WELCOME

Magnetics Workshop

“The Future of High Performance Magnets in the USA”

Crystal City, Arlington, VA, January 30, 2009
The aim of the Workshop is to bring together the very few remaining experts on permanent magnets in USA (producers, users, researchers/engineers) and discuss the needs, problems and challenges that must be addressed in order to revive the USA presence in this important and critical field, which hopefully will helps us to develop the next generation high performance magnets.
Objectives of the Workshop

- Discuss the current use of permanent magnets in military and commercial applications and point out problems and future needs.
- Promote, conduct and facilitate collaborative research and development on permanent magnets among the very few existing groups at universities, industrial institutions and government labs.
- Draw road maps to the year 2015 and beyond for materials, technologies and products that will lead to improving the magnetic properties of existing magnets and to discover better and less expensive magnets in the future.
The Future of High Performance Permanent Magnets in the USA

January 30, 2009
Hyatt Regency Crystal City at Ronald Reagan Washington National Airport
Arlington, VA

Agenda

00 - 8:15 REGISTRATION

George Hadjipanayis

35 - 8:50 Review of Current High Performance Magnets
William McCallum

50 - 9:05 High Performance Magnet Producers in USA
Michael Walmer

05 - 9:20 Status and Plans for Molycorp’s Rare Earth Business
Mark Smith

20 - 9:35 Applications in US Air Force
Earl Gregory

35 - 9:50 Applications in US Navy
Matthew Willard

50 - 10:05 Applications in US Army
John Prater

0:05 - 10:30 COFFEE BREAK

0:30 - 10:45 High-Performance Permanent Magnet Needs
and Applications at General Electric
Frank Johnson

0:45 - 11:00 Permanent Magnet R&D Needs for Synchrotron
George Rakowsky
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<td>Other Applications</td>
<td>Ed Richardson</td>
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<td>11:15 - 11:30</td>
<td>Halbach Permanent Magnet Structures</td>
<td>Dejan Trbojevic</td>
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<td>11:30 - 11:40</td>
<td>Use of Permanent Magnets in Future Refrigerators Based on the Magnetocaloric Effect</td>
<td>JinFang Liu</td>
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<td>11:55 - 12:10</td>
<td>Ongoing Research-Bottom Up</td>
<td>Peng Liu</td>
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<td>12:10 - 1:00</td>
<td>LUNCH</td>
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<td>1:00 - 1:15</td>
<td>Next Generation Permanent Magnets</td>
<td>George Hadjipanayis</td>
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<td>1:15 - 1:30</td>
<td>Nanocomposite and Future Research of Permanent Magnetic Material</td>
<td>Christina Chen</td>
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<td>1:30 - 1:45</td>
<td>Basic Studies/Modeled Structures</td>
<td>Ralph Skomski</td>
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<td>1:45 - 2:00</td>
<td>Fabrication of Rare Earth Compound Nanoparticles</td>
<td>Vincent Harris</td>
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<td>Fabrication of Fe$_{16}$N$_2$ Powders</td>
<td>S.G. Sankar</td>
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<td>Large Scale Fabrication of Nanocomposites</td>
<td>Bhanu Chelluri</td>
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<td>Group Discussions: Identify Needs/Problems/Challenges</td>
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<td>3:15 - 3:25</td>
<td>Presentation of Group 1: Research/Development</td>
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<td>Presentation of Group 2: Applications</td>
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<td>3:35 - 4:30</td>
<td>Proposed Plan to Move Forward</td>
<td>George Hadjipanayis</td>
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Permanent Magnets and Energy Efficiency

Energy product \((BH_m)\)

\[ H_{ag} \sim \sqrt{\frac{V_m (B_m | H_m)}{V_{ag}}} \]

\((BH)_m \sim H_{ag}^2 \frac{V_{ag}}{V_m} \)

\[ (BH)_{max} \text{ (kG\(\mu\))} \]

Materials:
- Nd-Fe-B
- Sm\(_2\)(Co-Fe-Cu-Zr)
- Sm\(_2\)(Co-Fe-Cu)
- Sm-Pr-Co
- Sintered SmCo
- KNS steel
- MK steel
- Alnico 5
- Columnar Alnico
- SmCo
- YCo
- Ba-Sr ferrite

Year:
- 1920
- 1930
- 1940
- 1950
- 1960
- 1970
- 1980
- 1990
Magnets are Critical for the USA

- Department of Defense
- Energy Related Applications

- Power Generation and Distribution
- Weapons Systems
- Automotive (Hybrid & Electric Vehicles/Cars)
- Information Storage Media
- Communications
- Medical Electronics and Bioengineering
More Electric Aircraft With Increased Power Capabilities

**MEA GENERATION I**
- **Baseline (1991)**
  - 130 KW
  - 100 Elec Loads
  - No 270 VDC Flt Critical Loads

**MEA GENERATION II**
- **Generation I (1998)**
  - 300 KW
  - >300 Loads
  - Flight Criticals
  - External IS/G

  **Generation II (2005)**
  - 500 KW
  - All Electric
  - 15-20x Reliability
  - Internal IS/G

  **Generation III (2012)**
  - Multi-Megawatt
  - Enabling Weapons
  - Int IS/G with SC Gen
  - Maint-Free Pwr Sys

Incorporating the F-22, C-141 Electric Starlifter, and more electric aircraft concepts into future generations for increased on-board power.
Temperature stability is a critical issue for any permanent magnet. Some applications set especially challenging requirements for the temperature stability.

Magnetic Bearings ($T_{op} \approx 425 \, ^\circ C$)

Magnet Rings ($T_{op} = 350 - 550 \, ^\circ C$)

Ion Engine in NASA’s Deep Space I
Permanent magnets can replace excitation winding of synchronous machines and eliminate the need for a mechanical gearbox, coupling the wind turbine to the generator (to adopt a varying wind speed and the constant grid frequency).

This 2.5 MW wind turbine from General Electric employs a permanent magnet generator, enabling higher efficiency at low wind speeds.
Hybrid Vehicles/Automobile Applications

- **Hybrid Vehicles**
  Hybrid-electric vehicles (HEVs) combine the benefits of gasoline engines and electric motors.

- **Hybrid car industry will grow because:**
  - Volatile oil market and cost of fuel.
  - Technology is maturing and becoming more feasible.
  - Environmental considerations.
  - The relative cost of hybrid vehicles will decrease in the coming years.

- **Other applications in a car!**

- **Magnet Requirements**
  - Typical Interior Permanent Magnet motors used in hybrid vehicles could use about 1 kg of magnets/car.
  - The hybrid vehicle market will most certainly impact the magnet business.
  - Assume all cars are hybrid cars in 20 years, and assume 50 million cars produced in a year. That means 50,000 tons additional magnets are required each year.
Permanent Magnet Market

- Global Sales - $9B, 2007¹
- Forecasted Sales - $11B, 2010¹
- Projected Sales - $21B, 2020¹
- China Produced ≈ 95% of the REO, 2007
- China Produced ≈ 76% of Sintered NEO (wt.)

¹ Terry Clagett Webmagnetics, Denver 2008
USA in Last Position

- In 1960’s US Dominated Permanent Magnet Market – Others Far Behind
- Today China, Europe, and Japan are Market Leaders
- We Lack in Infrastructure, Expertise and Resources

NO RESEARCH ON NEO MAGNETS IN USA!
U.S. will become totally dependent on foreign sources for magnetic technology in an era in which demand for this technology will be critical for our nation’s defense and economy.