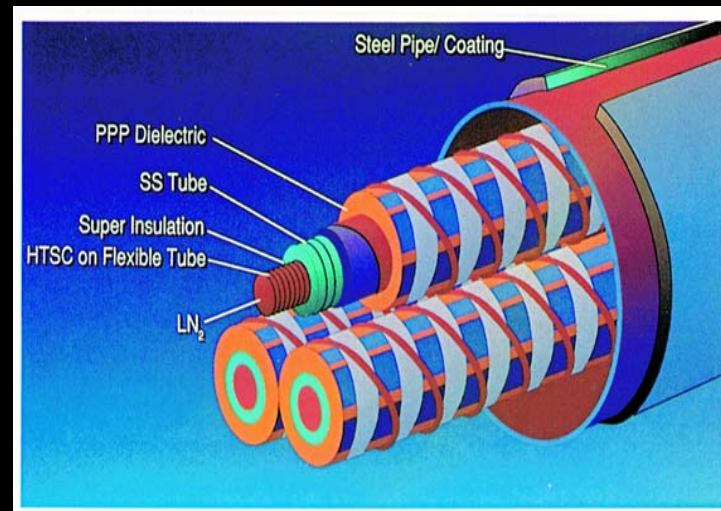
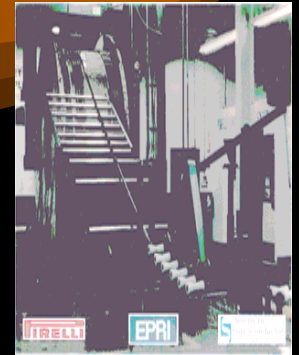
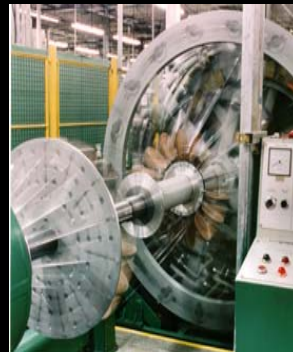


BSCCO OPIT/Ag Tape *Generation I Wire*



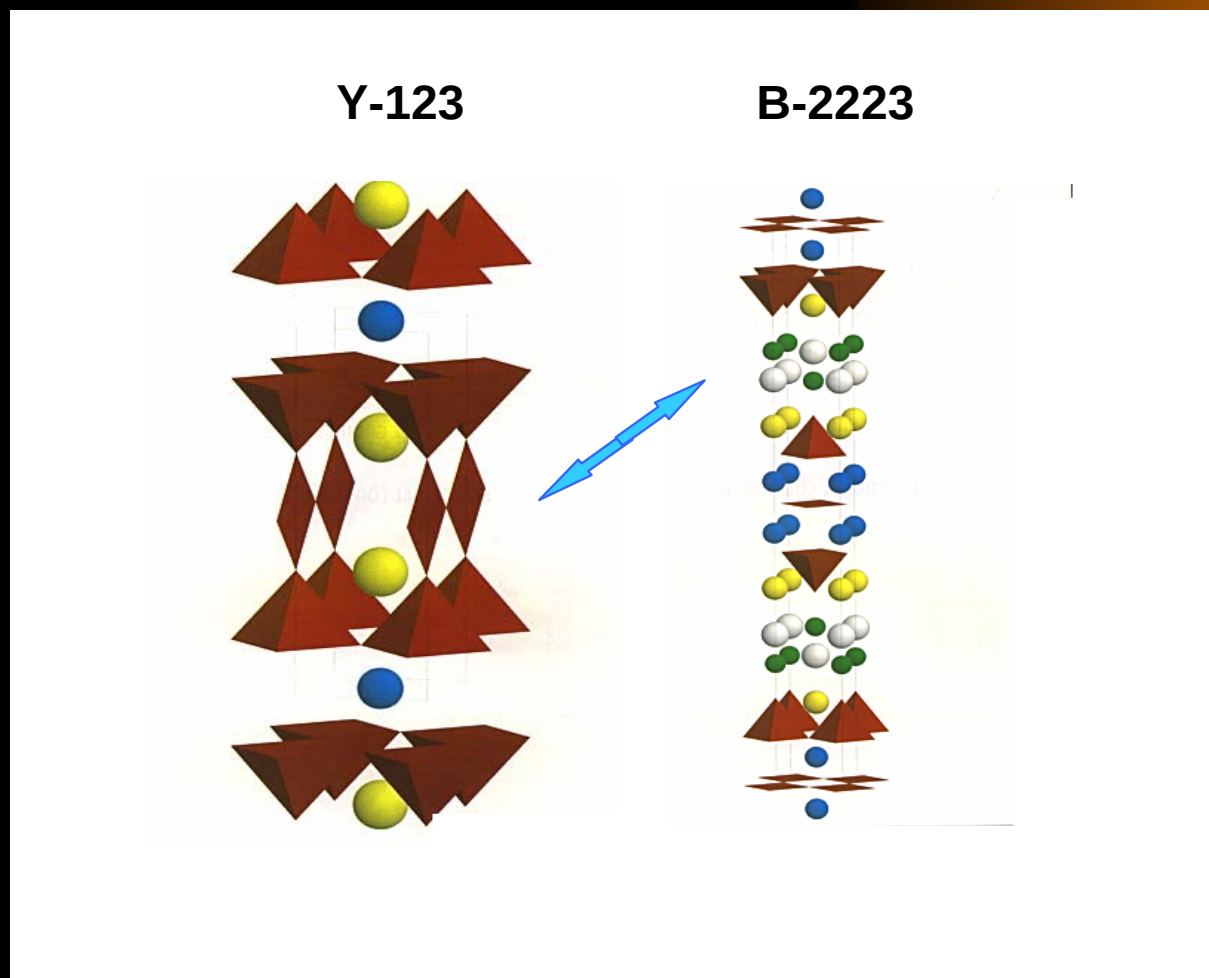
Power Applications: *Wire for Cables*

EPRI
Powering Progress



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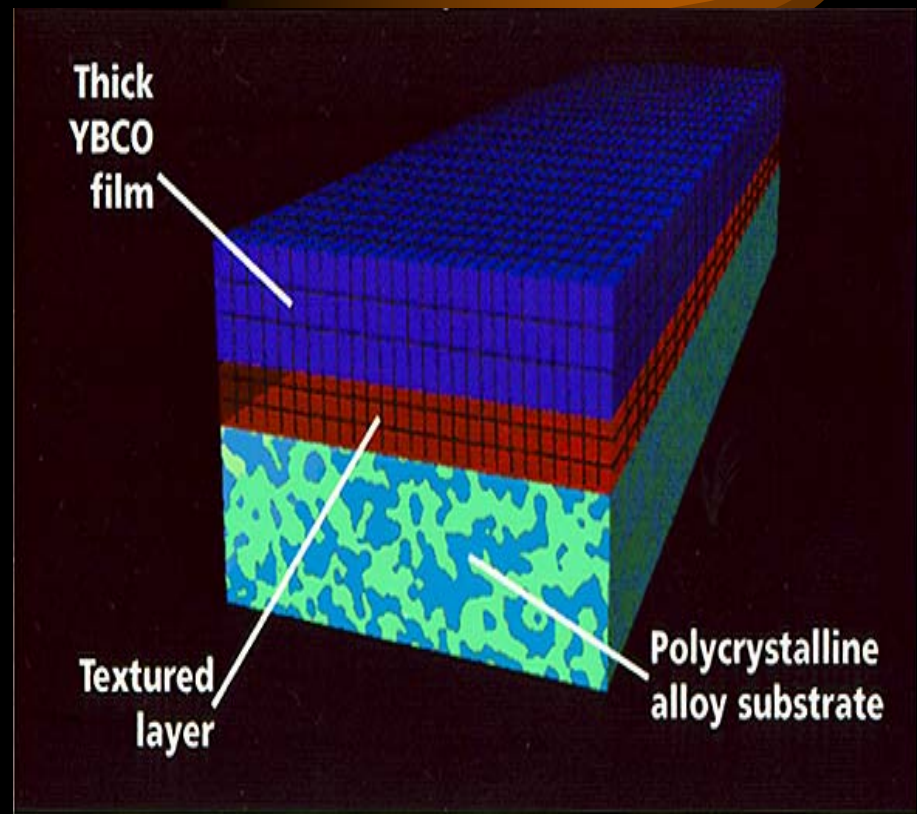
Layered CuO Perovskites



Coated HTSC Conductors **EPRI** Powering Progress

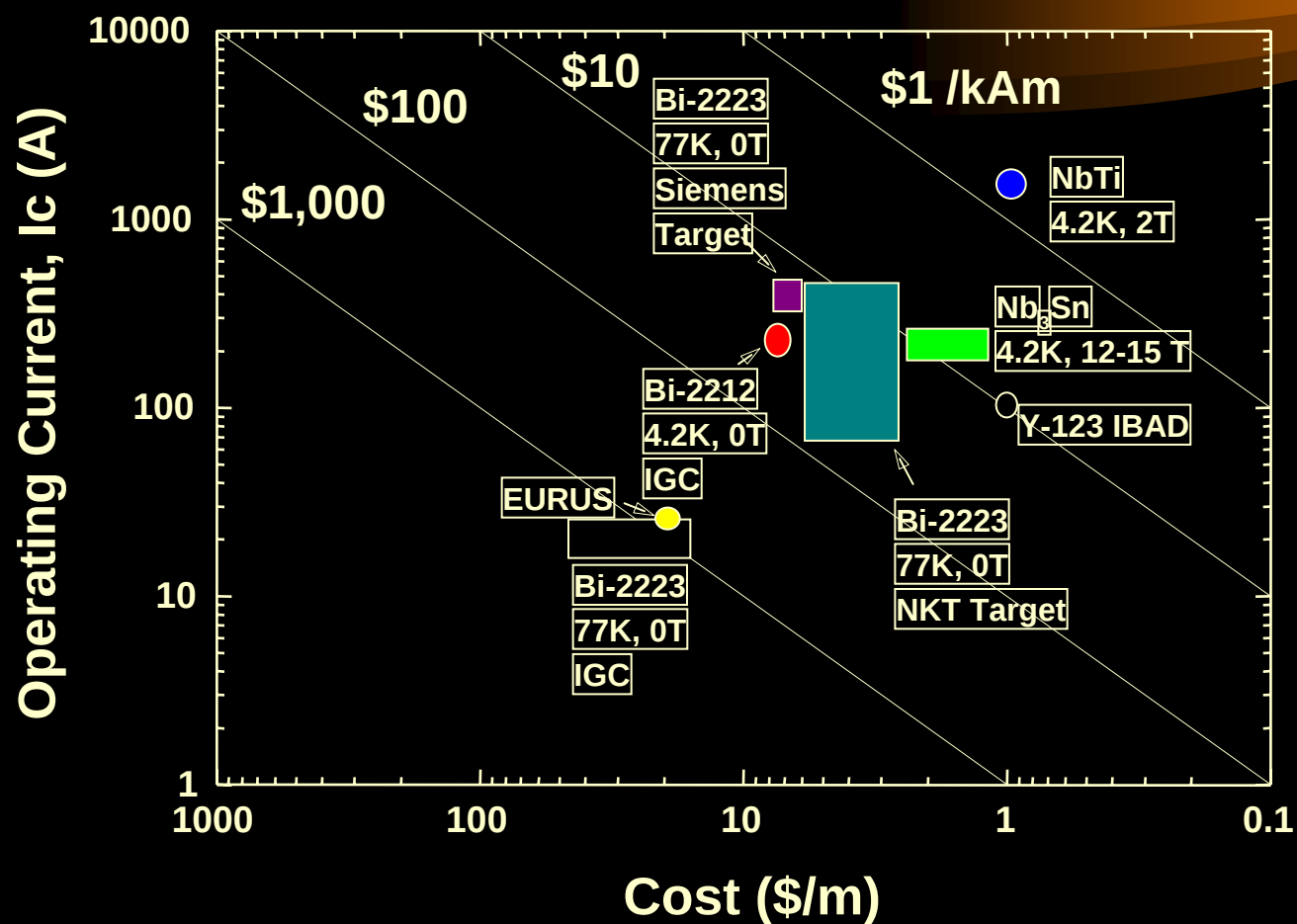
Generation II Wire

- Biaxially Oriented Y-123
- Out of Japan, LANL, ORNL
- EPRI/ASC Alliance to Commercialize



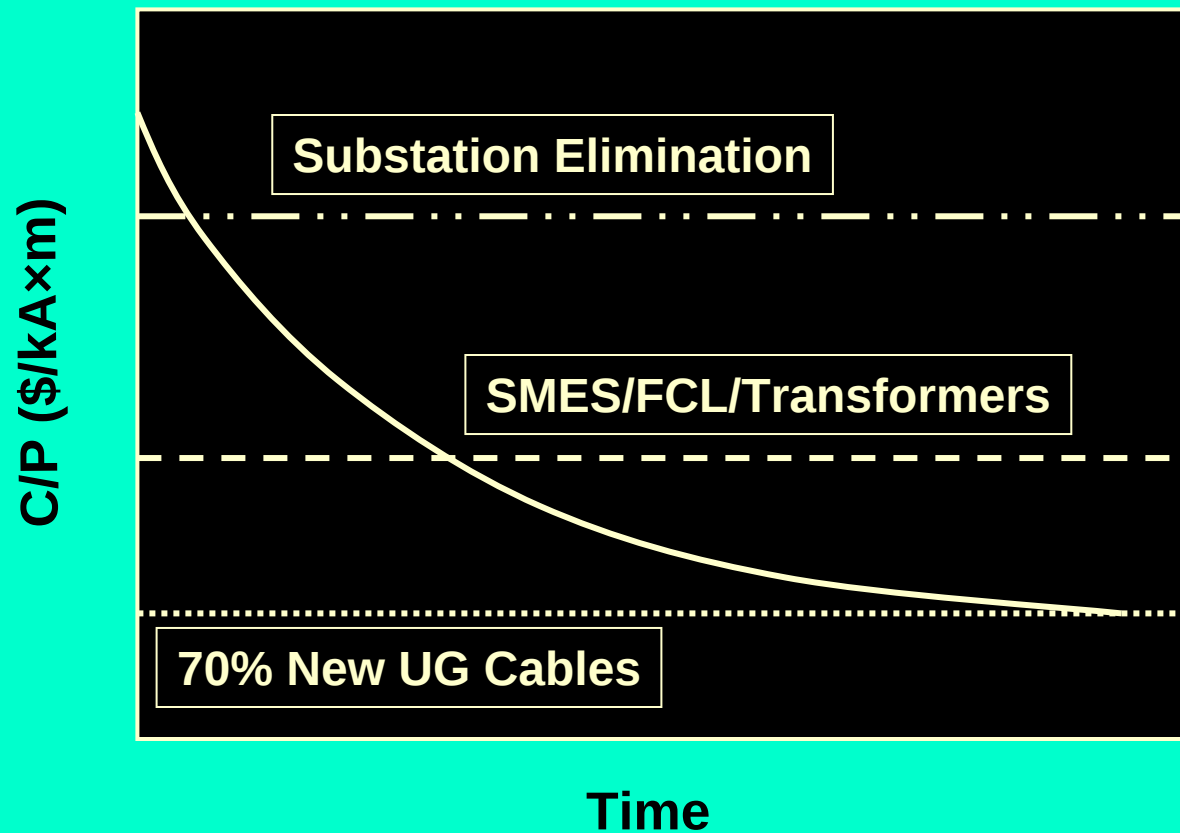
"The SokPlot"

"Sokolowski Plot" of HTSC Wire Performance and Cost



Wire C/P Market Entry Thresholds

EPRI
Powering Progress



Electricity & SC: *Weakest Scenario*

- **Fuel Types & Location**
 - Gas, Renewables Dominate - No More Nukes
 - Distributed Generation Grows
- **Geopolitics**
 - Regional Instability
 - Economic Gap between Nations Continues
- **Environment**
 - Carbon Sequestration Successful
 - Risk Abatement Deferred

Electricity & SC: *Strongest Scenario*

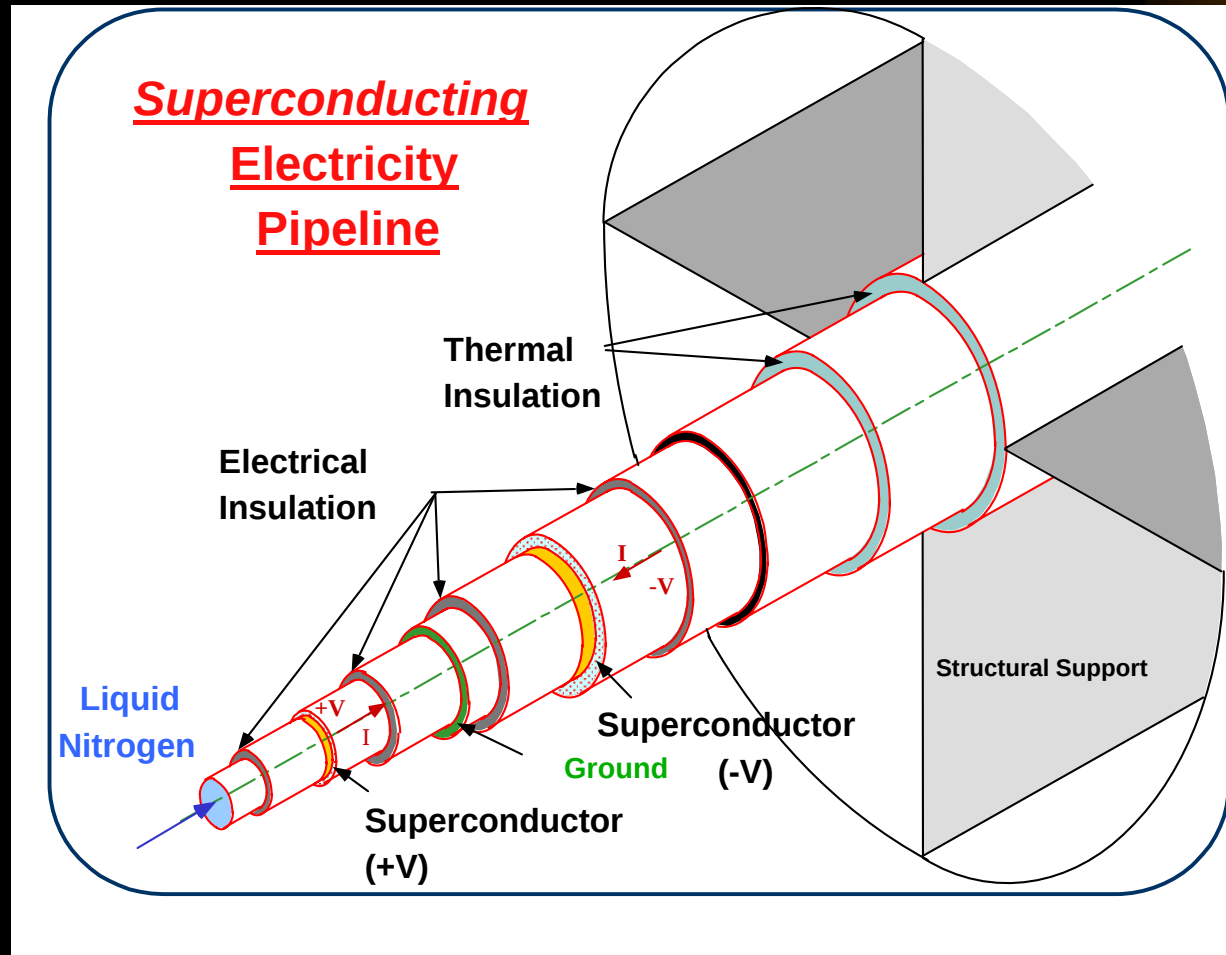
- **Fuel Types & Location**
 - Nukes, Hydro, Non-Transportables Dominate
 - Centralized Generation Grows
- **Geopolitics**
 - Regional Stability Achieved
 - Economic Gap between Nations Shrinks
- **Environment**
 - Risk Abatement Implemented
 - Global Climate Change Proven/Perceived

EPRI
Powering Progress



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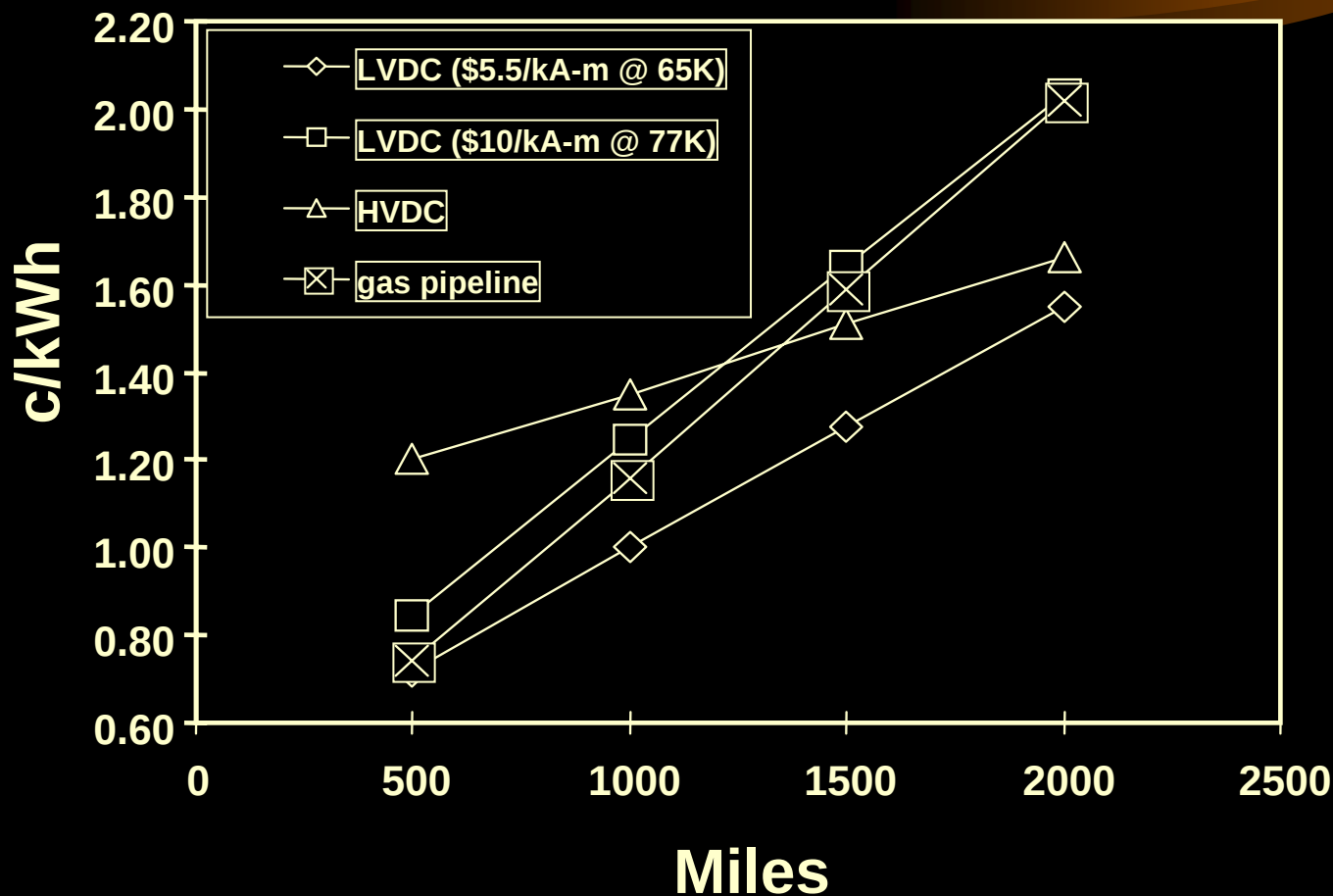
The Superconducting Electricity Pipe!



- Total Cryo System
- Power: 5 GW dc
- Cost: < Gas, HVDC > 500 Miles

Gas/HVDC Comparison

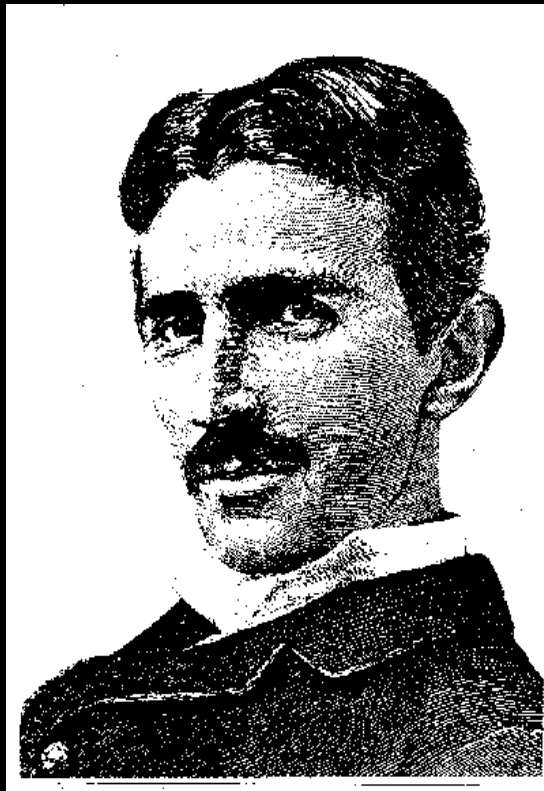
Marginal Cost of Electricity (Mid Value Fuel Costs)



Electricity Delivery

Is Its Future dc?

EPRI
Powering Progress



Tesla
Inventor,
Polyphase ac System



Edison
Maybe he was right after all!

P.M. Grant
IEEE PE Mtg
Superconductivity
4 February 1998